UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Dipartimento di Scienze Fisiche, Informatiche e Matematiche

Master's Degree Programme in Physics

Nanophysics and Nanotechnology

Curriculum
Experimental physics

Department of Physics, Informatics and Mathematics
Modena Campus

2 years
Full time
ECTS credits: 120

Description of the study plan

This study plan is designed to train students on the experimental methods for fabricating and controlling materials and components with dimensions on the nanoscale, i.e. from 1 to 100 nm. Applying advanced nanofabrication and characterization methods to materials makes it possible to obtain decisive control over their properties, and thereby construct unique nano-structured materials, interfaces and bio-systems with still unexplored physical properties. Students will have the opportunity to investigate fundamental physics down to the quantum regime. During the course of their studies, and particularly developing the thesis project, students will be involved in state-of-the-art research that makes up the field of nanophysics and nanotechnology in one of the modern and well equipped laboratories of the University, getting acquainted with advanced nanotechnologies and microscopies that can be used to develop devices and sophisticated instrumentations for use in many technological fields. This study plan is connected to ongoing research activities carried out by teachers in collaboration with several research centers in Europe, amongst which are Forschungszentrum Jülich (D), Max Planck Institut (D), University of Glasgow (UK), Maastricht University (NL), Polygone Scientifique in Grenoble (FR), Karlsruhe Institut fur Technologies (D). Many research activities are carried out in close connection with the National Institute for Nanosciences CNR-NANO which is located in Modena (www.nano.cnr.it) and which also collaborates to teaching. Thesis projects are available to be carried out within one of the experimental groups of the department and/or in collaborating European research groups, also within the Erasmus program.

Courses

Laboratory of Condensed Matter Physics

Year: I Term: I-II Hours: 48 CFUs: 6 SSD: FIS/01

A hands-on course to familiarize with the most used techniques in material research (electron microscopies, X-ray diffraction, electronic spectroscopies), designing and performing own experiments from scratch.

Characterization of nanostructures

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/01

An advanced course on characterization of 0D (dots, clusters), 1D (stripes, wires, tubes), and 2D (surfaces, films, buried layers) quantum systems and related devices, covering dimensionally-related physical properties and technological applications, modern experimental methodologies and instruments, and current approaches to nano-fabrication, with short stages at the characterization and/or fabrication facilities.

Magnetism and spintronic

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/01

A course devoted to quantum and statistical description of magnetic phenomena, from atomic level to collective effects, experimental techniques for magnetic characterization, and advanced applications in spintronics, magnetic recording, molecular magnetism, quantum technologies.

Quantum physics of matter

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/03

An advanced course on matter-light and matter-electron interactions, using quantum linear response theory to discuss elementary excitations of material systems and their spectral features: electronic and phonon excitations, excitons, plasmons, polaritons.

Statistical mechanics and phase transitions

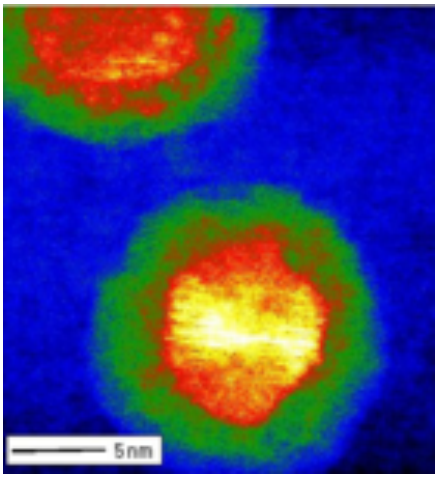
Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/03

An advanced course in classical and quantum statistical mechanics, dealing with modern theories and methods of phase transitions and critical phenomena, from mean-field to renormalization group theory, and the description of quantum condensates (BEC, superfluidity, superconductivity).

Advanced Quantum Mechanics

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/02

A self-contained course reviewing--under various, mathematically rigorous, points of view--the funda-



Scanning Ttransmission Electron Microscopy images in High Angle Annular Dark Field mode of Ni-NiO nanoparticles with a core-shell structure.

mentals of the theory, studying problems at the basis of modern physics, such as the quantization of the electromagnetic field and its interaction with matter, and the relativistic wave equations and their interpretative issues.

