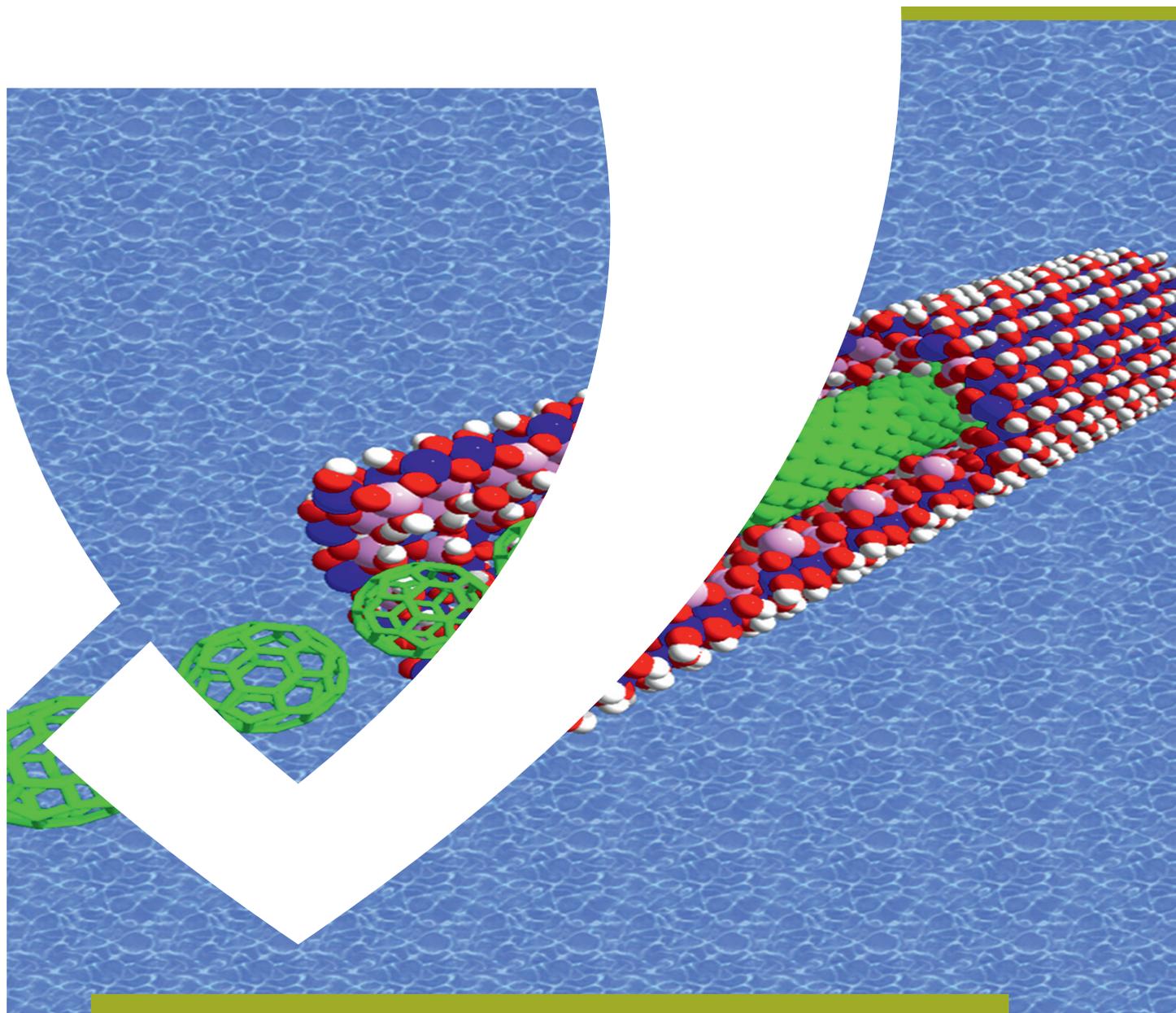




JACOBS
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School of Engineering and Science

Physical Sciences

Graduate Program

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1 General Information

1.1 Physical Sciences

Physical sciences encompass the study of physics, chemistry, nanoscience and further connected research areas. Together with experiments, key concepts and theories build the foundation of this research area. Physical Sciences are mainly concerned with physical and chemical properties, as opposed to the study of the characteristics of living things done in the life sciences though, e.g., biophysics becomes an increasingly important part of physical sciences also at Jacobs University.

The knowledge of physical science is, for example, important for the understanding and development of many things in daily life. Many products we use have been developed using the principles of physical sciences such as physics, chemistry and nanoscience. Research in this direction includes scientific and computational issues that are of critical relevance to all facets of society. Problems addressed include the fabrication of nanoparticles and new devices, the development of new drugs and finding new ways of how to deliver them and the fundamental nature of matter. At the same time, researchers in physical sciences trace the evolution of the universe, hunt for elusive sub-atomic particles, or design detection systems for toxins and explosives.

The present Physical Sciences Graduate Program consists of three tracks. The track "Physics" enables a broad study of the physical foundations of eminent problems, Physics forms the basis of our understanding of objects as diverse as elementary particles, molecules, living cells, electronic devices, stars and galaxies. The "Chemistry" track provides a broad background in chemical sciences. The track "Nanoscience" deals with problems at the nanometer length scale where the traditional sciences of physics, chemistry and biology lose their distinctiveness and merge into a new transdisciplinary science, commonly known as "Nanoscience" and its concomitant technology.

Since the studies of "Chemistry", "Physics" and "Nanoscience" have many common features and foundations, they have been combined in the Physical Sciences Graduate Program to allow for synergistic effects in both, teaching and research. At Jacobs University Bremen the Physical Sciences Graduate Program is supported mainly by the Center of Functional Materials and Nanomolecular Science NANOFUN and the Mathematics, Modeling, and Computing Research Center MAMOC. But also other centers such as the Molecular Life Science Research Center MOLIFE are connected to this graduate program.

1.2 General Structure

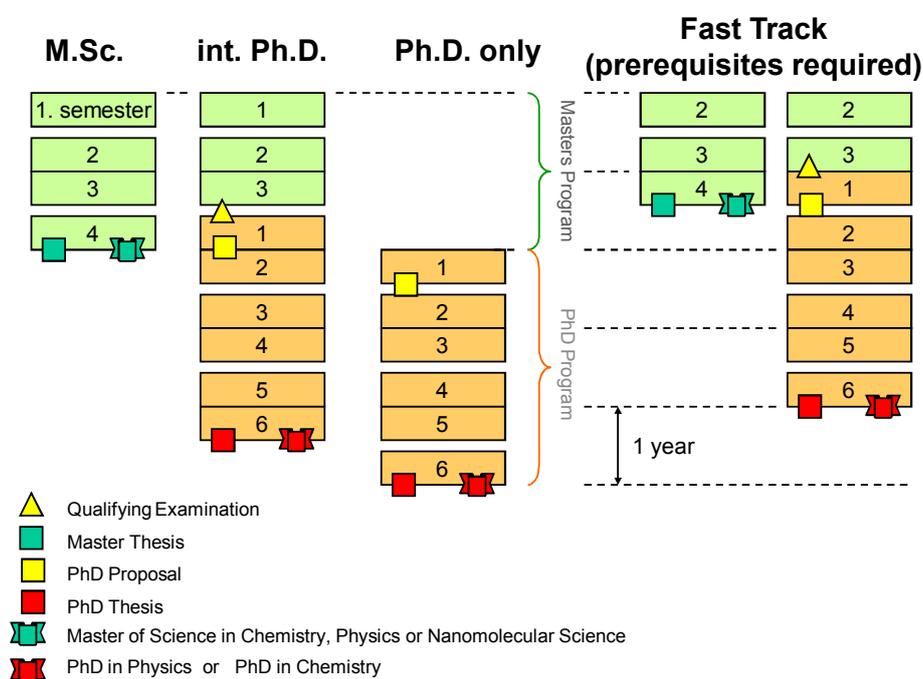
In all tracks, the "Physics", "Chemistry" as well as the "Nanoscience" track, the graduate program offers different options and degrees.

M.Sc. studies contain course work (3 semesters, 9 courses, and further seminars and research) and a Master Thesis in the 4th semester. Courses are designed to provide a broad education in physics, chemistry, and nanoscience including their applications. The 2-year program leads to a M.Sc. in Chemistry, Physics or Nanomolecular Science and contains a mandatory research component.

Integrated Ph.D. studies include the same course phase as the M.Sc. studies (3 semesters). Thereafter the students progress from the M.Sc. studies to the Ph.D. program by passing a Qualifying Exam (usually before the 4th semester of the Master's Program). An M.Sc. thesis

is not required. Thereafter the students proceed with the Ph.D. studies outlined below. This includes the fact that after eight months a Ph.D. proposal needs to be submitted and defended. **Ph.D. studies** are performed under the supervision of one of the faculty members of the Physical Science graduate program, which provides independent in-depth research experience and trains individuals in problem-solving skills. The program character is constituted mainly by research activities but also academic events such as seminars and colloquia, which all Graduate Students have to participate/attend on a regular basis. The 3-year program awards a Ph.D. in Chemistry or a Ph.D. in Physics.

A **Fast Track option** exists for qualified students. To be eligible for this option, some courses of the corresponding graduate track need already to be passed during the undergraduate phase in addition to those courses counted towards the undergraduate degree.



Note: A successfully passed Qualifying Examination and Ph.D. Proposal does not automatically imply Jacobs University funding during the 3-year Ph.D. Program following the course phase. For Ph.D. studies the choice of faculty members as Ph.D. supervisors might be restricted by limits in the available funding.

1.3 Prospects for Graduates/Career Options

The Physical Sciences Graduate Program is inherently cross-disciplinary, probably more so than many other areas of research. It has an impact on a very broad range of industries and technologies, including the chemical, pharmaceutical, semiconductor and computer industries and biotechnology as well as environmental, energy, information, materials and medical technologies.

Jacobs University's graduate program is firmly embedded in interdisciplinary research cooperations within Jacobs University and with various external partners, academic or commercial. These opportunities provide our graduates with the high caliber training sought after by potential employers.

While Jacobs University's graduate program in Physical Sciences will certainly equip students for careers at the frontiers of research and development in universities, research institutes and company laboratories, almost all of these employers also need trained graduates for positions in administration, technical support, service, and sales, to name but a few examples.

Finally, the fact that graduates of the program have learned to communicate with specialists from different fields is a highly relevant qualification in many consulting, policy-making, administration, and governmental jobs. In an increasingly technology-driven world, individuals in decision-making positions need to have sound knowledge on diverse topics such as computers and microelectronics, chemical technology, energy resources and sustainability, all of which are touched upon by an education such as Jacobs University's graduate program in Physical Sciences.



Fig.: Research in the femtosecond laser lab at Jacobs University.

Chemistry Track
with
Ph.D. in Chemistry
and
M.Sc. in Chemistry

2 Chemistry Track

2.1 Concept

2.1.1 Chemistry

Chemistry is the molecular basis of all science, including biology and physics. It is required to understand the interactions of large and small molecules in biochemistry and molecular biology. It is indispensable for the construction of new functional materials for applications in, e.g., fuel cells, light-emitting diodes, drug targeting. Only chemistry can provide new compounds for treatment and diagnosis of diseases. Chemistry is at the basis of the tools used for analysis of the contents of plants, of environmental pollutants, and of metabolites.

