



**POLITECNICO
DI MILANO**

**PhD School of the Politecnico di Milano
Regulations of the PhD Programme in:**

Physics

Cycle XXXI

Location: Milano Leonardo

1. General Information

PhD School of Politecnico di Milano

PhD Programme: PHYSICS

Location of the PhD Programme: Milano Leonardo

Subjects (SSD): FIS/01 Experimental physics; FIS/03 Physics of matter

PhD School Website: <http://www.polimi.it/phd>

PhD Programme Website: http://www.fisi.polimi.it/en/teaching/teaching_offer/phd

2. General presentation of the PhD Programme

Translating scientific knowledge into new technology and transferring innovation to the production system represent a necessary step for many companies, also dictated by an increasingly global market. For that purpose, a professional profile with a broad cultural background is needed. In particular, many advanced sectors of industry and research require good knowledge in topics such as condensed matter physics, optics, laser technology and instrumentation, and nanostructured materials.

The aim of the PhD in Physics at Politecnico di Milano is the training of personnel with strong research capacity, able to operate in basic and applied research and development facilities, and to manage and design high-tech and innovative products and processes in various industrial sectors. This application-oriented character clearly distinguishes the PhD Programme in Physics at Politecnico from those at the Schools of Science.

The education contents are strictly related to the research activities carried out in the research laboratories at the Department of Physics. Although a clear distinction is not possible, they can be divided into two main research tracks:

- 1) Laser physics, photonic devices and applications
(optics and quantum electronics, including biomedical applications of lasers, laser applications in optical communications; diagnostics for works of art; time-resolved optical spectroscopy; ultrashort light pulse generation and applications; UV and X optical harmonic generation)

- 2) Solid state physics: Advanced spectroscopy, scanning probe microscopy, nanostructure fabrication (photoemission; spin-resolved electronic spectroscopy; magneto-optics; X ray diffraction; magnetic nanostructures for spintronics; synchrotron radiation spectroscopy, positron spectroscopy, semiconductor nanostructures)

These research activities make use of advanced experimental laboratories located at Politecnico di Milano (Milano-Leonardo Campus and Como Campus), including:

- Coherent vibrational spectroscopy
- Spectroscopy with femtosecond time resolution
- Attosecond generation
- Coherent Raman spectroscopy and microscopy
- Applications of lasers in telecommunications
- Photonic and optofluidic devices
- Ultrashort laser pulse micromachining
- Solid state lasers
- Biomedical applications of lasers
- Time-domain diffuse optical spectroscopy
- Imaging and spectroscopy for Cultural Heritage
- Optical projection tomography
- Electron spectroscopy with spin resolution
- Magneto-Optics
- Growth and characterization of magnetic nanostructures for spintronics
- Scanning Auger Microscopy (SAM)
- Scanning Near-field Optical Microscopy (SNOM)
- Scanning Tunnelling Microscopy (STM)
- Spectroscopy with synchrotron radiation
- Spectroscopy with positrons
- Epitaxial semiconductor nanostructures for electronics and optoelectronics
- Optical and electron beam lithography

Moreover, many collaborations are on-going with high-level international institutions, such as: European Synchrotron Radiation Facility (ESRF) in Grenoble, Polytechnic University of Zurich (ETH) and Lausanne (EPFL), Ecole Polytechnique - Palaiseau (Paris), Paul Scherrer Institut (PSI), Institut de Ciència de Materials de Barcelona, Institut d'Electronique Fondamentale Université Paris-Sud, Argonne National Laboratory, Technical University of Denmark, Royal Institute of Technology (KTH, Stockholm), Max Planck Institute - Stuttgart, University College London, Interuniversitair Micro-Elektronica Centrum (IMEC) Leuven Belgium.

Students in our PhD Programme will therefore have a real opportunity to gain experience also in prestigious laboratories abroad.

3. Objectives

The main purpose of the PhD Programme in Physics at Politecnico di Milano is the development of an experimental approach in problem-solving techniques and the attainment of a high level of professional qualification. Scientific education and training to develop general research abilities in all areas of applied physics is increasingly needed by advanced technological companies in Italy, especially northern Italy, and abroad. The PhD Programme aims at providing engineers and physicists, after a Bachelor of Science ("Laurea", 3 years) and a Master of Science ("Laurea Magistrale", 2 years),

with a general education in the basic areas of applied physics and specific knowledge in condensed matter physics, optics, lasers and photonics.