Fundamental of Nanosciences

Year: I Term: I Hours: 48 CFUs: 6 SSD: FIS/03

Nanosystems are both quantum worlds with astonishingly new properties and the basis of new nanodevices. The course provides a conceptual and practical framework dealing with the physics and description of a set of prototype nanosystems, from nanotubes and graphene structures to nanocrystals, quantum wells, wires and dots.

Computational topology

Year: I Term: II Hours: 36 CFUs: 6 SSD: MAT/03

A course to familiarize with tools, algorithms, and computational issues in Topology for Data Science ensuing from the observation that "data has shape and shape matters", with an eye to problems arising in shape analysis, topological inference, and manifold learning.

Transport phenomena in Semicond. and Nanostructures

Year: I Term: II Hours: 48 CFUs: 6 SSD: FIS/03

A complete and modern course on electronic transport in condensed matter systems, from the semi-classical statistical approaches to fully quantum state-of-the-art descriptions, with application to the experimental signatures exposing fascinating phenomena taking place in quantum semiconductor nano-devices down to single-molecule transistors.

Synchrotron Radiation: basics and applications

Year: II Term: I Hours: 48 CFUs: 6 SSD: FIS/01

A course devoted to the working principles of synchrotrons and the use of emitted radiation, from description of single ultra-relativistic particles sources to essentials of instrumentation, storage rings, bending magnets, wigglers and undulators, free electron lasers, beam lines, with examples of ensuing popular techniques, X-ray diffraction, scattering and absorption, X-ray microscopy.

A visit to to ELETTRA labs in Trieste ends the course.

Laboratory of Computational Quantum Mechanics

Year: II Term: I Hours: 60 CFUs: 6 SSD: FIS/03

A course with hands-on tutorial sessions dealing with electronic structure computational techniques as applied to condensed matter systems, with special emphasis on Density Functional Theory, a parameter-free, atomistic and predictive description of materials.

Professionalizing Courses

Good Practices in Research

Year: II Term: I Hours: 18 CFUs: 3

A practical introduction to soft skills needed in industrial and academic research. How to present your result at a conference, or in a paper and get it published. How to keep your data and when you need to worry about intellectual property. How to construct a path that suites your aspirations, write your CV and apply for a high-tech job. All this is also put in context: the structure of research organization and funding in Italy and Europe, with its risks, challenges, and opportunities.

Research Integrity in Sciences

Year: II Term: I Hours: 18 CFUs: 3

A course starting from the study of recent cases of scientific misconduct, such as falsification, fabrication, plagiarism, to discuss actual aspects and concepts of research integrity, which is increasingly considered an essential aspect of research.

Suggested free choice course

Physics of Semiconductors

Year: - Term: I Hours: 48 CFUs: 6 SSD: FIS/03

The course deals with functional concepts of modern optical and electronic devices, from carrier and defect engineering, transport and carrier recombination dynamics, nanostructured semiconductors, up to their applications to transistors, laser, and solar cells.

Nanomechanics

Year: - Term: I Hours: 48 CFUs: 6 SSD: FIS/01

An advanced course to provide insight into elastic, thermal and kinetic properties of nano systems and their role in nano-technology, treating nano-materials, nano-tribology (friction, wear, contact mechanics), nano-electromechanical systems (NEMS), and nano fluidics. Students will master state-of-the-art approaches to design, perform and interpret miniaturized mechanical experiments directly inside electron microscopes like SEM or TEM, or STM/AFM microscopes.

Coordinator
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www.fim.unimore.it/site/en/home/teaching/physics-courses/msc-degree.html

For B.Sc. students

Students enrolled in the B.Sc. (Laurea Triennale) in Modena, who intend to follow this study plan, are suggested to attend some of the following optional courses during their B.Sc studies: Spettroscopia, Elettronica e Acquisizione dati.

Notes

Students interested in optoelectronic applications may want to choose Advanced photonic in place of Transport phenomena in semiconductor and nanostructures. Interested students may take Elaborazione numerica di segnali e immagini (in Italian) from the M.Sc. in Mathematics as a free choice course. Students interested in industrial applications may want to take Science-based innovation in place of Good practices in research and Research integrity in science. Ask the study plan coordinator for further indications.