



## SYLLABUS Academic year 2018/2019 (ANNEX TO THE TRAINING PROGRAMME)

Each PhD student must attend courses corresponding to 12 credits by choosing advanced courses organized:

- by the Doctoral Programme in Physics
- by the Master degree in Physics, or by other similar Master degree courses
- by other similar Doctoral programmes

Other mandatory activities include:

- Research activity followed by a tutor assigned by the Doctoral Programme Committee.
- Attendance of seminars organised by his/her own Research group
- Attendance of Dialogues, Colloquia and Joint Colloquia organized by the Department of Physics also on topics different from the research activity carried out by the PhD students.

Each student must submit his/her study plan to the Doctoral Programme Committee for the approval. The study plan must be previously agreed with the tutor.

The credits should be achieved within the end of the first year with the extension to the first semester of the second year only for Master degree courses activated in that time (for up to 6 credits).

PhD students can obtain up to 3 credits for the attendance of International Schools (Summer/ Winter school, etc.) upon the authorization by the tutor and the Doctoral Programme Committee and after passing an exam.

### Courses organized by the Doctoral School in Physics – a.y. 2018/2019

Professor	Course	Credits	Hours
R.S. BRUSA <b>**</b> (COORDINATORE)	<b>ADVANCED TECHNIQUES IN EXPERIMENTAL PHYSICS</b>	3	21
M. DAPOR	<b>PROBLEMS IN QUANTUM COMPUTING (NOT ACTIVATED)</b>		
M. DAPOR	<b>COMPUTATIONAL METHODS FOR TRANSPORT PHENOMENA (COURSE OF THE LM IN PHYSICS)</b>		
A. RECATI	<b>THEORY OF ENTANGLEMENT</b>	3	21
M. FERRARI, A. CHIASERA, A. CHIAPPINI	<b>OPTICAL AND SPECTROSCOPIC DIAGNOSTIC OF MATERIALS FOR PHOTONICS</b>	3	21
L. PAVESI	<b>INTEGRATED CLASSICAL PHOTONICS</b>	3	21
R. IUPPA, G. A. PRODI	<b>FUNDAMENTAL INTERACTIONS (PART OF THE LM COURSE)</b>	3	21
A. PERRECA	<b>ADVANCED INTERFEROMETRY</b>	3	21
TALENT (Training in Advanced Low-Energy Nuclear Physics)	<b>TO BE DEFINED</b>	6	45
ECT* (European Centre for theoretical Studies in Nuclear Physics and related Areas)	<b>ECT* DOCTORAL TRAINING PROGRAMME 2019</b>	*	
SISSA (Scuola Internazionale Superiore di Studi Avanzati)	<b>TO BE DEFINED</b>	*	

\*Up to 6 credits.

\*\*Prof. Brusa will coordinate the course with the support of the professors of the experimental research Laboratories.



## ADVANCED TECHNIQUES IN EXPERIMENTAL PHYSICS, PROF. R.S. BRUSA

### Prerequisites

The knowledge of a physics graduate is requested.

### Contents

This course is organized as a collection of 4 lecture cycles on different topics in advanced experimental physics. Each cycle is given by an invited scientist or a member of the department, and consists in about 4-5 hours of lectures. The topics are selected every year in experimental research areas of interest of the physics department, giving priority to topics not already discussed in other dedicated PhD courses, as for instance:

- 1) Antimatter experiments, anti-hydrogen, positron beams, atomic physics experiments with positronium, positron and positronium for matter studies;
- 2) Applications of particle beams in medicine;
- 3) Biophysics, in particular methods for the conditioning/investigation of single biological molecules and for the imaging;
- 4) Cold gases condensates, atomic interferometry;
- 5) Instrumentation and methods for observational astrophysics and cosmology;
- 6) Instrumentation and methods in condensed matter and glasses and in surface science;
- 7) Instrumentation for synchrotron radiation and free electron laser based experiments;
- 8) Particle and radiation detectors;
- 9) Photonic devices;

The selection of topics of the course depends also on the availability of lecturers coming from other research institutes. The schedule of the course has to match the agenda of the lecturers and it is provisionally planned.