2.1.2 Scope of the Chemistry track

The Chemistry track aims at bridging the gap between the knowledge about small molecules and the understanding of larger assemblies, of interest for biology or for physics. It also looks at the design, synthesis, and applications of molecules with unusual building blocks. A further focus is on the elucidation of compounds in natural products and food. The students will be prepared for these tasks in mandatory courses in Supramolecular Chemistry, Quantum Chemistry, Experimental Techniques, and Nanomolecular Science. They will get to know relevant theoretical and experimental tools. A strong focus is on the participation in research in three different groups. The track is distinguished by the following features:

- Strong focus on learning in a research context and in research projects
- Interdisciplinary working context extending both into basic research and applied research
- Choice of elective courses from chemistry, physics, and biochemistry/biotechnology to suit the individual interest and background

The chemistry faculty, forming the backbone of the teaching staff, is highly active in research and in this respect ranks among the highest of the German universities.

2.1.3 Target Group

The program is aimed at students with an excellent record in undergraduate chemistry or closely related subjects (chemical engineering, material science, biochemistry, biotechnology, physical chemistry). A very good working knowledge of English is mandatory. A minimum of four chemistry courses is highly desirable.

2.2 Graduation Requirements for the Chemistry Track

2.2.1 Course work requirements

90 ECTS from lectures, practical training and seminars

2.2.2 Graduation requirements for M.Sc. in Chemistry

Successful completion of course work, practical training, and seminars plus 30 ECTS for independent research and approved Master thesis. The course work consists of

- mandatory lectures: Supramolecular Chemistry, Introduction to Quantum Chemistry & Electronic Structure, Nanomolecular Science, and Experimental Techniques (20 ECTS)
- mandatory practical training: Physical Sciences Research Methods, Physical Sciences Advanced Guided Research I & II (30 ECTS)
- mandatory seminars: Current Topics in Physical Sciences, Physical Sciences Graduate Seminar I & II (15 ECTS)
- elective courses: see final chapter for a list of courses (25 ECTS)

Each course can only be counted once towards one of the M.Sc. or Ph.D. degrees offered in the program.

During the first three semester, 90 ECTS credit points for course work need to be accumulated. Out of this 90 ECTS points, 60 ECTS points are for lectures as well as seminars and 30 ECTS points for practical training and research. In case of an M.Sc. study, additional 30 ECTS points for Independent Research and the M.Sc. thesis in the fourth semester are mandatory.

Up to 20 ECTS credit points of the electives can be substituted by suitable graduate courses from other graduate programs at Jacobs University, certain 3rd year undergraduate specialization courses or courses in the framework of joint graduate schools with external universities. The latter courses might be offered as block courses in some cases. Substitutions are subject to approval by the Graduate Advisor and Program Coordinator. 3rd-year courses may only be credited if they have not been credited towards their undergraduate degree. Students can take additional courses (lectures, labs, seminars; within or outside the Physical Sciences graduate program; graduate or undergraduate level) in order to broaden or deepen their field of study.

2.2.3 Graduation requirements for Integrated Ph.D.

- Promotion to Ph.D. phase: Successful completion of course work plus qualifying exam.
- Qualifying Examination: Oral (or written) exam on Nanomolecular Science, Quantum Chemistry, and Supramolecular Chemistry, and one elective. The selection has to be discussed with the Academic Advisor and communicated to the Program Coordinator. In agreement with the Graduate policies, the Qualifying Examinations in Integrated Ph.D. Programs take place before the beginning of the fourth semester, assuming that the student has completed the coursework requirements. In case of an oral exam, at least three faculty members must be present, and the typical duration is no less than one hour. The Qualifying Examination has the outcome “pass” or “fail”.
- Requirements for Ph.D.: Admission to Ph.D. phase, approved Ph.D. proposal (proposal and oral defense), Ph.D. thesis and successful defense
- Ph.D. proposal: Every student needs to develop a written Ph.D. proposal incl. research plan in cooperation with his Ph.D. Advisor. It has to be presented in public upon invi-

tation by the Dean at most eight months after the qualifying exam or after entrance into the Ph.D. Program. The presentation of about 30 minutes should be followed by an oral defense of 30-60 minutes. The Dissertation Committee approves the Ph.D. Proposal. In exceptional cases, students might combine the Ph.D. proposal with an M.Sc. thesis in one document. This needs to be discussed in detail with and approved by the Graduate Advisor as well as the Program Coordinator.

- Ph.D. defense: After approval of the Ph.D. thesis, the candidate need to present his research in a presentation of 30-40 minutes followed by an oral defense of 45-90 minutes. The Dissertation Committee approves the Defense.

Any adjustments/amendments need to be discussed with the Program Coordinator. For further details please also see the Graduate Policies of the Jacobs University and the accompanying guidelines.

2.2.4 Graduation requirements for Ph.D. only

- The requirements for a Ph.D. include the admission to the Ph.D. phase, an approved Ph.D. proposal, an approved Ph.D. thesis and successful defense. The details are the same as described above. Please also see the Graduate Policies of Jacobs University and the accompanying guidelines.

2.3 Recommended Course Plan: Chemistry Track

Semester 1 Courses	Course Number	C	T
Supramolecular Chemistry	420432	5	m
Introduction to Quantum Chemistry & Electronic Structure		5	m
Physical Sciences Research Methods	420421	10	m
Current Topics in Physical Sciences	420472	5	e
Elective Course (see final chapter for a list of courses)		5	e
Semester 2 Courses	Course Number	C	T
Nanomolecular Science	420431	5	m
Experimental Techniques	(530461 & 530561)	5	m
Physical Sciences Graduate Student Seminar I	420511	5	m
Physical Sciences Advanced Guided Research I	420462	10	m
Elective Course		5	e
Semester 3 Courses	Course Number	C	T
Physical Sciences Graduate Student Seminar II	420412	5	m
Physical Sciences Advanced Guided Research II	420461	10	m
Elective Course		5	e
Elective Course		5	e
Elective Course		5	e
Semester 4 Courses (M.Sc. only)	Course Number	C	T
Physical Sciences Independent Research and M.Sc. thesis	420522	30	m

C = ECTS credit points, T=type (m=mandatory, e=elective)

Note:

1. Research Methods, Advanced Guided Research and M.Sc. Thesis comprises work in one or more experimental research labs or theory groups at Jacobs University on topics of current interest. A written M.Sc. thesis (40 pages suggested) and an oral presentation of the results are required. Students should contact faculty regarding a research topic.

Recommendation Professional Skills

The SES highly recommends attending the Professional Skills seminars offered by the Career Services Center. Those seminars include soft skills development seminars and application trainings which will help you cope with your studies and master internship and job search.

Further details can be found at the Teamwork server of the university at <https://teamwork.jacobs-university.de/confluence/display/APS>

Physics Track
with
Ph.D. in Physics
and
M.Sc. in Physics

3 Physics Track

3.1 Concept

3.1.1 Physics

Physics builds the foundation of the natural sciences and many engineering disciplines. It forms the basis of our understanding of objects as diverse as elementary particles, molecules, living cells, electronic devices, stars and galaxies. Their behavior and properties are governed by the same universal physical principles which are the central topics of any physics curriculum. Our society was shaped and will be shaped in the future by the emergence of new technologies (e.g., electrical power, information technology, nanotechnology) and by new insights from where we come and in which world we live (evolution, relativity, quantum mechanics, cosmology). Physics always has and will also in the future contribute to a better understanding of the world around us and improve our daily life by providing the basis for new technologies. Physics is also an experimental science and every theory or model of the world has to be verified by experimental evidence. For a physical understanding of natural phenomena in the world around us both approaches are necessary, a theoretical and abstract description of general principles but also the experimental knowledge how to obtain and analyse experimental data. With a M.Sc. or Ph.D. in physics students can contribute to advance the knowledge in different areas of science and engineering, or by solving problems related to challenges of global importance such as:

- What is the microscopic description of space, time and matter that is consistent with quantum physics and gravity?
- What will be the most effective future energy source and energy storage technology?
- What physical principles and methods can be used to develop new materials?
- How can we investigate and explain the motion of electrons on femtosecond time-scales?
- How can we understand the transport of antibiotics across membranes to develop new drugs against ever more resistant bacteria?

Research at the beginning of the 21st century concentrates on the investigation of small scale structures (quantum gravity, nanotechnology), large scale structures (astrophysics, cosmology), new materials discovered in interdisciplinary research, and complex systems requiring computational or new mathematical approaches.

3.1.2 Scope of the Physics track

The Physics track in the Physical Sciences graduate program builds on a broad and general B.Sc. in physics and leads to a further specialization and deeper insight in specific areas which is necessary to contribute to international competitive research. During the course work an emphasis is put on a balanced ratio of experimental, theoretical and applied physics with a strong research component. The core courses (quantum mechanics, statistical physics, field theory, condensed matter) build the backbone of the program track whereas by electives and specialization courses the individual preferences of students are taken into account. The primary areas of research and specialized teaching in physics at Jacobs University are material science and condensed matter physics, computational and experimental biophysics, theoretical and mathematical physics, and astrophysics. Especial emphasis is given on cross-disciplinary research and the overlap of physics with the life sciences, chemistry, mathematics, and astronomy. Some distinguishing points of the physics program track at Jacobs are:

- Strong focus on research and independent scientific work - starting in the first year
- Broad range of expertise and research interests of faculty to foster transdisciplinarity
- Exposure of students to substantial computational components
- Internationality, English as primary language for instructions and administration
- Possible choice of elective courses from other graduate programs connected to Research Centers at Jacobs such as “Research Center for Functional Materials and Nanomolecular Science (NANOFUN)”, “Mathematics, Modeling, and Computing (MAMOC)”, “Molecular Life Science Center (MOLIFE)” and the DFG Research Training Group “Models of Gravity”.

More than ten Physics faculty members contribute to teaching of the physics track in the Physical Sciences graduate program and conduct active research in the fields of condensed matter, laser physics, biophysics, classical and quantum gravity, mathematical and statistical physics and many other topics. Many of these subjects are both tackled from the side of theoretical as well as experimental physics. The research of faculty is supported by numerous postdoctoral fellows and students.

3.1.3 Target Group

The program is intended for national and international students with an excellent record in undergraduate physics or a closely related subject (e.g., physical chemistry, material science, ...). Since English is the primary language on campus, a very good working knowledge of English to read and discuss scientific topics is a mandatory prerequisite for students enrolling in the program. Applicants for the graduate physics track should have already experienced physics research in their undergraduate studies, and are now keen to extend their physics background and deepen their knowledge in a specific area of physics. To do so a certain level of curiosity paired with analytical-mathematical thinking, but also persistence and structured working are necessary. For students interested in the integrated Ph.D. option an additional academic set of mind, scientific creativity and enthusiasm for hard work and independent research is a further requirement.

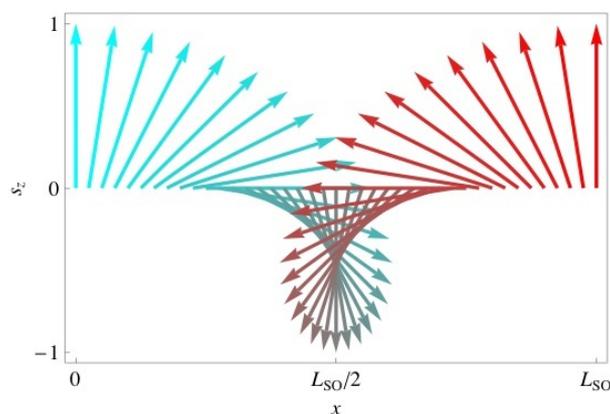


Fig.: Spintronics, the manipulation of the electron spins for energy efficient storing and transport of information, requires a detailed understanding of spin dynamics and transport.

