UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA Dipartimento di Scienze Fisiche, Informatiche e Matematiche

Study plan in

Nanophysics and Nanotechnology

Master's Degree Program in Physics – Curriculum Experimental Nano-physics & Quantum Technologies

Overview

This study plan is designed to train students on the experimental methods for fabricating and controlling materials and components at 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, to construct unique nano-structured materials with still unexplored physical properties.

Students have the opportunity to investigate fundamental physics down to the quantum regime. During classes and developing the thesis project, students are 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 used to develop devices and sophisticated instrumentations in many technological fields.

Opportunities

This study plan is connected to ongoing research activities carried out in collaboration with research centers in Europe, such as Forschungszentrum Jülich (D), Max Planck Institut (D), Univ. of Glasgow (UK), Univ. of Maastricht (NL), Polygone Scientifique in Grenoble (FR), Karlsruhe Institut fur Technologies (D).

First Year

Laboratory of nanostructures mandatory

The course covers the entire nanotechnology chain, starting from raw nanomaterials (semiconductor nanowires, 2D materials, nanotubes) passing through the fabrication of devices (lithography techniques), up to electrical and thermal transport measurements and in manufactured nanodevices. Classical and quantum transport experiments will be discussed.

Magnetism, spintronics, and quantum technologies mandatory

A course on quantum and statistical description of magnetic phenomena, experimental techniques for magnetic characterization, and advanced applications in spintronics and molecular magnetism. The course offers an overview on some of the emerging quantum technologies for quantum computing and quantum sensing, introducing basic concepts for the functioning of superconducting devices, on the use of spin resonance on color centers and fundamentals of cryogenics.

Laboratory of electron miscroscopy and holography mandatory

Modern TEMs are powerful instruments, giving access to structural and chemical information at the sub-nanometer scales. This course provides a comprehensive introduction to Transmission Electron Microscopy and to electron holography for the study of electromagnetic fields in magnetic materials and electronic devices.

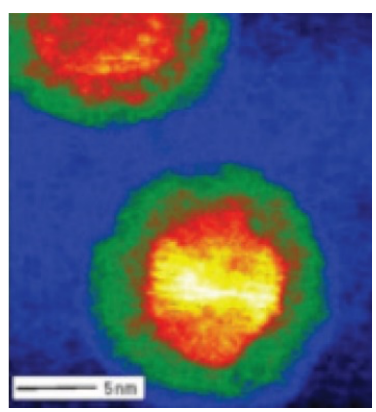
Synchrotron radiation: basics and applications mandatory

A course on the working principles of synchrotrons and the use of emitted radiation, from description of single ultra-relativistic particles sources to essentials of storage rings, bending magnets, wigglers and undulators, free electron lasers, beam lines. Examples of ensuing popular techniques, as X-ray diffraction, scattering, absorption and X-ray microscopy, are discussed and a visit to to ELETTRA labs in Trieste ends the course.

Advanced spectroscopic and imaging methods

X-ray photoemission and absorption spectroscopies are among the most used techniques to characterize the properties of materials. Recent technological advances have made it possible to achieve very high spatial resolutions on the nanometer scale and temporal (on the femtosecond scale), opening the window to a new universe of phenomena.

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



Study plans help you to choose courses within a curriculum leading to an in-depth training in a given area of physics. The suggested choices can be tailored to the students' scientific interests. The program coordinator and the Study plan coordinator may give you further indications.

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Many research activities are carried out in collaboration with the National Institute for Nanosciences CNR-NANO located in Modena (www.nano.cnr.it) which also collaborates to teaching.

Thesis projects are available within one of the experimental groups of the department and/or in collaborating European research groups, also within the Erasmus program or the Double Degree Program. The acquired skills enable students to pursue employment in international private and public laboratories, or to proceed for a PhD within the Graduate School in Physics and Nanoscience or Modena and worldwide.

Notes

Courses Advanced quantum mechanics and Quantum information processing might substitute Statistical mechanics and Quantum Field theory, respectively, to match one's interest in applications to the quantum world. Laboratory of quantum simulation of materials, e.g. in place of Machine learning and deep learning enable students to pursue state-of-the-art simulations of materials.

Ask the study plan coordinator for further indications.

Nanoscience and quantum materials

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.

Quantum physics of matter

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.

Physics of semiconductors

A course providing all the necessary ingredients to understand the fascinating physical properties of semiconductors, from their electronic structure description to transport phenomena, and how to exploit them in devices like transistors, or to observe novel states of matter like the quantum Hall liquid.

Nano-mechanics

An experimental insight on the methods, procedures and apparata used in advanced research to investigate mechanical properties of materials at the nanoscale, with detailed case studies. Experiments on nano-objects are carried out in the lab, aiming at defining their intrinsic tribological properties and their macroscopic effect.

Statistical mechanics and phase transitions

An advanced course in statistical mechanics, from theoretical foundations to phase transitions and critical phenomena, including quantum condensates (BEC, superfluids, superconductors). Attendees are introduced to modern theoretical methods, from the Ginzburg-Landau theory to the statistical field theory and the renormalization group approach.

Second Year

Quantum information processing

An introduction to the theory behind quantum computers and QIP in general. Topics range from the basic concepts of QIP such quantum entanglement and generalized quantum dynamics, to fundamental QIP algorithms, such as Shor's factoring, passing through quantum cryptography.

Numerical algorithms for signal and image processing **as free choice course**

A course to introduce the basic properties of Fourier transform as a tool for signal analysis, from continuous to discrete settings. Applications to signal and image filtering and compression will be presented also with some laboratory activity in the Matlab environment.

Machine learning and deep learning **as free choice course**

A course to illustrate the main architectural and computing paradigms for high-performance systems, from the embedded and high-end domains. The course also describes the challenges of parallel programming for multi-core CPUs and GPU, with hands-on experience.

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