4. Professional opportunities and job market

The PhD at Politecnico di Milano offers a wide range of opportunities in the fields of advanced technologies, such as photonics and optoelectronics (lasers, optofluidic devices), advanced physical instrumentation (electronic and atomic microscopy, nuclear magnetic resonance), biomedical optics (optical tomography, non-invasive diagnostic devices), vacuum technologies (thin film depositions), and material technologies (microelectronics and nanotechnologies).

Concerning Italy and similar Countries, the following professional profiles are well established:

- Manager of devices, equipment and systems (see above), to solve methodological and technological problems within large industries and companies.
- Designer of advanced optoelectronic devices and systems, relying on a physical background and competencies in optics and laser technologies to promote, design and realize new components and devices in high-tech industries as well as small innovative enterprises.
- Researcher in industries, universities, research centres, operating in the technological areas outlined above.

Interesting opportunities are found also at international level, where technological innovation is even more relevant than in the national scenario. In this frame, the PhD Programme in Physics at Politecnico provides excellent preparation for a highly competitive international arena.

5. Enrolment in the PhD Programme

5.1 Admission requirements

Italian and foreign citizens can apply. They are requested to have graduated in accordance with the pre-existing laws D.M. 3.11.1999 n. 509 or have a master of science degree in accordance with D.M. 3.11.1999 n. 509 or a master of science in accordance with D.M. 22.10.2004 n. 270 or similar academic degree obtained abroad, equivalent for duration and content to the Italian degree and for an overall duration of university studies of at least five years.

The certified knowledge of the English language is a requirement for admission. Please refer to the Ph.D. School web site for details.

The admission to the programmes will be decided according to the evaluation of the curricula of the studies, of the motivation letter, and of an illustrative paper about the development of a possible PhD research, which candidates will send contextually with their application to the admission announcement.

5.2 Admission deadlines and number of vacancies

The number of available positions is indicated in the Call for admission to the 31st cycle of PhD Programmes: <http://www.polimi.it/phd>

Scholarships both on general and on specific themes are available, in accordance with what is specified in the call for admission.

6. Contents of PhD Programme

6.1 Requirements for the attainment of the title:

The attainment of the PhD title in Physics requires at least three years full time of study, research, and development of the PhD thesis.

The PhD Programme in Physics requires **30 credits** from PhD level courses to be acquired as indicated in the following section 6.3

6.2 Development of the research and of the PhD thesis

The aim of the PhD programmes of Politecnico di Milano is the development of a research-oriented mind-set, with expertise and skills in a specific research topic.

These skills provide the PhD students with major opportunities of improving their scientific capabilities in view of a personal commitment either in the academic field or in public and private organisations.

The main objective is the development of an original personal research track. The PhD thesis must contribute to increasing knowledge in the research field of the candidate, and has to be coherent with the research topics developed at the Department of Physics, where the PhD Programme is carried out. The PhD thesis shall contain and discuss the original contribution of the candidate, with respect to the state of the art in the relevant research field.

The PhD research will be developed according to the guidelines of a supervisor, who shall support the candidate in the setting-out and in everyday activities regarding the development of the thesis.

The supervisor does not have to be a member of the Academic Board and can also belong to an institution other than Politecnico di Milano. The supervisor can be supported by one or more co-supervisors.

To develop the capability of carrying out research activities, the candidate must attend courses according to the PhD Programme, defined for his/her study plan, and pass them with a positive evaluation.

For each candidate admitted to the Programme, a tutor, belonging to the Academic Board, is appointed. The tutor supervises and supports the candidate in his/her overall training path. The same person can act as both supervisor and tutor.

The choice of the courses will be overseen by the tutor and will be formalized in a study plan to be approved by the Coordinator of the PhD Programme.

Other activities for the development of personal skills and research expertise are encouraged during the PhD Programme.

The candidates must acquire the capability to present and discuss their work to the research community. Consequently, both attendance at international conferences and publication of research results in reviewed international journals are encouraged.

The candidates are also encouraged to carry out part of their research activities (up to six months) in contact with other research groups in their field of interest, possibly abroad, to acquire further skills for the development of their research work and thesis.

The duration of the Programme is normally three years.