3.2 Graduation Requirements for the Physics Track

3.2.1 Course work requirements

90 ECTS from lectures, practical training and seminars

3.2.2 Graduation requirements for M.Sc. in Physics

Successful completion of course work, practical training, and seminars plus 30 ECTS for independent research and approved Master thesis. The course work consists of

- three out of the following four lectures: Advanced Quantum Mechanics, Advanced Statistical Physics, From Molecules to Matter and Classical and Quantum Field Theory (15 ECTS)
- mandatory practical training: Physical Sciences Research Methods, Physical Sciences Advanced Guided Research I & II (30 ECTS)
- mandatory seminars: Current Topics in Physical Sciences, Physical Sciences Graduate Seminar I & II (15 ECTS)
- elective courses: see final chapter for a list of courses (30 ECTS)

Each course can only be counted once towards one of the M.Sc. or Ph.D. degrees offered in the program.

During the first three semester, 90 ECTS credit points for course work need to be accumulated. Out of this 90 ECTS points, 60 ECTS points are for lectures as well as seminars and 30 ECTS points for practical training and research. In case of an M.Sc. study, additional 30 ECTS points for Independent Research and the M.Sc. thesis in the fourth semester are mandatory.

Up to 20 ECTS credit points of the electives can be substituted by suitable graduate courses from other graduate programs at Jacobs University, certain 3rd year undergraduate specialization courses or courses in the framework of joint graduate schools with external universities. The latter courses might be offered as block courses in some cases. Substitutions are subject to approval by the Graduate Advisor and Program Coordinator. 3rd-year courses may only be credited if they have not been credited towards their undergraduate degree. Students can take additional courses (lectures, labs, seminars; within or outside the Physical Sciences graduate program; graduate or undergraduate level) in order to broaden or deepen their field of study.

3.2.3 Graduation requirements for Integrated Ph.D.

- Promotion to Ph.D. phase: Successful completion of course work plus qualifying exam.
- Qualifying Examination: Oral (or written) exam on three of the four core topics and one elective. The four core topics are quantum mechanics, statistical physics, condensed matter physics, as well as classical and quantum field theory. The selection has to be discussed with the Academic Advisor and communicated to the Program Coordinator. In agreement with the Graduate policies, the Qualifying Examinations in Integrated Ph.D. Programs take place before the beginning of the fourth semester, assuming that the student has completed the coursework requirements. In case of an oral exam, at least three faculty members must be present, and the typical duration is no less than one hour. The Qualifying Examination has the outcome “pass” or “fail”.
- Requirements for Ph.D.: Admission to Ph.D. phase, approved Ph.D. proposal (proposal and oral defense), Ph.D. thesis and successful defense

- Ph.D. proposal: Every student needs to develop a written Ph.D. proposal incl. research plan in cooperation with his Ph.D. Advisor. It has to be presented in public upon invitation by the Dean at most eight months after the qualifying exam or after entrance into the Ph.D. Program. The presentation of about 30 minutes should be followed by an oral defense of 30-60 minutes. The Dissertation Committee approves the Ph.D. Proposal. In exceptional cases, students might combine the Ph.D. proposal with an M.Sc. thesis in one document. This needs to be discussed in detail with and approved by the Graduate Advisor as well as the Program Coordinator.
- Ph.D. defense: After approval of the Ph.D. thesis, the candidate need to present his research in a presentation of 30-40 minutes followed by an oral defense of 45-90 minutes. The Dissertation Committee approves the Defense.

Any adjustments/amendments need to be discussed with the Program Coordinator. For further details please also see the Graduate Policies of the Jacobs University and the accompanying guidelines.

3.2.4 Graduation requirements for Ph.D. only

- The requirements for a Ph.D. include the admission to the Ph.D. phase, an approved Ph.D. proposal, an approved Ph.D. thesis and successful defense. The details are the same as described above. Please also see the Graduate Policies of Jacobs University and the accompanying guidelines.

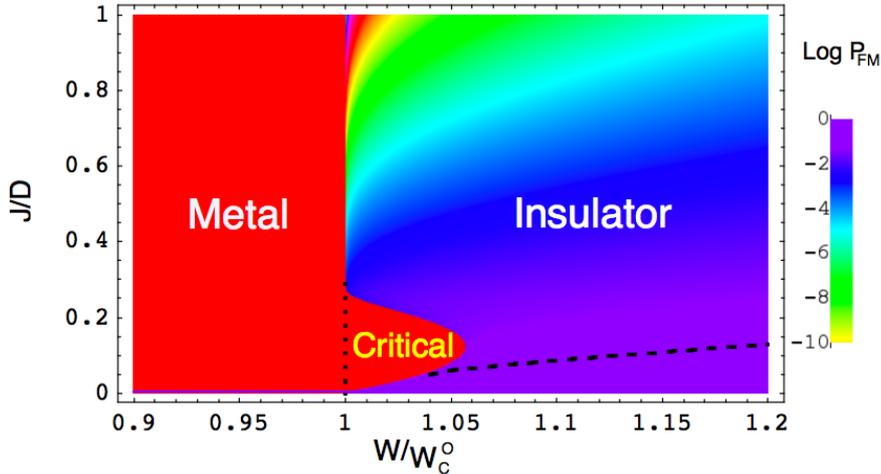


Fig.:The Quantum Phase Diagram, here shown as function of Disorder W and Exchange Coupling J , reveals rich physics: A new quantum phase of matter, the critical metal, arises due to the interplay of Disorder and Spin Correlations.

3.3 Recommended Course Plan: Physics Track

Semester 1 Courses	Course Number	C	T
Advanced Quantum Mechanics	420531	5	m
Physical Sciences Research Methods	420421	10	m
Current Topics in Physical Sciences	420472	5	e
Elective Course (see final chapter for a list of courses)		5	e
Elective Course		5	e
Semester 2 Courses	Course Number	C	T
Advanced Statistical Physics		5	m
From Molecules to Matter	420441	5	m
Physical Sciences Graduate Student Seminar I	420511	5	m
Physical Sciences Advanced Guided Research I	420462	10	m
Elective Course		5	e
Semester 3 Courses	Course Number	C	T
Classical and Quantum Field Theory		5	m
Physical Sciences Graduate Student Seminar II	420412	5	m
Physical Sciences Advanced Guided Research II	420461	10	m
Elective Course		5	e
Elective Course		5	e
Semester 4 Courses (M.Sc. only)	Course Number	C	T
Physical Sciences Independent Research and M.Sc. thesis	420522	30	m

C = ECTS credit points, T=type (m=mandatory, e=elective)

Notes:

1. Though all four courses "Advanced Quantum Mechanics", "Advanced Statistical Physics", "From Molecules to Matter", and "Classical Field Theory" are highly recommended, only 15 ECTS from these courses are mandatory for graduation.
2. Research Methods, Advanced Guided Research and M.Sc. Thesis comprises work in one or more experimental research labs or theory groups at Jacobs University on topics of current interest. A written M.Sc. thesis (40 pages suggested) and an oral presentation of the results are required. Students should contact faculty regarding a research topic.

Recommendation Professional Skills

The SES highly recommends attending the Professional Skills seminars offered by the Career Services Center. Those seminars include soft skills development seminars and application trainings which will help you cope with your studies and master internship and job search.

Further details can be found at the Teamwork server of the university at <https://teamwork.jacobs-university.de/confluence/display/APS>

Nanoscience Track
with
Ph.D. in Chemistry or Physics
and
M.Sc. in Nanomolecular Science

4 Nanoscience Track

4.1 Concept

4.1.1 Nanoscience

The physical sciences have reached a state that enables us, at least in principle, to build objects at the ultimate level of finesse, one atom or molecule at a time, with ultimate precision. At the nanometer length scale, the traditional sciences of physics, chemistry and biology lose their distinctiveness and merge into a new transdisciplinary science, commonly known as "Nanoscience" and its concomitant technology. In this new scientific endeavour, each of the traditional sciences has an invaluable contribution to make. Given the scope of Nanoscience and Nanotechnology, it is not surprising that they hold answers to our most pressing material and technological needs. For example, advanced organic solar cells based on new functional materials, fuel cells incorporating nano-catalysts and novel hydrogen storage systems based on molecularly engineered materials could help solve our energy problems in a sustainable way. Wires, transistors, and storage media of the size of single molecules will introduce a paradigm shift in information technology. The construction of molecular shuttles, rotors and wheels realizes mechanical tools at the nanoscopic level, while the design of molecular barrels, cups, chains and knots transfers macroscopic objects to the nanoscale. Molecular medicine is looking for ultrasmall and less invasive detection techniques in diagnostics and delivering systems employing nanocontainers to advance progress and treatment of diseases. These are just a few examples of how (molecular) nanotechnology can transform our future.

4.1.2 Scope of the Nanoscience track

The track in Nanoscience is highly transdisciplinary. Physics has developed novel observation and manipulation tools for single atoms and molecules and provides quantum physics as the fundamental science of the small. *Chemistry* as the science of molecules reveals the functional, conformational and structural relationship with in and between molecules; it can nowadays design molecules and supramolecular assemblies with unprecedented complexity. Research in *biology* is currently revealing the toolbox of real-life molecular machinery and teaches us how nanosized objects can be self-assembled into complex systems in which dynamic nanomolecular functions like signalling, catalysis, transport, and locomotion can be realized in a controlled way. Finally, *materials science* converts the nanoscale properties of components into macroscopic materials with entirely novel properties and functionalities.

The Nanoscience track in the Physical Sciences Graduate Program at Jacobs University reflects the need for transdisciplinary training. Faculty from the physical, chemical and biological sciences provide lectures and lab classes in the nano-related aspects of their fields. The education covers different classes of nanomaterials, different synthesis and characterization methods, various theoretical and computational approaches as well as application areas of nanomaterials. The course work provides interdisciplinary breadth to the degree granted. The M.Sc. or Ph.D. thesis allows for the in-depth study of a particular topical research area in the lab of the participating faculty. Thus participants emerge from the program track with a versatile background in Chemistry, Physics and Nanoscience, as well as with the ability to perform independent research in a results-oriented approach.

4.1.3 Target Group

The program is aimed at students with an excellent record in undergraduate chemistry, physics or closely related subjects (material science, physical chemistry, ...). A very good working knowledge of English is mandatory. A minimum of four course in the area of chemistry and/or physics is highly desirable.

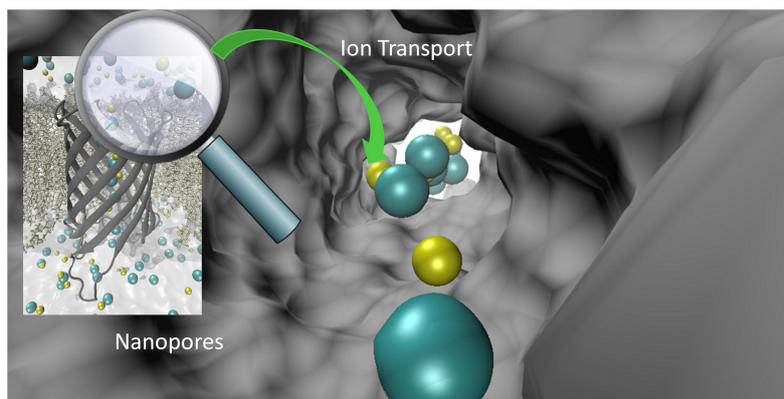


Fig.: Ion and substrate transport through nanopores by theory and experiment.

