Ph.D School in Applied Physics

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History

The Ph.D School in Applied Physics was founded during the Academic Year 1999-2000.

The first students began their study and research activity in the spring of 2000 and will discuss their Ph.D. thesis early 2003.

Aim

The aim of the Ph.D School in Applied Physics is to train graduate Science students in Physics research into subjects involving applications and/or scientific and technological transfer from the world of research to the world of industrial production.

The range of applications considered is chosen so as to be as wide as possible, consistent with available expertise, and includes applications to other sciences and research activities relevant to industries or to public organizations (such as health and environmental bodies).

During the three years of its existence the Ph.D School in Applied Physics has pursued this aim along two lines:

a) student training and research activities in fields that are complementary to those traditionally followed by the Ph.D School in Physics and that combine aspects of pure research with applications. Here the term application refers mainly to the use of physical methods and know-how in other research fields, often outside physics.

b) establishing direct contacts with the world of high technology industrial production and training students and developing research projects in direct connection with such industries. Application in this case refers to the transfer of technology and of physics know-how to public services (health authorities, environmental bodies, etc).

Obviously the two lines are not mutually exclusive and partly overlap. At the start of the Ph.D School in Applied Physics line a) has been the most successful, mostly because its success relies on local resources that can be organized over a short time scale. Already from the second year of its existence we have been able to present the activity of the Ph.D School in Applied Physics in Pisa to a wider audience and to establish working contacts (Alcatel, Stella Maris, CNIT) along the aims of line b).

In future years we think it important to maintain this double role and to balance these two approaches effectively. The aim is to open the way for the students of the Ph.D School in Applied Physics either to pursue an academic type research career in a wider range of research field where a knowledge of physics is needed or to allow them to enter successfully a non academic career in the high technology industrial sector.

This opening up of employment opportunities for highly trained physics students is particularly important in the presently stagnant job market for young scientists.

At the present time we are not yet in a position to assess how successful this approach will be in practice, since the first graduate students will only discuss their thesis in the coming winter.

The first indications we have is that, although Italian industries and public institutions may not be too keen to invest in advanced technology, our Ph.Ds will have a relatively easy entry into the job market.

This can be facilitated by opening up the training we provide to the students of the Ph.D School in Applied Physics, their research opportunities and their employment opportunities beyond the national scene.

Such an opening towards a wider, fully international view of scientific research is pursued by exploiting existing research connections in order to attract students from abroad, as has been done with increasing success over the last few years in spite of the economically limited grants we can provide, and by offering incentives to our Ph.D students to complete part of their training in research centers abroad.

Present curricula

The present structure of the Ph.D School in Applied Physics comprises the following five Curricula:

1. detector development and high precision measurements: particle detectors and detectors for gravitational waves and noise detectors for environmental applications.
2. spectroscopic technique: metrology, development of optical traps, laser sources and nanometric microscopy.

3) physical methods and technologies applied to Biology, Medicine and the Environment}: Computer Aided Diagnosis (CAD) for mammographies to Positron Emission Tomography for pharmaceutic or oncological applications.

4) advanced materials: polymers and liquid crystals, crystal insulating materials for optoelectronic applications atomic nano-lithography and film deposition.

5) plasma and space physics: nonlinear systems, applications to fusion research in magnetized or laser generated plasmas, turbulence studies and numerical simulations in fluids and plasmas.

Up to now the Ph.D. students in Applied Physics are relatively evenly distributed among these five curricula.

Research activities

Development of *silicon sensors* for high energy physics. Presently, experimental groups are running large silicon detectors at SLAC (BABAR experiment) and at FERMILAB (CDF). Promising developments: high-resistivity silicon detectors with integrated electronics, pixel detectors, and phototransistors for X-ray and minimum ionizing particle detection.

Implementation of an electronic system able to *recognize 100,000 digital pictures per second*. These pictures are generated by detectors for high energy physics and can be considered as snapshots of very complex sub-nuclear events.

Large spectrum expertise in the fields of electronics,computer science, and applied mathematics; results of great interest for *ultra fast reconstruction of shapes or complex images* from a large amount of digitized data.

Participation in a number of international experiments in *high energy particle physics*.

Atomic and molecular spectroscopy and its application to frequency *metrology* and atomic frequency standards. Feasibility study of an optical frequency standard referred to a two-photon transition in a Calcium atomic sample confined in a magnetooptical trap at *mK* temperature. Construction of a frequency measurement system based on comb frequency generation by femtosecond laser. New devices are experimented for frequency mixing with very large broadband, up to 1 *THz* and further.

Applications of *laser cooled atoms*, particularly atom nano-lithography. Thin film laser deposition. Nanometer scale *scanning probe microscopy and spectroscopy*. Production and characterization of structures with lateral dimensions in the nanometer scale, that are a key issue for the transition from the micro-electronics to the nano-electronics.

Insulating-crystal spectroscopy and their use as active media for solid state laser (in particular oxide and fluoride samples).

Facility for *growing fluoride crystals*. The facility consists of two Czochralski furnaces operating in controlled Ar atmosphere at temperatures up to 1100 C.

(Tm,Ho:LiYF4 Tm,Dy:BaY2F 8 BaY2F 8 Nd:BaY2F 8 Tm,Ho:BaY2F 8 Ce:BaY2F 8)

Raman spectroscopy in the low frequency region (5-200 cm^{-1}) of glass formers.Optical characterization of rare earth crystals (Raman spectroscopy, fluorescence spectra, lifetime measurements). Temporal development of second harmonic generation to study relaxation phenomena in polymers.