6.3 Objectives and general framework of the teaching activities

The PhD Programme and the PhD School may activate various types of training activities (courses, seminars, project workshops, laboratories). They all will aim at:

- creating common starting knowledge for the PhD Programme;
- examining the basic research issues (problems, theories, research methods) which represent the cornerstone of the PhD Programme and clearly identify its position in the cultural landscape;
- developing selected research topics and issues related to the thesis work.

Courses are offered in English, unless otherwise specified for individual courses.

The PhD Programme warrants the availability of a teaching path provided entirely in English.

Some teaching activities (structured teaching activities) entitle the student with ECTS credits; other activities (typically more specialised ones), for which it is difficult to make an assessment and quantification of learning, fall within the scientific activities that the Academic Board will take into account in the overall evaluation, but whose value is not individually quantified in ECTS.

The tables here below show the foreseen path for the candidates and refer to coursework activities. At the same time, the Programme foresees that the candidate is devoted to the research activity in a continuous way, following the lead of his/her supervisor and of the Academic Board.

First/Second Year

Within the first two years, the candidate is expected to acquire 30 ECTS following the rules summarized here below and described in the following:

Course type	Number of ECTS (min-max)	Notes
PhD School Courses	5 – 15	Chosen from the list available at: http://www.dottorato.polimi.it/en/during-your-phd/phd-school-courses
Courses characterising the PhD Programme	15 – 25	Chosen among the 40 ECTS offered by the Department of Physics (see Table A, and: http://www.dottorato.polimi.it/en/phd-programmes/active-phd-programmes/physics/)
Other PhD Programmes	0 – 10	http://www.dottorato.polimi.it/en/phd-programmes/active-phd-programmes/

Third year

The third year should be devoted entirely to the research and to the development of the PhD thesis.

PHD PROGRAMMES

A) The PhD Programme in Physics organises the following **Characterising Courses** (see table A). For the admission to the final exam the acquisition of at least **30 ECTS** is **mandatory**. These credits have to be acquired through the “**characterising**” **PhD courses** offered by the PhD Programme.

Table A: PHD COURSES CHARACTERISING THE PhD PROGRAMME

Name of the Course	Professor	Academic Year	Language	Credits
Advanced optical microscopy and applications	A. Bassi, G. Chirico	2015-16	English	5
Multiscale materials modeling	P. Folegati	2015-16	English	5
Special relativity and its implications	E. Puppini	2015-16	English	5
Photon migration and wave diffusion in random media	A. Torricelli	2015-16	English	5
Plasmonics	P. Biagioni, G. Della Valle	2016-17	English	5
Electronic structure of solids	P. Folegati	2016-17	English	5
Spectroscopy of solids	G. Ghiringhelli	2016-17	English	5
Optical Properties of low-dimensional materials	F. Scotognella	2016-17	English	5

B) The PhD School organises every year **General and Interdoctoral courses**, and courses taught by foreign professors.

The acquisition of **at least 5 credits** is **mandatory** among the courses of B type. The list of PhD courses organized by the PhD School is available at the following page: <http://www.dottorato.polimi.it/en/during-your-phd/phd-school-courses/>

Table B SUGGESTED CROSS –SECTORAL COURSES OR WITH A FOREIGN PROFESSOR

The following table shows the courses offered by the Department of Physics in 2015-16 as General or Interdoctoral courses of the PhD School.

Name of the Course	Professor	Academic Year	Language	ECTS
Physical methods for Cultural Heritage	G. Valentini	2015-16	English	5
Scientific Communication in English	T. Sluckin	2015-16	English	5

A complete list of the PhD School courses (both Interdoctoral and General courses) offered in 2015-16 can be found at: <http://www.dottorato.polimi.it/en/during-your-phd/phd-school-courses>

The list of courses offered in 2016-17 will be made available later on.

C) Other PhD courses

Up to 10 off the 30 mandatory credits can be obtained choosing among PhD courses of type A or B, or among other courses provided by other PhD Programmes at Politecnico.

PREPARATORY COURSES

If the supervisor and the tutor finds it useful or necessary for the candidate to attend preparatory courses (chosen among the courses activated at the Politecnico di Milano) the Board of Professors of

the PhD Programme can assign some extra-credits to be acquired to complete the training path. The credits acquired in this way will be considered as additional, in relation to the mandatory credits to be acquired with the PhD courses.

