Study plan in

Nanophysics and Nanotechnology

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

M.Sc. program in Physics – Curriculum Experimental nanophysics and 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.

More info and suggestions from

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Program website
www.fim.unimore.it/LM/FIS

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Fist year

Laboratory of nanostructures (M) – F Rossella

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

Magnetism, spintronics, and quantum technologies (M) – M Affronte

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 microscopy and holography (M) – M Beleggia

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 (M) – S D'Addato

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.

Physics of semiconductors (D) – S D'Addato

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.

Nanoscience and quantum materials (D) – E Molinari

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 (D) – R Magri

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.

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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). Many research activities are carried out in collaboration with the National Institute for Nanosciences CNR-NANO in Modena which also contributes 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 our **Double Degree program**

Employment

The acquired skills enable students to pursue employment in international private and public laboratories, or to proceed for a PhD, both within the **Graduate School in Physics and Nanoscience** in 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.

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Advanced spectroscopic and imaging methods (D) – R Biagi

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

Nano-mechanics (D) – A Rota

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.

Laser and photonics (D) – E Da Como

This course will introduce the physics of lasers and their operation principles. The taught material will cover the unique properties of laser light and some of their applications in science and technology. The second part of the course will introduce the basic components of advanced photonic devices, such as waveguides, optical fibres and the nonlinear optical phenomena therein.

Second year

Quantum information processing (D) – P Bordone

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

Numerical algorithms for signal and image processing (F) – S Bonettini

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 for scientific applications (F) – F Grasselli

An introduction to key ideas and techniques in machine learning for applications in physics, from basic principles to advanced topics in supervised and unsupervised learning, including worked hands-on examples. Subjects include Gaussian Process Regression, Bayesian Inference, Kernel methods, Deep Neural Networks, Convolutional Neural Networks, and Encoder-Decoder models.

Legend: (M) mandatory course for this curriculum; (D) chosen within distinctive (*caratterizzanti*) courses; (R) chosen within related (*affini*) courses; (F) selected as a free choice course

This study plan is a suggested set of courses, chosen within the curriculum, to ensure an in-depth professional training combined with the broad spectrum of skills required to modern scientists. Mandatory, distinctive and related courses provide the natural background of this study plan. However, the study plan can also be tailored to the students' scientific interests. Ask the study plan coordinator for further indications.