### Schedule

Period: **between December 2018 and June 2019**

Further information: [robertosennen.brusa@unitn.it](mailto:robertosennen.brusa@unitn.it);

### Exam

PhD students will give a seminar of 20 minutes on an experimental topic related to the four lectures or to an experimental research presented in the Dialogues, Colloquia and Joint Colloquia. The topic is freely chosen by the PhD student but must be previously agreed with the coordinators of the course and must be different from the field of research of the PhD student.



## THEORY OF ENTANGLEMENT, DR. A. RECATI

### Prerequisites

Non-relativistic Quantum Mechanics

### Contents

- The formalism of quantum mechanics for finite degrees of freedom
- Special case: Qubits
- Bipartite systems: pure entangled and product states
- Quantifying the entanglement
- Quantum circuits, Teleportation.
- Bipartite systems: mixed entangled and product states
- Entanglement Witnesses and Bell inequality
- Peres - Horodecki and other criteria for entanglement
- Some application: entanglement and quantum phase transition; entanglement and fluctuations; entanglement and Hawking radiation...

### Schedule

martedì 11 dic 8:30-10:30 aula A209

giovedì 13 dic 10:30-12:30 aula A224

martedì 18 dic 8:30-10:30 aula A209

giovedì 20 dic 10:30-12:30 aula A224

after Christmas to be fixed.

Further information: [alessio.recati@unitn.it](mailto:alessio.recati@unitn.it);

### Exam

To be decided with the students: presentation of an argument, written report or some analytical or numerical calculation

### Bibliography

Lectures notes



## OPTICAL AND SPECTROSCOPIC DIAGNOSTIC OF MATERIALS FOR PHOTONICS,

DR. M. FERRARI, A. CHIASERA, A. CHIAPPINI

### Prerequisites

The typical skills of a Physics, Engineering graduate are requested.

### Contents

Phenomenological course

#### Programme

- Introduction to Glass Photonics
- From bulk to nano- and microscale photonics systems
- Rare earth –activated glasses
- Photonics devices fabrication and assessment
- Radiative and non-radiative transitions
- Transition probability
- Energy transfer
- Optical parameters, dispersion curve
- Absorption and emission cross sections; Quantum efficiency
- Light scattering for characterization of material properties
- Confined structures: Planar waveguides
- Confined structures: Nanospheres
- Confined structures: Direct and inverse opals
- Confined structures: Spherical Microresonators
- Confined structures: 1D - Microcavities
- Nanocomposites systems and transparent glass ceramics
- Integrated optics
- Resonant fluorescence line narrowing and spectral hole burning
- Single ion emission
- Homogeneous and inhomogeneous emission and absorption band
- Energy conversion
- Energy trapping
- Plasmonic structures
- Fluorescence enhancement using different sensitizers – metallic and semiconductor nanoparticles, lanthanides ions, nanocrystals.
- Fibers and fiber lasers
- Nano -micro thermometers
- Solar energy conversion by quantum cutting.
- Lightning
- Persistent luminescence
- Scintillators

### Schedule

From January to March 2019

### Exam

Seminar and discussion

### Bibliography

Specific papers and books will be suggested during the lectures



## INTEGRATED CLASSICAL AND QUANTUM PHOTONICS, PROF. L. PAVESI

### Prerequisites

The knowledge of the Maxwell equations, of Quantum Mechanics, of the physics of semiconductors and of the basics of optical devices.

### Contents

This course is organized as a journal club, where a seminal paper on the course argument is introduced and discussed during each class. The basic concepts behind the papers will be presented and the individual integrated circuits will be carefully analyzed. Students have to read the papers before the class and it is expected that during each class the students will contribute to the discussion via their own understanding of the paper. A selection of papers will be proposed at the course start and those which will be used will be determined on the basis of the student interests. A possible list of topics is

- 1) Integrated optical network
- 2) Optical biosensors
- 3) Photonic neural network
- 4) General purpose microwave photonics processors
- 5) On-chip quantum interference between silicon photon-pair sources
- 6) Quantum simulation with interacting photons
- 7) Quantum teleportation on a photonic chip

### Schedule

Period: January – February 2019

### Exam

PhD students will report on a paper, different from those discussed in the classes, about the course topic and which has been agreed with the lecturer. The student presentation will last 20 minutes.

### Bibliography

To be suggested.