SPECIALISTIC COURSES, LONG-TRAINING SEMINARS

The attendance to specialist courses, workshops, schools, and seminar cycles is encouraged. These courses and workshops can be inserted in the study plan as optional “additional teaching”, although they are not evaluated (and therefore not qualified as credits).

6.4 Presentation of the study plan

Each PhD candidate will have to submit his/her study plan. The candidate will have the opportunity to review it periodically (every three months) in order to adapt it to possible changes of the training offer or needs motivated by the development of his/her study plan. The study plan is approved by the Coordinator of the PhD Programme, according to the modalities established by the Board of Professors of the PhD Programme itself.

6.5 Instructions for the annual exams

Every year the candidates present their work to the Academic Board, and are evaluated for admission to the next year.

After each annual evaluation, the candidates admitted to the next year will receive an evaluation (A/B/C/D). If the candidate does not pass the exam, he/she will qualify as a “Repeating candidate”(Er) or “not able to continue with the PhD (Ei)”.

At the end of the third year, candidates who have performed a significant part of their thesis work, but still need time to complete it may obtain an extension of 6 or 12 months.

6.6 Instruction for the preparation of the PhD thesis

The PhD study and research work will be carried out full-time during the three years of the PhD course. The possibility of internships or study periods in Italian or foreign companies or external entities and universities is foreseen.

The main objective of the thesis work is the development of an original research contribution. The PhD thesis must contribute to increasing knowledge in the research field of the candidate, and must be coherent with the research issues developed in the Department of Physics.

The PhD research will be developed following the guidelines of a Supervisor who supports the candidate in setting-out and everyday activities regarding the development of the thesis.

At the end of the third year, the research work and the thesis are evaluated by an Examination Committee composed of at least three members, including at least two external examiners.

7. Laboratories, PhD Secretary Services

7.1 Laboratories

The PhD students will join advanced research laboratories of the Department of Physics, learn about experimental techniques, contribute to research activity, and attend meetings and internal seminars aimed at providing more in-depth knowledge on specific research topics. A non-comprehensive list of the experimental laboratories is provided here below:

1 - Ultrashort light pulse generation and applications to the study of ultrafast phenomena in the matter

- Attosecond Reaction Microscope
- Femtosecond laser laboratory
- High-energy attosecond pulse laboratory
- Laboratory for coherent Raman spectroscopy and microscopy
- Laboratory for IR-VIS ultrafast spectroscopy
- Laboratory for XUV ultrafast spectroscopy
- Positron laboratory
- Terawatt laser laboratory

2 - Solid state lasers and photonic devices for integrated systems

- Characterization of photonic and optofluidic devices
- Frequency comb laboratory - Campus Point (Lecco)
- High-resolution and high-precision laser spectroscopy
- Laboratorio virtuale di elettromagnetismo computazionale
- Laboratory of coherent vibrational spectroscopy
- Solid state lasers
- Two-photon polymerization by femtosecond lasers
- Ultrashort laser pulse micromachining
- Wet etching in hydrofluoric acid for microfluidic circuits

3 - Photonics for health, food and cultural heritage

- Diffuse Optical Spectroscopy
- Diffusive Optical Phantoms
- Fast Fluorescence Molecular Tomography
- Fluorescence Spectroscopy
- Functional Near Infrared Spectroscopy
- Gated Photon Counting
- Imaging Spectroscopy for Cultural Heritage
- Near Infrared Spectroscopy for Food
- Optical Mammography
- Optical Projection Tomography

4 - Epitaxial growth and nanostructure fabrication

- Electron Beam Lithography
- Materials and devices for Spin Electronics
- Nanobio
- Scanning Tunnelling Microscope
- Semiconductor growth
- Versatile Electron Spectroscopy Instrumentation

5 - Electronic, optical and magnetic properties of low-dimensional systems

- Magneto-Optical Kerr
- Scanning Auger Microscope
- Scanning probe microscopy
- Scanning near-field optical microscopy

Synchrotron radiation facilities
Ultrafast Photoemission and Optical Spectroscopy
Variable energy positron annihilation spectroscopy

7.2 PhD Secretary Services

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8. Internationalisation and other activities

The carrying-out of study and research activities at other laboratories is strongly recommended. As mentioned in section 2, the students can take advantage of scientific collaborations that are on-going between the Department of Physics and several high-level international institutions.

The university proposes also the opportunity of joint PhD paths with foreign universities and of joint and double PhD programmes. Further information is available on the PhD School Website and on the PhD Programme website.