4.2 Graduation Requirements for the Nanoscience Track

4.2.1 Course work requirements

90 ECTS from lectures, practical training and seminars

4.2.2 Graduation requirements for M.Sc. in Nanomolecular Science

Successful completion of course work, practical training, and seminars plus 30 ECTS for independent research and approved Master thesis. The course work consists of

- mandatory lectures: Supramolecular Chemistry, Introduction to Quantum Chemistry & Electronic Structure **or** Advanced Quantum Mechanics, Nanomolecular Science, and From Molecules to Matter (20 ECTS)
- mandatory practical training: Physical Sciences Research Methods, Physical Sciences Advanced Guided Research I & II (30 ECTS)
- mandatory seminars: Current Topics in Physical Sciences, Physical Sciences Graduate Seminar I & II (15 ECTS)
- elective courses: see final chapter for a list of courses (25 ECTS)

Each course can only be counted once towards one of the M.Sc. or Ph.D. degrees offered in the program.

During the first three semester, 90 ECTS credit points for course work need to be accumulated. Out of this 90 ECTS points, 60 ECTS points are for lectures as well as seminars and 30 ECTS points for practical training and research. In case of an M.Sc. study, additional 30 ECTS points for Independent Research and the M.Sc. thesis in the fourth semester are mandatory.

Up to 20 ECTS credit points of the electives can be substituted by suitable graduate courses from other graduate programs at Jacobs University, certain 3rd year undergraduate specialization courses or courses in the framework of joint graduate schools with external universities. The latter courses might be offered as block courses in some cases. Substitutions are subject to approval by the Graduate Advisor and Program Coordinator. 3rd-year courses may only be credited if they have not been credited towards their undergraduate degree. Students can take additional courses (lectures, labs, seminars; within or outside the Physical Sciences graduate program; graduate or undergraduate level) in order to broaden or deepen their field of study.

4.2.3 Graduation requirements for Integrated Ph.D.

- Promotion to Ph.D. phase: Successful completion of course work plus qualifying exam.
- Qualifying Examination: Oral (or written) exam on Nanomolecular Science, Introduction to Quantum Chemistry & Electronic Structure **or** Advanced Quantum Mechanics, Supramolecular Chemistry, and one elective. The selection has to be discussed with the Academic Advisor and communicated to the Program Coordinator. In agreement with the Graduate policies, the Qualifying Examinations in Integrated Ph.D. Programs take place before the beginning of the fourth semester, assuming that the student has completed the coursework requirements. In case of an oral exam, at least three faculty members must be present, and the typical duration is no less than one hour. The Qualifying Examination has the outcome “pass” or “fail”.
- Requirements for Ph.D.: Admission to Ph.D. phase, approved Ph.D. proposal (proposal and oral defense), Ph.D. thesis and successful defense

- Ph.D. proposal: Every student needs to develop a written Ph.D. proposal incl. research plan in cooperation with his Ph.D. Advisor. It has to be presented in public upon invitation by the Dean at most eight months after the qualifying exam or after entrance into the Ph.D. Program. The presentation of about 30 minutes should be followed by an oral defense of 30-60 minutes. The Dissertation Committee approves the Ph.D. Proposal. In exceptional cases, students might combine the Ph.D. proposal with an M.Sc. thesis in one document. This needs to be discussed in detail with and approved by the Graduate Advisor as well as the Program Coordinator.
- Ph.D. defense: After approval of the Ph.D. thesis, the candidate need to present his research in a presentation of 30-40 minutes followed by an oral defense of 45-90 minutes. The Dissertation Committee approves the Defense.

Any adjustments/amendments need to be discussed with the Program Coordinator. For further details please also see the Graduate Policies of the Jacobs University and the accompanying guidelines.

4.2.4 Graduation requirements for Ph.D. only

- The requirements for a Ph.D. include the admission to the Ph.D. phase, an approved Ph.D. proposal, an approved Ph.D. thesis and successful defense. The details are the same as described above. Please also see the Graduate Policies of Jacobs University and the accompanying guidelines.

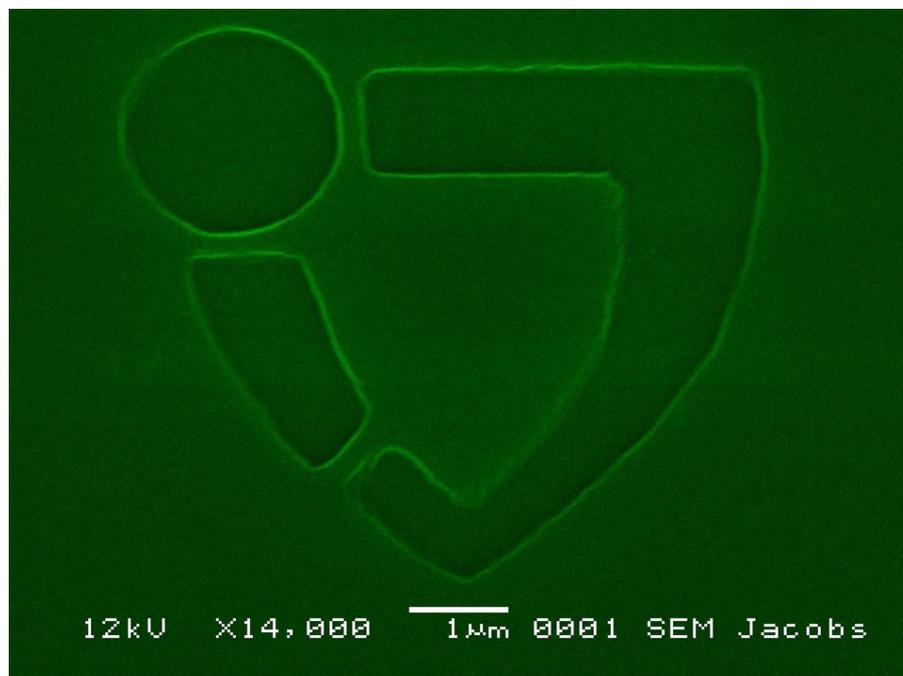


Fig.: Jacobs University logo on the micrometer scale.

4.3 Recommended Course Plan: Nanoscience Track

Semester 1 Courses	Course Number	C	T
Supramolecular Chemistry	420432	5	m
Introduction to Quantum Chemistry & Electronic Structure or Advanced Quantum Mechanics	420531	5	m
Physical Sciences Research Methods	420421	10	m
Current Topics in Physical Sciences	420472	5	e
Elective Course (see final chapter for a list of courses)		5	e
Semester 2 Courses	Course Number	C	T
Nanomolecular Science	420431	5	m
From Molecules to Matter	420441	5	m
Physical Sciences Graduate Student Seminar I	420511	5	m
Physical Sciences Advanced Guided Research I	420462	10	m
Elective Course		5	e
Semester 3 Courses	Course Number	C	T
Physical Sciences Graduate Student Seminar II	420412	5	m
Physical Sciences Advanced Guided Research II	420461	10	m
Elective Course		5	e
Elective Course		5	e
Elective Course		5	e
Semester 4 Courses (M.Sc. only)	Course Number	C	T
Physical Sciences Independent Research and M.Sc. thesis	420522	30	m

C = ECTS credit points, T=type (m=mandatory, e=elective)

Note:

1. Research Methods, Advanced Guided Research and M.Sc. Thesis comprises work in one or more experimental research labs or theory groups at Jacobs University on topics of current interest. **Research experience has to be gained in research groups from different research disciplines.** A written M.Sc. thesis (40 pages suggested) and an oral presentation of the results are required. Students should contact faculty regarding a research topic.

Recommendation Professional Skills

The SES highly recommends attending the Professional Skills seminars offered by the Career Services Center. Those seminars include soft skills development seminars and application trainings which will help you cope with your studies and master internship and job search.

Further details can be found at the Teamwork server of the university at <https://teamwork.jacobs-university.de/confluence/display/APS>

Physical Sciences Faculty,
their Research and Research Foci

5 Physical Sciences Faculty, their Research and Research Foci

5.1 Faculty

Marcelo Fernandez-Lahore (Biochemistry):

- Bioprocess intensification and Process proteomics
- Downstream processing of natural compounds
- Meta-Integration in downstream processing
- Continuous processing unit operations for biotechnology
- Process modeling, simulation, design and scale-up

Jürgen Fritz (Biophysics):

- Single molecule biophysics
- Atomic force microscopy & force spectroscopy
- Nanomechanical sensors

Detlef Gabel (Chemistry):

- Boron chemistry for medicinal and technical applications
- Drug design
- Testing of biochemical and biological activity of drugs and substances

Betti Hartmann(Theoretical Physics)

- Classical field theory
- Solitons
- Topological defects
- Black holes

Thomas Heine (Theoretical Materials Science)

- Nanoelectronics and nanoelectromechanics 1- and 2-dimensional materials
- Separation of quantum liquids
- Combinatorial computational materials design
- Molecular framework compounds for hydrogen storage and catalysis
- Nanoparticles for photocatalysis
- Development of density-functional theory based methods

Stefan Kettemann (Theoretical Physics)

- Spintronics
- Magnetism
- Quantum transport
- Quantum Phase transitions

Ulrich Kleinekathöfer (Computational Physics and Biophysics):

- Energy and charge transfer using wave packet dynamics
- Biological and artificial light harvesting
- Ion and substrate transport through membranes
- Quantum transport in molecular wires
- Computational physics

Dietmar Knipp (Electrical Engineering):

- Electronic devices
- Photonics
- Organic materials and electronics
- Nanooptics
- Optical sensors

- Thin film technologies
- Nano fabrication

Ulrich Kortz (Chemistry):

- Synthetic Inorganic and Organometallic Chemistry
- Structural Inorganic Chemistry
- Polyoxometalate Chemistry
- Hybrid Organic-Inorganic Assemblies
- Catalysis, Magnetism, Electrochemistry

Nikolai Kuhnert (Chemistry):

- Analytical Chemistry
- Supramolecular chemistry
- Natural Product Chemistry

Arnulf Materny (Chemical Physics):

- Laser spectroscopy on nano-structured systems in the frequency and time domain

Hildegard Meyer-Ortmanns (Theoretical Physics)

- Statistical physics in- and out-of-equilibrium
- Nonlinear dynamics
- Stochastic processes
- Evolutionary game theory
- Optimization problems
- Complex systems in Network Science

Werner Nau (Chemistry):

- Supramolecular functional materials
- Biopolymer dynamics and function
- Fluorescent sensors and probes

Thomas Nugent (Chemistry):

- Total synthesis (pharmaceutical and natural product drugs)
- Enantioselective catalytic methods development
- Organometallic chemistry
- Process research

Danilo Roccatano (Chemistry):

- Solvent models for MD simulations
- Peptide secondary structures in solution
- Protein dynamics and folding
- Development of bioinformatics tools for bioengineering

Gerd-Volker Röschenthaler (Chemistry):

- Syntheses of fluorinating reagents and fluorinated building blocks for biological active compounds and for industrial processes
- Synthesis of fluorinated liquid crystal molecules
- Solar cell development
- Synthesis of lithium battery electrolyte salts and additives
- Bisphosphonates, fluorinated heterocycles, and bioactive platinum complexes

Peter Schupp (Physics):

- Mathematical/Theoretical Physics
- Noncommutative and Generalized Geometry
- Quantum Theories of Gravity, String/M-Theory

- Coherent States, Quantum Information

Joachim Vogt (Space physics)

- Analysis of data from multi-satellite geospace missions
- Auroral plasma physics and magnetosphere-ionosphere (M-I) coupling
- Effects of geomagnetic variations on system Earth

Veit Wagner (Physics):

- Nanoelectronics
- Single molecule transistors
- Functionalized organic materials and plastic electronics

Mathias Winterhalter (Biophysics):

- Substrate recognition and translocation on a single molecular level
- Functionalisation of surfaces and nanocapsules with biomaterials

5.2 Research Centers and Training Groups

Center of Functional Materials and Nanomolecular Science NANOFUN

NANOFUN applies fundamental theoretical and molecular knowledge to the development of functional materials and nanostructures, and ultimately, actual applications, new devices and improved products. This includes areas like photovoltaics, hydrogen storage, fuel cells, batteries, photocatalytic conversion of carbon dioxide, nanoelectronics for computers, and sensors.