## FUNDAMENTAL INTERACTIONS, DR R. IUPPA AND PROF. G.A. PRODI

### Contents

#### Description

This course aims at describing frontier experiments on fundamental interactions, pointing out common and distinctive features of different fields of Physics. We will discuss the most important observational results of the last two decades in High Energy Physics, Flavor Physics, Astroparticle Physics and Search for Dark Matter, Neutrino Physics and Astrophysics, Gravitational Wave Astronomy and Cosmology. Lectures will be focused on experimental techniques, showing strength points and explaining intrinsic limits of sensitivity.

#### Organization

This is a lecture course in which topics are presented by the teacher.

#### Course objectives

- To provide PhD students with basic knowledge of modern experimental techniques applied in research fields different from theirs.
- To introduce PhD students to scientific methods and techniques widespread in particle and astroparticle Physics.
- To give PhD students a taste of what the hunt for Dark Matter currently.

#### Course topics

- Gravitational Wave Astronomy, compact binary stars populations, tests of General Relativity and consequences in cosmology.
- Standard Model and Beyond. The  $\Lambda$ CDM model.
- Detecting particles, how to.
- The problem of MASS. The electroweak sector. LEP, Tevatron and the LHC. The Higgs sector. Searches for New Physics.
- The problem of BARYOGENESIS. CP violation. CPT violation measurements. Cosmic antimatter asymmetry.
- The problem of DARK MATTER. Hypotheses. Spin-dependent/spin-independent. The WIMP miracle. Direct and indirect searches.
- The problem of NEUTRINOS. Neutrino mass. Neutrino oscillation. Neutrinoless double-beta decay. Astrophysical neutrinos.

### Schedule

To be defined.

### Exam

Grading plan

Written exam (quizzes): 25%

Short report on a topic agreed with the teacher: 25%

Oral exam: 40%

Attendance: 10%

### Bibliography

Teacher notes will be made available on time.



## ADVANCED INTERFEROMETRY, DR A. PERRECA

### Prerequisites

The knowledge of physics at graduate level is requested.

### Contents

The course will present advanced interferometric techniques for current and future experiments. Interferometry is an important investigative technique in the fields of astronomy, photonics, engineering metrology, optical metrology, plasma physics, biomolecular interactions, optometry and quantum mechanics. Several interferometers topology are widely used in science for the measurement of small displacements, refractive index changes and surface irregularities down to quantum limited sensitivity. This course will describe principles and effects of various interferometry topologies and example of applications.

The course is organized as follows:

#### Topology

- Plane waves and Gaussian beams. Michelson Interferometer: contrast, displacement sensitivity, shot noise. Fabry-Perot cavities: stability, resonance condition, finesse. The Pound-Drever-Hall technique for the locking of cavities. Other interferometer topologies: Sagnac interferometer, Mac-Zehnder interferometer: scheme and characteristics. More interferometric techniques: time delay interferometry, laser-ranging interferometry.

#### Advanced Interferometry for Gravitational Waves detectors

- Brief introduction to gravitational waves. Detection of gravitational waves. LIGO-Virgo interferometers at the time of their detections: Detection principle, Main noise contributions, Sensitivity curve. Future earth based GW detectors. Project for space based interferometers

#### More application of advanced interferometry

- Interferometry for the Gravity Recovery and Climate Experiment GRACE: introduction and working principle, current results. The next future: Grace follow-on.
- Interferometry for rotation measurements: the Sagnac effect. Application: ring-laser and gyro-lasers. Ring lasers for geodesy measurements. Ring lasers for general relativity measurements. The Lens-Thirring effect.

#### Improving the interferometer sensitivity

- Quantum nature of light. Coherent and squeezed states. Application of squeezed light in advanced interferometry: the case of GW interferometers.

### Schedule

From January 2019

### Exam

Seminar and discussion

### Bibliography

Specific papers and books will be suggested during the lectures



UNIVERSITY  
OF TRENTO - Italy

Department of Physics

Doctoral Programme in Physics

## TALENT 2019

Programme not yet available: <http://www.ectstar.eu/talent>

## ECT\* DOCTORAL TRAINING PROGRAMME 2019

Programme not yet available: <http://www.ectstar.eu/node/195>

## SISSA COURSES

Courses of the Master degree in Physics (<http://offertaformativa.unitn.it/it/lm/fisica/studiare-e-frequentare>)  
Starting in the second semester of the a.y. 2018/2019.