MASTER OF SCIENCE IN ENGINEERING

Module Description, available in: EN

Physics on micro and nano scale

General Information

Number of ECTS Credits

3

Module code

FTP_PhyMNS

Valid for academic year

2024-25

Last modification

2020-03-16

Coordinator of the module

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Explanations regarding the language definitions for each location:

- Instruction is given in the language defined below for each location/each time the module is held.
- Documentation is available in the languages defined below. Where documents are in several languages, the percentage distribution is shown (100% = all the documentation).
- The examination is available 100% in the languages shown for each location/each time it is held.

	Lausanne			Lugano	Zurich		
Instruction					**X** E 100%		
Documentation					**X** E 100%		
Examination					**X** E 100%		

Module Category

FTP Fundamental theoretical principles

Lessons

2 lecture periods and 1 tutorial period per week

Entry level competences

Prerequisites, previous knowledge

- Optics: Basics of wave optics;
- Physics: The students are able to solve simple differential equations, know linear algebra and can handle electromagnetic forces and fields.
- Mathematics: Basics for engineers (bachelor Level)

Brief course description of module objectives and content

The module “Physics on micro and nano scale” focuses on physical effects and their applications in photonics, electrical engineering, medical engineering and mechanical engineering which become relevant, when technical systems get miniaturized. In the first step of miniaturization - from macro to micro – the principal physics remains unchanged, but the dominant physical effects change due to a changed surface to volume ratio. Surface related effects become dominant. With further miniaturization – from micro to nano - quantum phenomena become dominant and lead to completely new physical concepts. When the typical size of objects is between several nanometers and a few micrometres we can observe a wealth of fascinating effects that today are the basis for applications from advanced sensing to medical applications, ultrasmall mechanical devices, nanophotonics etc.

A first main topic of this module relates to surface effects. Microstructured surfaces, for example, play an important role in mechanical systems in terms of nano-roughness and nanotribological properties. In nature, such microstructures lead e.g. to the Lotus effect or to different colour effects, and in medicine, micro and nanostructured surfaces help to significantly improve the acceptance of implants by the human organism. Another interesting topic is surface functionalisation, which can be designed to reduce e.g. wear, corrosion, ice-formation or bio-fouling on materials; surface functionalization is furthermore an important step in the design of chemical and biochemical sensors.

A second main topic deals with quantum effects that are related to spatial confinement in physical systems. The discretization of energy levels in atomic systems, for example, forms the basis for the understanding of light-matter interaction. Prohibited states in periodic solids lead to band gaps in semiconductors, which provide the basis for modern electronics. In a similar way, "forbidden" states can also be generated in dielectric periodic structures. The so called photonics band gaps enable completely new forms of light guidance in photonic crystals. Quantum dots and quantum wires are further quantum objects that have an important meaning in modern electronics.

A third topic covers new materials structures on the micro and nanoscale. Nanoparticles and nanofibers in biology and medicine offer completely new opportunities in diagnostics and research. Graphene consists of only one layer of carbon atoms and has been the subject of the most modern research since its discovery. The unique properties of the thinnest material in the world could be used in many different ways - for mechanical components, solar cells, medical sensors or in electronics, due to its enormous conductivity and the quantum Hall effect, which already occurs at room temperature. Nanoparticles and nanostructures also play an important role in the field of nanophotonics. The interaction of light with nanostructures leads to novel effects such as plasmonics and opens up new possibilities in optoelectronics and microelectronics.

Aims, content, methods

Learning objectives and competencies to be acquired

After completion of this module the students will:

- know the fundamental aspects of quantum mechanics and understand the quantum nature of the nanoworld
- know the phenomena of nano-and microstructures influencing surface and material properties (e.g. structural colours, tribo-mechanical and wetting behaviour)
- know the processes that govern the functionalisation of surfaces
- know the fundamental quantum mechanical concept of discretization and resulting consequences such as discrete energy states, electronic and photonic band gaps, quantum dots and quantum wires and their applications in modern photonics, electronics and medicine
- know the function and application of nanoparticles and nanofibers in biology and medicine
- know the interaction of light with dielectric, semiconductor and metallic nanoparticles (incl. plasmonics)

Module content with weighting of different components

- From macro to micro to nano: scaling of physical systems and the consequences (3 lessons)
- Quantum mechanics and Quantum Nature of the Nanoworld: Schrödinger equation, discrete energy levels, sizing effects (6 lessons)
- Nano- and microstructured surfaces: Physics of nano tribology, structural colours, and nanostructures for medical applications (6 lessons)
- Functional surfaces: Physics of wetting behaviour, adhesion, and applications (e.g. wear reduction, anti-icing or anti-sticking surfaces, surfaces for fluidic and sensor applications) (6 lessons)
- Electronic and photonic bandgaps: Physical basics and applications (6 lessons)
- Quantum dots and quantum wires: ISFETs (ion-sensitive field-effect transistors) and BioFETs (field effect biosensors) for electronics and biotechnology (3 lessons)
- Nanoparticles and fibers: Basics and applications in medicine, biology, and sensor developments (6 lessons)
- Nanophotonics: Interaction of light with nanoparticles and nanostructures (dielectric, metallic, semiconductor) (6 lessons)

Teaching and learning methods

Lectures and self-study

Practical exercises and case studies

Literature

Lecture notes, application oriented summary articles or slides with indication of sources for further reading will be distributed.

Introduction to Nanoscience & Nanotechnology, Gabor L Hornyak et al. , CRC Press, 2009.

Nanophysik und Nanotechnologie, Edward Wolf, Wiley-VCH, 2014

Assessment

Certification requirements

Module does not use certification requirements

Basic principle for exams

As a rule, all standard final exams are conducted in written form. For resit exams, lecturers will communicate the exam format (written/oral) together with the exam schedule.

Standard final exam for a module and written resit exam

Kind of exam

Written exam

Duration of exam

120 minutes

Permissible aids

Aids permitted as specified below:

Permissible electronic aids

No electronic aids permitted

Other permissible aids

Personal formulary: two A4 pages

Special case: Resit exam as oral exam

Kind of exam

Oral exam

Duration of exam

30 minutes

Permissible aids

Aids permitted as specified below:

Permissible electronic aids

No electronic aids permitted

Other permissible aids

Personal formulary: two A4 pages