Dielectric studies of *relaxation phenomena in disordered systems* (glass formers, polymers e composites). Glass transition and molecular dynamics in supercooled liquids under pressure, temperature and connectivity changes, charge transport in micro-porous systems. Industrial applications: dielectric monitoring of polymerization processes, microwave treatment of materials, moisture content measurements, rock wettability.

Relaxation processes in materials from oligomers to polymers. Dependence of relaxations processes on materials thickness of interest for high data storage devices (nano-writing techniques). Study of aging phenomena via calorimetric and ESR spectroscopies.

Studies of *polymeric materials* by High-Field Pulsed Electron Spin Resonance. Relaxation processes of polymers in the range $10 *ps* - 100 *μs*. Dynamics of polymer-polymer interface and the order-disorder phase transition of block copolymers. *Numerical simulation of polymers* using Molecular-Dynamics algorithms.

Research in the detection of *gravitational waves* and study of their sources (The Physics Department has been involved in design, construction and commissioning of the Virgo detector). R\&D for materials and devices with *high mechanical Q* to reduce thermal noise (in collaboration with physicists of the California Institute of Technology and of NAO in Japan).

Experience in position control has motivated the constitution of a spin off company to apply the know how, among others, to the *stabilization of sea borne platforms for geophysical investigation*.

Digital Medical Imaging both in morphological and functional studies developed within the INFN-Interdisciplinary research group and finally developed in collaboration with the biologist and the clinical environment. Development of integrated systems under experimental test in a biology or clinical environment: *digital mammography, small animal imaging and positron emission mammography*}.

Nonlinear optics in strong fields and collective interactions in collisionless, tenuous and cold plasmas produced by multiphoton ionization. Harmonic generation by wave-mixing.

Nonlinear plasma processes in the solar atmosphere and in the solar wind, theory and *numerical simulations*.

Magnetized plasmas. Nonlinear dynamics of collisionless collective systems: applications to magnetic fusion experiments and to space physics.

Relativistic plasmas. Laser produced plasmas, nonlinear optics in plasmas, parametric instabilities, applications to inertial fusion and to X-ray sources, particle acceleration for oncological treatment.

Physics of the minor bodies of the *Solar System*. Collisional and dynamical evolution of Main Belt *asteroids* and Near Earth asteroids.

Studies

The research and study curriculum of the Ph.D. School in Applied Physicslasts three years.

During the first year students attend two courses (that are either specific to the Ph.D School or are shared from subjects of the final year of the undergraduate courses in Sciences and Engineering or from other Ph.D Schools).

In the second year students follow a more advanced course specific to their research subject.

The courses are chosen with the aim of providing appropriate training to each student in his specific field and at the same time of strengthening the students general physics background.

From the first year, students start their research activity within a research group, either at the Physics Department or at a different Research Institution (in the latter case a supervisor from the Physics Department is appointed to work alongside the "local" supervisor).

Students are encouraged to spend part of their Ph.D. studies at research institutions abroad on the basis of common research activities. There is also active, direct collaboration with high technology industrial companies.

At the end of the second year students must present an extended synopsis of their research work and they must complete their thesis in three years.

Their thesis will be examined by a committee of professors of the Ph.D. School in Applied Physics after it has been refereed by two experts in the field of the thesis chosen from outside Pisa University, either in Italy or abroad.

Seminars from visiting experts and from Ph.D students complete the scientific activity of the School.

Admission and studentships

Since the foundation of the School the number of students admitted has more than doubled

4 (2000)

5 (2001)

9 (2002

Approximately half of the students receive a three year grant from the University of Pisa (or from other research institutions or high technology industries).

The other half are usually maintained by funds from research groups or from short-term grants of various origin.

As the Ph.D School in Applied Physics started to develop and to be recognized at a national level, grants from high technology industries (Alcatel, Stella Maris) and from research institutions

(CNR, ENEA, INFM, CNIT) became available and contributed to the growth of the number of students admitted.

New connections with public and private research institutions are currently being sought.

In the year 2002 a special effort was made in order to attract students from outside the University of Pisa and from abroad: 2 Galilei students including 1 foreign student from Russia.

This same policy is being followed for the enrollment for the year 2003 : 2 Galilei foreign students, from France and Romania respectively, were enrolled in July based on their curricula

The selection for the normal entry based on an oral and written examination is being held in these days.

Expected developments

The most important goal of the Ph.D School in Applied Physics during its first three years of existence was to test its ability to provide science students with an effective and high quality training in a wide range of research fields in Physics, in different research environments and with the aim of improving the connection with the high technology industrial world.

In the future we plan to strengthen the already good interaction we have recently reached with industries interested in physical and technological know-how.

The small number of students and the diversity of their research interests has limited at first the number of courses the Ph.D School in Applied Physics could provide directly in an effective way.

This was compensated by the choice of available courses offered within the Pisa scientific community that is sufficiently wide to cover all the different necessities of the students.

In the future, if the increase in the number of students seen in these three years will continue, as is expected as the existence and effectiveness of this Ph.D school becomes better known, we plan to increase the number of courses offered directly by the Ph.D School in Applied Physics.

We will also take greater advantage of the new opportunities offered by the Galileo Galilei School in order to start real interdisciplinary activities and to initiate new collaborations and new research lines (e.g. in collaboration with the School in Computer Science).

After the initial phase of the Ph.D school during which a number of different research and training activities had to coalesce into this new structure and establish themselves as a recognized structure in the Pisa scientific world, a wider international cooperation including a more wide spread exchange of students will be pursued (in particular at the European Community level).