Mathematics, Modeling, and Computing Research Center MAMOC

The MAMOC (Mathematics, Modeling, and Computing) Research Center hosts research at the interface between mathematics, theoretical natural sciences, modeling, and high-performance computing with applications in engineering and science. It is a place for research within and between these areas, and strives to contribute to the modeling of complex systems. The main goals of the center are to foster (a) fundamental research in mathematics and theoretical natural sciences, (b) modeling of complex systems in engineering and science, (c) development of computational methods, algorithmic design and scientific computing.

Molecular Life Science Research Center MOLIFE

The Molecular Life Science Center (MOLIFE Center) studies subjects including the structure, behavior and function of vital bio-molecules such as proteins and nucleic acids, regulation of gene expression, the activity and mechanisms of cells, and the theoretical description and modeling of biological structures, mechanisms and processes. Research at the molecular level plays a central role in all disciplines of modern life sciences. For the first time, a mechanistic understanding of the phenomenon of life in all its facets is within reach. Molecular Life Science provide essential contributions in Molecular Medicine, Energy and Sustainable Development, Culture and Philosophy, Public Responsibility and Society.

Computational Laboratory for Analysis, Modeling, and Visualization CLAMV

The Computational Laboratory for Analysis, Modeling and Visualization (CLAMV) is the center for scientific computing at Jacobs University. This includes participation in scientific research projects as well as graduate teaching. CLAMV provides and maintains hardware and

software facilities and gives support for running projects. In addition to the on-campus facilities CLAMV provides access to high-performance computing centers. CLAMV / Jacobs University cooperates with BremHLR (Competence Center of High Performance Computing Bremen) and HLRN (High Performance Computer North) and other centers for high-performance computing.

Graduate School (RTG) Models of Gravity

A Research Training Group involving gravity research groups at Jacobs University and the universities of Bremen, Oldenburg, Bielefeld, Copenhagen (NBI), and Hannover with expertise ranging from string theory, over effective theories of gravity all the way to observations and applications has been established in 2012.

The main theme of the RTG is the study of models of gravity which, e.g., emerge as effective theories in the low energy limit of string theory or other approaches to quantum gravity. Beside the purely theoretical study of properties of these generalized models we also intend to discuss issues related to Dark Matter, Dark Energy, and the Pioneer anomaly. The studies mainly consist of first finding analytically or numerically solutions of the generalized Einstein equations in four and higher dimensions under various conditions, and then characterizing the properties of these solutions, in particular, by studying the motion of test particles. The test particles may be classical point particles, particles with structure, or quantum fields. The obtained results will also be of importance for various experimental projects carried out at the participating institutes. The structure of the research program demonstrates the synergies obtainable from the complementary expertises of the participating groups. Four main features characterize this RTG: (i) An active and internationally well recognized research topic. (ii) The increase of the already existing synergetic cooperation between the members. (iii) A unique offer of courses and a well balanced educational scheme. (iv) The enhancement of the role of women in this area of physics.

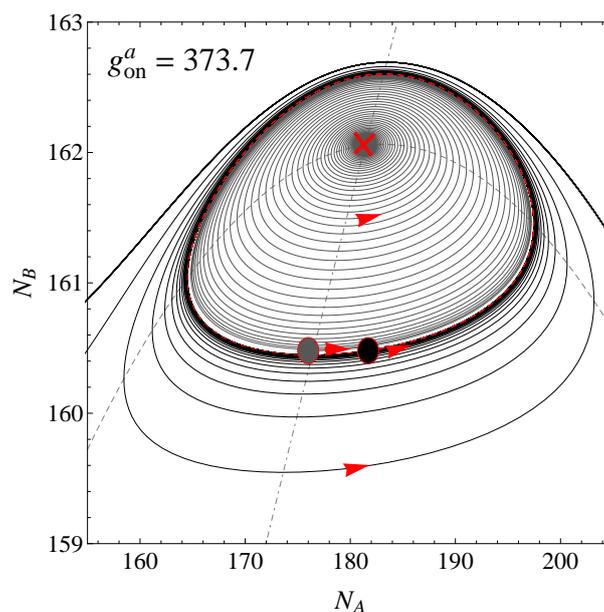


Fig.: Trajectories in a dynamical systems of two interacting proteins A and B. N_A and N_B denote their respective numbers.

Course Offerings

6 Course Offerings

6.1 Regular Courses

420441 – From Molecules to Matter

Short Name: MoltoMat

Instructors: Ulrich Kleinekathöfer

Credit Points: 5 ECTS, mandatory in Physics and Nanoscience

Semester: Fall

Course content The first part of the course provides foundations as basis knowledge necessary for understanding and describing nano-scale systems covering fundamental physical aspects. It covers the statistical approach to thermodynamics of multi-particle system. Quantum statistics of electrons, vibrations and photons are introduced to calculate various thermodynamic properties. Furthermore electromagnetic fields and there modification in matter and in cavities is addressed. Throughout the first part special emphasis is given to the scaling behaviour from infinite systems to systems of finite size. The second part provides a survey of the field nano-scale systems and will start off with an introduction to imaging, characterisation and manipulation techniques of nanoobjects and single molecules. This includes scanning probe microscopies (e.g. STM, AFM, SNOM) and other single molecule detections and analysis techniques (patch clamp, optical tweezers, fluorescence spectroscopy and microscopy). Also, fundamental properties of nanoscale materials (confinement, size dependent properties) will be discussed. The module is rounded of by a short account of methods to create nanostructures at surfaces.

Textbooks

- Introductory Nanoscience: Physical and Chemical Concepts, M. Kuno (Garland, 2011)
- Solid State Physics, N.W. Ashcroft, N.D. Mermin (Rinehart&Winston, 1976);
- Scanning Probe Microscopy: Analytical Techniques, Ed. R. Wiesendanger
- Nanoelectronics and Information Technology, Ed. R. Waser

420431 – Nanomolecular Science

Short Name: Nanomol

Instructors: Werner Nau, Ulrich Kortz, Jürgen Fritz

Credit Points: 5 ECTS, core course in Chemistry and Nanoscience

Semester: Fall

Course content This courses on Nanoscience which provide a survey of the field, both from a chemical and physical point of view. After a general introduction to the field, the course will focus on the (chemical) synthesis of various nanoparticles, including fullerenes and carbon nanotubes as well as metallic, semiconducting and ceramic nanoparticles. Aspects of their structure, properties and selected applications (catalysis) will also be covered. Finally, nanoporous materials (zeolites) and nanocrystalline materials will be treated. The second module will start off with an introduction to imaging, characterisation and manipulation techniques of nanoobjects and single molecules. This includes scanning probe microscopies (e.g. STM,

AFM, SNOM) and other single molecule detections and analysis techniques (patch clamp, optical tweezers, fluorescence spectroscopy and microscopy). Also, fundamental properties of nanoscale materials (confinement, size dependent properties) will be discussed. The course is rounded off by a short account of methods to create nanostructures at surfaces.

420432 – Supramolecular Chemistry

Short Name: SupraChem

Instructors: Nikolai Kuhnert, Detlef Gabel, Werner Nau

Credit Points: 5 ECTS, core course in Chemistry and Nanoscience

Semester: Spring

Course content The course will introduce the principal design of nanomolecular systems, their characteristic properties, principal functions and applications. The focus will lie on organic and biological functional systems and on applications in the physical sciences, thus complementing the inorganic, materials-related and methodological aspects covered in Nanomolecular Science. It deals with supramolecular chemistry, the construction of nanomolecular functional systems including shuttles, photonic devices, molecular rotors and machines, and molecular containers, including biological examples and applications, e.g., drug delivery and high-throughput screening. Synthetic aspects of supramolecular assemblies, both of discrete monodisperse nature (calixarenes, functionalized fullerenes, cyclodextrins, cucurbiturils), as well as less well defined polydisperse systems like dendrimers will be discussed.

xxx – Introduction to Quantum Chemistry & Electronic Structure

Short Name: IntQC

Instructors: Thomas Heine

Credit Points: 5 ECTS, core course in Chemistry and Nanoscience

Semester: Fall

Course content The course will cover the different approaches to solving the Schrödinger equation: Born-Oppenheimer Approximation, Hartree-Fock Method, Perturbation Theory, Density Functional Theory. Examples and exercises will allow the student to determine when which method is applicable for electronic structure calculations, and how it can be applied to specific problems.

xxx – Experimental Techniques

Short Name: ExpTech

Instructors: Physical Sciences Faculty

Credit Points: 5 ECTS, core course in Chemistry

Semester: Fall

Course content The different methods for structure elucidation, spectroscopy, imaging, and microscopy available at Jacobs University will be presented and the application to molecular

and solid state chemistry will be pointed out. Exercises will allow the student to apply the methods to relevant problems.

420531 – Advanced Quantum Mechanics

Short Name: AdvQM
Instructors: Stefan Kettemann
Credit Points: 5 ECTS, core course in Physics
Semester: Fall

Course content

- Symmetry in Quantum Mechanics
- Scattering Theory
- Geometric phases
- Entanglement, Interpretations, etc.
- Path integrals
- Correlation Functions and Linear Response
- Green's functions

2004xx – Advanced Statistical Mechanics

Short Name: AdvStatPhys
Instructors: Hildegard Meyer-Ortmanns
Credit Points: 5 ECTS, core course in Physics
Semester: Fall

Course content The course starts with a summary on ideal quantum gases of bosons and fermions. It covers topics like Bose-Einstein condensation, real gases, the virial expansion, spin systems and magnetism. A number of analytical methods will be presented to predict features of systems which are in equilibrium. The last part gives an introduction to concepts for systems out-of-equilibrium that are currently at the frontiers of research. Topics here are the Boltzmann equation, kinetic gas theory and a variety of stochastic processes, in particular with Brownian motion.

Prerequisite for this course is an undergraduate course on the basics of thermodynamics and statistical physics.

2004xx – Classical and Quantum Field Theory

Short Name: FieldTheor
Instructors: Peter Schupp
Credit Points: 5 ECTS, core course in Physics
Semester: Spring

Course content All fundamental forces of nature are described in terms of fields (at least at currently experimentally accessible energy scales). Classical and quantum field theory provides the foundation for much of physics. A thorough knowledge of the theory is indispensable for

particle physics and gravitational physics and very helpful for condensed matter/solid state physics and many other fields. The course includes a review of relevant background material in physics and mathematics.

