# . – Advanced techniques for physics research

## Prof. Luca Gavioli

***COURSE COURSE AIMS AND INTENDED LEARNING OUTCOMES***

The course aims to provide students with the basics of important instruments used in research laboratories: vacuum systems, atomic force scanning microscopy, electronic scanning microscopy, mass spectroscopy.

In addition, the course aims to develop the student's ability to work in a research laboratory in an independent manner and to deal with the problems related to carrying out research work independently. Finally, it aims to improve the ability to produce a scientific report on the work performed.

At the end of the course, the student will know the basics of vacuum technology and two of the most common scanning microscopy techniques in the industrial and academic fields. He will be able to define the requirements for a vacuum system. He/She will be able to choose the operating modes of an electronic scanning microscope according to the information necessary for the research work. He/she will be able to choose the operating modes of the atomic force microscope depending on the purpose of the experiment. He/she will be able to critically analyze the experimental data provided by the techniques described in the course.

Through the experimental research work the student will develop his own judgment autonomy in reference to the problems that must be faced in the development of the research work.

The student will be able to analyze and organize the data obtained in a synthetic way and to describe through appropriate graphs the information that can be deduced from the acquired data.

***COURSE CONTENT***

Vacuum hardware and pumps

Mass spectrometry

Atomic force scanning microscopy

Electronic scanning microscopy

Conducting research in groups.

***READING LIST***

Ferrario, *Introduzione alla tecnologia del vuoto: Cap 1-4,* 8-11, Patron ed

*Foundations of Vacuum Science and Technology*, Lafferty, J. M.; Wiley & Sons

*Atomic, Molecular and Optical Physics: Charged Particles*, F.B. Dunning, R.G. Hulet, Academic Press (Ch. 6)

*Scanning Probe Microscopies: Atomic Scale Engineering by Forces and Currents,* A. Foster W. Hofer (Springer)

*SEM and X-Ray microanalysis,* J. Goldstein et al. (Kluwer)

*Electron Microscopy and Analysis,* Peter J. Goodhew, J. Humphreys, R. Beanland (Taylor & Francis)

*Introduction to Atomic Force Microscopy Theory Practice Applications,* P.E. West

*Force-distance curves by atomic force microscopy*, B. Cappella, G. Dietler, Surf. Sci. Rep. 34, 5, 1999

*Force measurements with the atomic force microscope:Technique, interpretation and applications*  H.-J. Butt, B. Cappella,M. Kappl, Surf. Sci. Rep. 59, 1, 2005

*Fundamentals of scanning probe microscopy*, V.L. Mironov

Furthermore: each experience requires a part of bibliographic research with material provided by the laboratory managers.

***TEACHING METHOD***

Teaching includes lessons carried out with cooperative learning activities. Students are required to independently study successive parts of theoretical notions, which are discussed jointly in class with students and teachers. Students are divided into small groups in which the problems encountered in the study are dealt with and questions that are discussed collectively are selected. The exercise activity is carried out through a group work in the research laboratory.

***ASSESSMENT METHOD AND CRITERIA***

The course includes the drafting of a report on the research work carried out. This relationship is discussed individually at the time of the oral examination, in which the candidate must show that he is able to scientifically discuss the issues addressed and described in the report.

The oral test also ascertains the degree of assimilation of the concepts, the knowledge of the tools and experimental methods described in the course, not excluding references to prerequisites or connections between parts of the same.

The evaluation of the oral test will take into account the logical rigor and the effectiveness and correctness of the exposition, enhancing the assimilation of concepts and their personal re-elaboration by the candidate. The final grade is unique and takes into account 35% of the evaluation of the report and 65% of the oral interview.

***NOTES AND PREREQUISITES***

Because of the form of teaching adopted, presence in the classroom is fundamental, to encourage active participation in the discussion.

Prerequisites. The student must possess the basic knowledge of thermodynamics, classical mechanics, electromagnetism and optics.

Covid 19

In case the current Covid-19 health emergency does not allow frontal teaching, remote teaching will be carried out following procedures that will be promptly notified to students.

Professor Gavioli receives in the office prior short notice via e-mail to define the time: luca.gavioli@unicatt.it