Topics: Special relativity, point particles and extended objects in background fields, continuum limit and fields; the scalar field, symmetries and conservation laws; gauge symmetry and gauge fields, Maxwell's equations and their solutions, boundary value problems, electromagnetic radiation, electromagnetic fields in media (optics); non-abelian gauge theory, spontaneous symmetry breaking with applications in particle physics and condensed matter theory; general relativity, Einstein's equations and important solutions; applications to the physics of stars, black holes, and cosmology; quantum field theory, canonical quantization, path integrals, Feynman diagrams, renormalization; selection of more advanced topics.

420452 – Structural Methods in Nanoscale Science

Short Name: StrucMethNanoScaleSci

Instructors: Ulrich Kortz

Credit Points: 5 ECTS, elective

Semester:

Course content This course deals with modern analytical instrumentation used for the structural characterization of inorganic compounds, e.g. nuclear magnetic resonance spectroscopy, electron spin resonance spectroscopy, NQR, mass spectrometry, Mössbauer spectroscopy, and diffraction techniques. The course is designed to teach students interpret experimental data, understand the material published in modern research journals, and make decisions about what techniques will be the most useful in solving particular structural problems. The course makes a strong connection between theoretical topics and the real world of practicing chemists.

Textbooks

- Structural Methods in Inorganic Chemistry, Eds. Ebsworth, Rankin, Cradock (CRC Press)

200472 – General Relativity

Short Name: GenRel

Instructors: B. Hartmann

Credit Points: elective, 5.0 ECTS

Semester: Spring

Course content General Relativity describes Gravitation in terms of the curvature of space-time. While in Special Relativity, space-time is rigid, it becomes dynamical in General Relativity and interacts with matter/energy. The interaction between matter and space-time is governed by the famous Einstein equations. The first part of the course is concerned with the mathematical and geometrical aspects of General Relativity, while the second part will contain consequences of the theory such as black holes and cosmological models.

200332 – Advanced Solid State Physics

Short Name: ASSP
Instructors: S. Kettemann
Credit Points: elective, 5.0 ECTS
Semester: Spring

Course content This course offers an overview and guideline to understand modern problems of solid state physics including Superconductivity, Bose-Einstein condensation, Ferromagnetism, Spintronics, (Fractional) Quantum Hall Effects, Kondo Effect, Strongly Correlated Systems, and Quantum Phase Transitions

2004xx – Phase Transitions and Critical Phenomena

Short Name: PhaseTrans
Instructors: Hildegard Meyer-Ortmanns
Credit Points: elective, 5 ECTS
Semester: Fall

Course content Phase transitions are ubiquitous phenomena in nature. They are found in systems ranging from the early universe, particle physics, condensed matter physics, neural networks, biological systems, and computer science. For example, they go along with a change of the systems' symmetries, their particle contents, their state of magnetization, their memory capacity, their patterns of synchronization, or with a change of the convergence speed of algorithms for solving optimization problems in computer science. Often these changes are quite abrupt, and only a detailed analysis reveals their characteristic precursors, in particular if we have to deal with critical phenomena. We shall provide examples from different branches of physics and beyond. After presenting a classification scheme of phase transitions and their phenomenological characterization, we consider the Ginzburg-Landau theory as one of the basic analytical tools for their prediction and analysis, followed by a primer to the renormalization group which leads to a theoretic understanding of critical phenomena. Under certain conditions critical phenomena may be even self-organized, so that no fine-tuning of parameters is needed. We shall give an outlook to this phenomenon, called self-organized criticality. Prerequisite for this course is an undergraduate course on the basics of thermodynamics and statistical physics.

420501 – Theory for Spectroscopy Simulations

Short Name: Theoretical Spectros
Instructors: Thomas Heine
Credit Points: elective, 5 ECTS
Semester: Fall

Course content This course the theory for simulations of spectroscopy data will be given. The course will cover molecular (infrared, Raman, UV/Vis, NMR, ERP) and solid state (EELS, XANES, XAS, XES, PES) spectroscopy as well as XRD. Homeworks will cover computer experiments and individual reading assignments.

420471 – Transport Physics and Electronic Devices

Short Name: TransPhysElecDev
Instructors: Veit Wagner
Credit Points: elective, 5 ECTS
Semester: Spring

Course content The course introduces to the phenomena of transport processes in condensed matter and the physical concepts to describe them. This includes the discussion of heat, sound and electronic transport. With emphasis on the latter, electronic devices serve as model systems to understand the transport in macroscopic structures as well as in nano-scale devices. Required modifications of macroscopic transport models to describe transport in nano and single molecule structures are introduced and discussed. In parallel to theoretical concepts the basic experimental techniques applied to analyze transport properties are introduced.

xxx – Molecular Physics

Short Name: MolPhys
Instructors: Arnulf Materny
Credit Points: elective, 5 ECTS
Semester: Fall

Course content Molecular Physics is on the one hand closing the gap between Atomic Physics and Solid State Physics and on the other hand creates an important link to Chemistry. The course will start with a brief repetition of atomic physics concepts (quantum numbers, He atom, orbital approximation, exchange). The molecular Hamiltonian and the Born-Oppenheimer approximation will be then be used to describe electronic structure as well as ionic and covalent bonding. Vibrational structure and wavefunctions will be introduced and rotational energy levels will be discussed. Ionisation and dissociation will be pointed out as important molecular energy scales. Techniques for the experimental characterization of molecules will be also an important part of the lecture with special emphasis on optical spectroscopy. Keywords here are e.g. "selection rules", "Franck-Condon principle", "Raman scattering", and "absorption spectra".

Basic knowledge of the undergraduate Quantum Physics courses will be required. Atomic Physics basics will be partially repeated, but previous experience from an introductory course would be advantageous.

530462 – Computational Challenges in Biology and Biophysics

Short Name: CompBiol
Instructors: Marc-Thorsten Hütt; Ulrich Kleinekathöfer
Credit Points: elective, 5 ECTS
Semester: Spring

Course content Computational approaches to analyzing, understanding and predicting biological processes have developed rapidly in the last decade and have by now an important role

in virtually every fields of biological research. With these lectures we aim at highlighting the current computational achievements in different areas of biology, their limits and possible future developments. Topics include: predicting protein structure from sequences, understanding genome evolution, simulating cells, Molecular and Brownina dynamics, simulating membrane transport with atomic resolution, predicting epidemic spreading of diseases and analyzing patterns of brain activity.

530421 – Biological Thermodynamics, Kinetics, and Separation

Short Name: BioThermKinSep
Instructors: Jürgen Fritz; Mathias Winterhalter
Credit Points: elective, 5 ECTS
Semester: Spring

Course content This course focuses on the thermodynamics and kinetics of structure formation and association of biomolecules, a theme of central importance for biological recognition. It includes a discussion of theoretical methods to describe thermodynamic driving forces for association and structure formation and how to analyze cooperative effects. The course is also intended to give a comprehensive overview on experimental methods to measure thermodynamic contributions and how to investigate the kinetics of biological processes at various time scales. In addition, separation methods that are based on differences in the physical properties of proteins and other biomolecules will be discussed in detail. The course focuses on the experimental methods and theoretical background to understand the biophysics of cellular membranes. The framework is an introduction to systems, experimental and theoretical methods in biophysics. The course should address biophysics interested M.Sc. students.

200352 – Principles and Applications of Optical Spectroscopy

Short Name: Spectroscopy
Instructors: Arnulf Materny
Credit Points: elective, 5 ECTS
Semester:

Course content Optical spectroscopy is a powerful technique for investigating electronic and vibrational properties of a variety of systems. In nanostructured systems, the techniques of absorption, reflection, luminescence, and light-scattering spectroscopies are capable of providing invaluable information about diverse aspects. This course gives an introduction to the different spectroscopic techniques which are used in the field of laser spectroscopy. The prerequisites will be the lectures on quantum mechanics of atoms, molecules, and solids. In the beginning, the instrumentation of laser spectroscopy will be introduced. Especially the different types of lasers will be explained. Then techniques making use of the spectral information will be discussed, starting with absorption and luminescence spectroscopy. Other examples are Raman spectroscopy and finally also nonlinear spectroscopic methods. The course will after this introduce the methodology of femtosecond time-resolved spectroscopy, which gives access to the dynamics of both internal molecular processes and chemical reactions. At the end of the

course, possible applications of the spectroscopic techniques (e.g. in combination with SNOM) for the investigation of nanostructures will be discussed.

Textbooks

- Wolfgang Demtröder, Laser Spectroscopy (Springer, NY, 2002), 3rd ed.

420492 – Nanoanalytics

Short Name: NanoAna

Instructors: Veit Wagner

Credit Points: 5 ECTS, elective

Semester:

Course content This Graduate level course is designed for physicist and students of neighboring disciplines, i.e. chemists and electrical engineers, with basic knowledge in solid state physics. It introduces in systematic order experimental methods for condensed matter analysis with special emphasis on methods with relevance to nanoscience. Where necessary special sample preparation methods are discussed together with the measurement principle and the measurement quantities and measurement accuracy. Methods discussed include basic methods, like x-ray diffraction, photo electron spectroscopy and scanning electron microscopy, up to advanced complex machinery as e.g. high resolution techniques available at synchrotron radiation facilities.

420502 – Density-Functional Theory

Short Name: DFT

Instructors: Thomas Heine

Credit Points: elective, 5 ECTS

Semester: Spring

Course content The course addresses graduate students (Ph.D. and Master) specializing in Theoretical Physics and Chemistry and those who want to use Computational Physics and/or Chemistry with solid background in these projects. All participants need to have a login on the university supercomputer facility (access can be provided beforehand),

The aim of the course is to teach both the theoretical foundations of DFT as well as the tricks of the trade. The course will cover:

1. Hohenberg-Kohn Theorems
2. Electron correlation functionals
3. Exchange-correlation functionals
4. DFT in local basis set representation
5. Pseudopotentials / Effective Core Potentials
6. DFT in plane wave representation
7. FR-LAPW and PAW
8. Relativistic effects
9. Limitations of DFT
10. London dispersion correction

11. Time-Dependent DFT
12. Quantized-Liquid DFT

There is no standard text, chapters are taken mainly from the original literature, but also from the Parr-Young, Dreizler-Gross and Cramer texts.

Tutorials and homeworks will be combined to a logical unit. The students will learn to use some example codes (ADF/BAND, TurboMole, VASP, WIEN2k). Phd Students will be actively involved in the tutorials.

420551 – Computational Solid State and Surface Physics

Short Name: CSSSP
Instructors: Thomas Heine
Credit Points: 5 ECTS, elective
Semester: Fall

Course content In the lectures, the topics will be introduced from the experimental and from the theoretical viewpoints. The aim is to show what exactly is simulated (with all models and approximations clearly discussed), and what is measured (with explanations about accuracy and secondary effects). Students will be in charge of the Hands-On sessions. They will present a short review of the problem to the class, and explain it on a concrete example. Then, in a Hands-On session, the computational task - that is, how exactly the simulation is carried out - will be explained. The information will be presented in front of the class, and the tutorial shall be prepared in a document that will be distributed in class. Finally, the homeworks will be presented. Students will work closely with an instructor in order to prepare Hands-On session, tutorial and homeworks. Homeworks can be solved individually or in groups. They will be graded by the student and instructor responsible for the respective Hands-On session.

200391 – Physics of the Early Universe

Short Name: PhysEarlyUniverse
Instructors: B. Hartmann
Credit Points: 5 ECTS, elective
Semester:

Course content While particle physics deals with physics on the smallest scales, cosmology is mainly concerned with physics on the largest scales. To understand the structure we see in the universe today, it is vital to have knowledge about the early universe. Due to the extreme conditions in the early universe, especially the high energies, which (up to now) cannot be simulated in terrestrial accelerators, it is a very good testing ground for theories beyond the standard model such as Grand Unified Theories (GUTs) or even String Theory. In this sense, the early universe is the main ground to understand the interplay between cosmology and astrophysics on the one hand and particle physics on the other hand. In this lecture, we will start with a brief overview of what is known about the universe today. Topics include the cosmic microwave background, the large-scale structure of the universe as well as the abundance of different elements. In what follows, we will illustrate how these observations can be explained

in the so-called "Hot Big Bang" model of the universe. Topics here are nucleosynthesis, baryogenesis as well as phase transitions and the inflationary epoch.

200421 – Strings, Branes, and Matrices

Short Name: StringBranMat
Instructors: P. Schupp
Credit Points: 5 ECTS, elective
Semester:

Course content A contemporary introduction to selected topics of high-energy physics with focus on string theory; brief review of relevant topics from quantum field theory (path integrals, supersymmetry); closed and open strings and their quantization, background fields, D-branes, effective actions; M(atr)ix theory; non-commutative geometry and string theory; choice of advanced topics.

210322 – Gravity in Geophysics and Planetary Sciences

Short Name: GravityGeoPlanet
Instructors: J. Vogt
Credit Points: 2.5 ECTS, elective
Semester: Spring

Course content Gravity anomalies on planetary surfaces result from density inhomogeneities in the interior and can thus provide information about the composition and structure of the subsurface. On large spatial scales, gravity meters and accelerometers on orbiting spacecraft are the most efficient means to map gravity anomalies. In geophysical exploration, gravity methods are used to study anomalies on small and regional spatial scales. This course provides a general introduction to gravity methods in both geophysics and planetary sciences. We utilize potential theory and spherical harmonics for large scales. Gravity data processing and interpretation are discussed in the light of geophysical inverse methodology.

210332 – Magnetism in Geophysics and Planetary Sciences

Short Name: MagnetismGeoPlanet
Instructors: J. Vogt
Credit Points: 2.5 ECTS, elective
Semester: Spring

Course content On Earth and other planets, magnetic phenomena are found on a wide spectrum of spatial scales ranging from small-scale magnetic anomalies caused by magnetized surface rocks to global magnetic fields generated through dynamo action in planetary interiors. This course provides a general introduction to magnetic fields and magnetic methods in both geophysics and planetary sciences. Topics include magnetic instruments, measurements, data processing, interpretation and modeling.

xxx – Reductionism in Physics and its Relation to Philosophy

Short Name:

Instructors: Hildegard Meyer-Ortmanns

Credit Points: 2.5 ECTS, elective

Semester:

Course content The aim of the course is to discuss both the success and the limitations of methodological reductionism in physics. The first part shall illustrate reductionism's success in different areas of physics: relativity theory, gauge theories of the standard model, self-organized processes like pattern formation in cosmology, the renormalization group approach in condensed matter theory, and more generally in topics of multi-scale modeling. Guiding principles and tools shall be analyzed that make this success possible. The second part deals with limitations of reductionism which show up when the goal is to predict not only a single aspect, but the whole variety of emergent phenomena on a higher level, starting from a known underlying level of description. Furthermore, the very formulation of physical laws in stochastic and deterministic versions shall be reviewed, and along with them, an important topic in the theory of evolution that is related to the role of contingency and necessity in systems' time evolutions, in particular in the evolution of the universe. From illustrations of the successful application of reductionism in different branches of physics, undergraduate students are expected to receive first reviews on great achievements in physics rather than obtaining a detailed understanding. A deeper understanding can be gained upon specialization on the graduate level. On the other hand, pointing out the limitations of reductionism opens the view for the need to include other disciplines than physics to approach complex systems in all its facets.

210392 – Geophysical Time Series Analysis

Short Name: GeoTimeSeries

Instructors: J. Vogt

Credit Points: Lecture, 5.0 ECTS, elective

Semester: Spring

Course content In geosciences and space physics, data often come in the form of time series. This course covers important approaches to time series analysis such the statistical description of data, correlation and regression, auto-correlation and cross-correlation functions, Fourier analysis, spectrum estimation, filtering, and modeling of data. Short reviews of the underlying theory are embedded in hands-on computer lab sessions where the students familiarize with the practice of time series analysis and interpretation. They learn to assess the potential and the limitations of the analysis methods, and apply them to measurements.

200xxx – Condensed Matter Field Theory

Short Name: CondMatField

Instructors: S. Kettemann

Credit Points: Lecture, 5.0 ECTS, elective

Semester: Fall

Course content Over the past few decades, in concert with ground-breaking experimental advances, condensed matter theory has drawn increasingly from the methods of low-energy quantum field theory. This course is aimed at elevating graduate students of condensed matter theory to a level where they can engage in independent research. It emphasizes the development of modern methods of classical and quantum field theory with applications oriented around condensed matter physics. Methods covered include second quantization, path and functional field integration, mean-field theory, Ginzburg-Landau Theory of critical phenomena, the renormalization group method, and topological field theories. These Methods are applied to phenomena of modern physics like superconductivity, Bose- Einstein condensation, magnetism, quantum Hall effect, Kondo effect and Quantum Phase Transitions. The discussion will be rooted firmly in practical experimental application. As well as routine exercises, the course will guide through extended and challenging problems, designed to provide a bridge between formal manipulations and research- oriented intuitive thinking.

Prerequisites: Solid State Physics, Quantum Mechanics I and II, Statistical Physics

560351 – Biophysical Chemistry

Short Name: Biophys

Instructors: Mathias Winterhalter

Credit Points: 5 ECTS, elective

Semester:

Course content Interactions between molecules, such as antibody-antigen, enzyme-substrates, receptor-membrane are the base of biological processes. This course introduces current theoretical and experimental tools to quantify such interaction between biomolecules. We begin with a molecular view to introduce the relevant forces and interaction necessary to understand and perform molecular modeling. In a second part we follow a more macroscopic thermodynamic view: substrate binding or partitioning, cooperative effects, transport across membranes to name a few keywords. The third part is devoted to kinetic phenomena and the necessary experimental techniques as relaxation theory, correlation spectroscopy, stopped flow.

560331 – High-throughput screening technology

Short Name: HTS

Instructors: Helge Weingart

Credit Points: 5 ECTS, elective

Semester:

Course content High throughput screening (HTS) is a tool in the discovery of pharmaceutical, chemical, and agricultural compounds. HTS is a main selective tool in big-scale research programs like drug discovery. Methods of HTS are basically methods of analytical biochemistry (photometry, purification, electrophoresis, kinetic assay, radioisotopes, immunoassay, descriptive statistics, regression analysis, etc), that is why HTS course explicitly covers these subjects, because firm knowledge of methods of analytical biochemistry is crucially important for assay design, its validation, and following data analysis and decision making. During the

course we also will learn principles of the various detection techniques (light absorption, fluorescence, radioisotope technique). Consequently, the pivot part of the HTS is assay design, where detection techniques are one of the essential parts, and following statistical treatment of the results will lead to making of the decision. Also we will learn physical principles and operational basics of many analytical biochemical instruments used for multi-sample analysis (microplate readers, scintillation counters) as well as consumables for the HTS. In this course we will cover state of the art technologies including automated liquid handling machines (robots) and techniques used in HTS. A focus will be on genetic engineering techniques and screening systems involved. Additionally required automation and engineering approaches will be covered in detail. The goal is to provide students with a background that enables them to successfully implement HTS strategies in real world applications of high-tech industry by mining the created diversity and finding the needle in haystack.

400301 – Computational chemistry and biochemistry

Short Name: CompChem

Instructors: Danilo Roccatano

Credit Points: 5 ECTS, elective

Semester:

Course content The course provides the an introduction to modern methods of computational chemistry, quantum chemistry and molecular simulation, as the most widely used techniques. The quantum chemistry part covers basis sets, the variational principle, Slater determinants, the Hartree-Fock method, an overview of post-Hartree-Fock methods and density-functional theory. The molecular simulation part deals with force fields, molecular dynamics, Monte Carlo and analysis methods. In both areas, applications and examples are chosen from chemistry and biochemistry.

560302 – Design of biomolecules and systems

Short Name: CompChem

Instructors: Danilo Roccatano

Credit Points: 5 ECTS, elective

Semester:

Course content The course is intended to give an overview on theoretical/computational aspects of biological molecule and system design. It provides an introduction to different bioinformatics and molecular modeling methods to study structure, dynamics and function of biomolecular system in solution and at interfaces, molecular recognitions, drug design and virtual screening methods. Practical homeworks and lab tutorials are assigned to deeper the understanding of the methods and tools learn in the theoretical lectures.

xxx – Food and agricultural chemistry

Short Name: FoodChem

Instructors: Nikolai Kuhnert

Credit Points: 5 ECTS, elective

Semester:

Course content The course will address the problems and challenges of how to feed a growing global population.

It will cover lectures on basic nutritional requirements of dietary plants, basics of agricultural practice, the basic science and risks associated with the use of fertilizers, pesticides and genetically modified organisms. The basics of food composition and biochemistry determining nutritional value of selected foods will be covered. Further topics will include methods for food analysis and characterization, legal requirements for food quality control and food safety, aspects of human and animal nutrition, use of alternative food sources, nutraceuticals, industrial processing of food, factors affecting food production and distribution and the effect of agriculture on the environment.

400342 – Organometallic Chemistry

Short Name: OrgMet

Instructors: Gerd Röschenthaler

Credit Points: 5 ECTS, elective

Semester:

Course content Main Group Metal and Transition Metal Organyls (synthesis, bonding and structures, stability, reactions and use), electron deficient systems, sigma- and pi-bonding, sandwich complexes, environmental aspects, heterogenous and homogenous catalysis, industrially important processes (e.g. Fischer-Tropsch Reactions, Wacker Oxidation, Hydroformylation, Coupling Reactions).

xxx – Fluorine chemistry

Short Name: FChem

Instructors: Gerd Röschenthaler

Credit Points: 5 ECTS, elective

Semester:

Course content This course deals with the different aspects of the chemistry of fluorine-containing organic compounds with an emphasis on physical and chemical peculiarities of organic fluorine compounds, synthesis and reactivity, ecological problems, applications of organofluorine compounds, fluorine-containing diagnostic and pharmaceutical compounds and their mode of action, fluorine-containing liquid crystals for active-matrix displays.

xxx – Introduction to medicinal chemistry

Short Name: MedChem
Instructors: Detlef Gabel
Credit Points: 5 ECTS, elective
Semester:

Course content The course gives an introduction into non-covalent interactions important between drugs and proteins and other drug targets and their physiological consequences. Topics include: Discovery and design of biologically active compounds; mode of action; structure-activity relationships; testing of activity; modifications of lead structures, and combinatorial chemistry.

400312 – Advanced Synthesis

Short Name: AdvSynth
Instructors: T. Nugent
Credit Points: 5 ECTS, elective
Semester:

Course content Building on basic knowledge of functional group transformations and stereochemistry, strategies for the synthesis of complex organic molecules (natural products and pharmaceutical drugs) will be discussed. In this context, the importance of the order and type of transformation (retrosynthetic analysis) required for brevity in synthesis will be stressed. Functional group compatibility, the use of modern reagents, and the control of stereochemistry (chirality) through the use of remote and proximal functional groups vs enantioselective catalysts will be covered.

400341 – Structure and Mechanism

Short Name: StrucMech
Instructors: T. Nugent, W. Nau
Credit Points: 5 ECTS, elective
Semester:

Course content The course will deal with the area of physical-organic chemistry and requires the fundamental knowledge from undergraduate organic and physical chemistry courses, such as Advanced Chemistry AI and BI. The course will cover the following areas: Conformational analysis and molecular mechanics, applications of molecular orbital theory and valence bond, reactive intermediates, spectroscopic methods of studying chemical reactions and reaction mechanisms, and applications to various reaction types. Two special chapters will be dedicated to mechanistic photochemistry and supramolecular chemistry.

Textbooks

- Structure and Mechanism, F. A. Carroll (Brooks/Cole, 1998)

400342 – Advanced Organic Synthesis

Short Name: AdvOrgSynthesis

Instructors: T. Nugent

Credit Points: 5 ECTS, elective

Semester:

Course content Building on your basic knowledge of functional group transformations and stereochemistry, strategies for the synthesis of complex organic molecules (natural products and pharmaceutical drugs) will be discussed. In this context, you will learn the importance of the order and type of transformation (retrosynthetic analysis) required for brevity in synthesis. To do so, we will cover functional group compatibility, the use of modern reagents, and the control of stereochemistry (chirality) through the use of chiral auxiliaries vs. enantioselective catalysis. Finally, all of these aspects will be assessed, learned and applied through the use of reaction mechanisms (arrow pushing).

Textbooks

- Organic Chemistry, Oxford University Press 2001, Clayden, Greeves, Warren, and Wothers, ISBN: 0 19 850346 6
- Supplementary material: Current Literature

420402 – Organocatalysis

Short Name: OrgCat

Instructors: T. Nugent

Credit Points: 5 ECTS, elective

Semester:

Course content Ten years ago only transition metal or enzyme mediated enantioselective catalysis were pursued. Organocatalysis is now a third option, providing competitive, as well as complementary, solutions for the synthesis of diastereo- and enantioenriched pharmaceutical drugs and natural products. The underlying premise is that low molecular weight chiral organic molecules can be designed and employed for the catalytic activation of achiral starting materials culminating in asymmetric bond formation. The catalysis concepts originate from Bronsted acid and base chemistry and rely heavily on covalent activation and/or strong chiral counter ion effects. When bifunctional organocatalysts are used, weaker, noncovalent, attractive forces (notably hydrogen bonding) become important. Use of these and other steric and electronic design features allow chemists to control the trajectory, facial approach, and conformation of reacting chemical partners. Students interested in this course will feel comfortable with the material discussed in the first year of organic chemistry, and would like to strengthen and expand their understanding of those concepts regarding the stereocontrol (transition state analysis) that permits access to the advanced building blocks required for natural product synthesis.

420xxx – Nanomolecular Materials in Biotechnology

Short Name:

Instructors: Marcelo Fernández-Lahore

Credit Points: 5 ECTS, elective

Semester:

Course content The course is intended to give an overview on nanomolecular materials and systems used in various fields of biotechnology such as product recovery and polishing. Theoretical as well as experimental aspects will be presented in detail including methods for tailoring materials and proteins. Applications and scale-up problems will be explained on selected examples of chemical and pharmaceutical companies. In addition we intend to use a software tool, recently developed at the university Bremen, for modelling, predicting and designing product recovery procedures.

200302 – Elementary Particles and Fields

Short Name: ExpTheoPhys A II

Instructors: B. Hartmann

Credit Points: Lecture, 5 ECTS

Semester: Spring

Course content This course provides an introductory overview about theoretical and experimental aspects of elementary particle physics, quantum field theory and nuclear physics. The Standard Model of particle physics is introduced and experimental and phenomenological aspects of particle physics are discussed. Theoretical topics include gauge theories of the fundamental forces of nature, an introduction to quantum field theory and Feynman diagrams.

200312 – Semiconductor Devices and Advanced Optics

Short Name: ExpTheoPhys B II

Instructors: Veit Wagner and Arnulf Materny

Credit Points: Lecture, 5 ECTS

Semester: Spring

Course content Topics include semiconductors and devices like transistors, LED's, and solar cells for semiconductor devices. The optics part deepens and extends the optics of General Physics. Important issues from modern optics (e.g. dielectric coatings, nonlinear optics, time-domain properties) as well as advanced theoretical descriptions (e.g. Jones vectors, ray matrices) will be introduced.

200331 – Computational Physics

Short Name: CompPhys

Instructors: U. Kleinekathöfer

Credit Points: Lecture, 5 ECTS

Semester:

Course content Computational physics discusses a number of practical, numerical solutions for typical problems in physics. While the very nature of physics is to express relationships between physical quantities in mathematical terms, an analytic solution of the resulting formulas is often not available. Instead, numerical solutions based on computer programs are required to obtain useful results for real-life physics problems. The first part introduces basic numerical techniques such as for integration, interpolation, root finding, function optimization, and solving differential equations which are important tools in any numerical approach not only in physics. In the second half of the course, modern applications like molecular dynamics and Monte-Carlo techniques are discussed, including analysis of data resulting from such approaches.

Since the course includes numerous examples and exercises for programming codes, some programming skills in Fortran or C are strongly recommended as prerequisites.

200371 – Fundamentals of Hydrodynamics

Short Name: Hydro

Instructors: A. Khalili

Credit Points: elective, 5 ECTS

Semester: Fall

Course content The Fluid Dynamics course addresses fundamental equations, which govern many flow problems occurring in science and engineering. We start with the concept of continuum and Lagrangian versus Eulerian approach. Based on conservation laws of physics, we derive continuity, momentum and energy equations. As special cases of general flow equations, irrotational flows and hydrostatics will be considered. Further, hydrodynamic instability, turbulence, waves, rotation, geostrophic flows, and flow through porous medium will be treated as special topics. The course will be accompanied with performing experiments at Jacobs University and MaxPlanck Institute for Marine Microbiology in Bremen. All mathematical tools that are needed will be treated prior to lectures.

200372 – Computational Fluid Dynamics

Short Name: CFD

Instructors: A. Khalili

Credit Points: elective, 5 ECTS

Semester: Spring

Course content Computational fluid dynamics (CFD) has become one of the most sophisticated tools, beside the analytical and experimental methods, for solving problems in fluid dynamics, heat and mass transfer. This course will introduce the physical and mathematical foundations of CFD for incompressible viscous flows, and to provide students with a working knowledge of CFD. By the end of the course, the successful student will be able to develop, debug, and analyze a finite difference code that solves the Navier-Stokes equations. The course will start by an introduction to numerical methods and explain what is CFD. Next, basic equations of fluid mechanics are reviewed. The partial differential equations are, then classified. Finite difference methods are explained, and different solution techniques for systems of linear

algebraic equations are explained. Finally, important issues such as the stability and convergence criteria are explained, when dealing with CFD.

6.2 Seminars and Practical Training

420472 – Current Topics in Physical Sciences

Short Name: CurrTopics
Instructors: Coordinated by one faculty member
Credit Points: 5 ECTS, mandatory
Semester: Fall

Course content The course introduces current topics of physics, chemistry and nanomolecular science. Lectures will be taught by various faculty members according to their expertise. For each field an overview of the scientific background, the motivation and major challenges is provided. This is complemented by an in depth discussion of a specific research topic in each discipline. Each student will select two different fields of chemistry, physics or nanomolecular science, for which (s)he writes a term paper following the scheme of a Ph.D. proposal under the supervision of the corresponding faculty member. Grading is based on the quality of the term papers and attendance.

420511 – Physical Sciences Graduate Student Seminar I

Short Name: GradSemI
Instructors: alternating
Credit Points: 5 ECTS, mandatory
Semester: Spring

Course content The graduate seminar exposes the students of the graduate programs in Physical Sciences to recent developments in the fields. The topics are selected together with the Instructor of Record and need to be presented in front of the other participants.

420412 – Physical Sciences Graduate Student Seminar II

Short Name: GradSemII
Instructors: alternating
Credit Points: 5 ECTS, mandatory
Semester: Fall

Course content In this graduate seminar the students present topics from the Advanced Guided Research I or the Physical Science Research Methods course.

420421 – Physical Sciences Research Methods

Short Name: ResMeth
Instructors: Coordinated by one faculty member
Credit Points: 10 ECTS, mandatory
Semester: Fall

Course content The Practical Training on Research Methods is mandatory for students enrolled in the Physical Sciences Graduate Program. This course exposes the student to different experimental and theoretical techniques employed in the various physics groups at Jacobs University. The Research Training consists of six units of two weeks each from which at least two units need to be performed in a theoretical group and two in an experimental group. Moreover, it is possible to combine two units in one group if this introduces different techniques. This course is a prerequisite for the Advanced Guided Research courses.

420462/420461 – Physical Sciences Advanced Guided Research I/II

Short Name: AdvGResI/II
Instructors: Coordinated by one faculty member
Credit Points: 10 ECTS, mandatory, 12 h/week
Semester: Spring/Fall

Course content The Advanced Guided Research courses are mandatory for students enrolled in the Physical Sciences graduate program. During two consecutive courses the students are exposed to a specific research area of physics in-depth. For this the student is required to participate in the research activities of a Jacobs University faculty member that participate in the Physical Sciences graduate program. Typically a continuous project defined by the supervising faculty member is conducted during the consecutive Advanced Guided Research courses. The research can involve experimental and/or theoretical topics. Grading for this course is based on lab performance and the quality of research reports. Furthermore, the Advanced Guided Research courses should enable the students for preparing a M.Sc. thesis in the 4th semester or entering the Ph.D. phase.

420522 – Physical Sciences Independent Research and M.Sc. Thesis

Short Name: IndRes
Instructors: Coordinated by one faculty member
Credit Points: 30 ECTS, mandatory, full week
Semester: Spring/Fall

Course content The Independent Research and M.Sc. Thesis denotes a course in which students work independently, but under supervision, on assigned research problems. Learning goals of this course are build on those of all other course. Students need to mobilize everything they have learned so far in order to master the tasks in the Thesis course. The research can involve experimental and/or theoretical topics. The research work of the student has to be summarized in written document, the Master's Thesis. Furthermore the work is presented in a

scientific seminar. Grading for this course is based on lab performance and the quality of the Master's Thesis research reports.

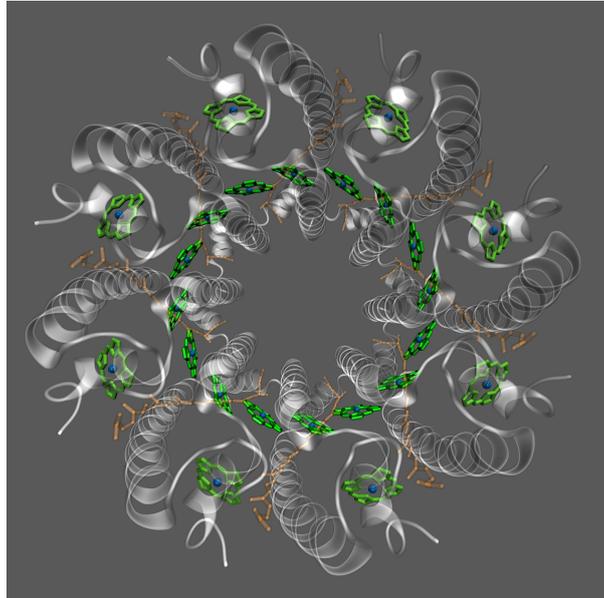


Fig.: Molecular simulations, electronic structure theory, and quantum mechanics are combined to understand the elementary steps in photosynthesis.

