



Title: *Ultrafast Laser Physics*

Lecturers: Giulia Fulvia Mancini

Duration: 20 hours of frontal lectures

CFU: 4

Period: March - May 2025

Content: **Learning pre-requisites:**

A basic (M.Sc.) knowledge of Photonics and Spectroscopy are recommended

**Learning Objectives:**

The course will cover fundamental concepts and recent developments in the field of ultrafast laser physics, and it will introduce the basic theory to understand ultrafast ( $10^{-15}$ - $10^{-9}$ s) phenomena in chemistry, biology and condensed matter physics. It has the goal to give also to the non-expert an efficient starting position to enter the field of ultrafast laser physics providing all the detailed derivations. The course will cover fundamental technological and theoretical aspects of: (i) Linear pulse propagation and dispersion compensation, (ii) Nonlinear pulse propagation and nonlinear optics with ultrashort pulses, (iii) Pulse generation, pulse duration measurements

**Program and contents:**

Principles of femtosecond laser systems

- Overview of laser oscillators and pulse amplification
- Parametric generation and amplification
- Pulse measurement/characterization

Time-resolved methods

- Transient absorption (pump-probe) spectroscopy and fluorescence up-conversion
- Time-resolved core-level spectroscopies (X-ray absorption, emission, photoelectron spectroscopy, etc.) using synchrotron and XFEL radiation, as well as table-top High Harmonic Generation (HHG) sources
- Electron-based methods (scattering, crystallography, microscopy, spectroscopy)

Theory (no, or minimal, pre-existing knowledge is required)

- Non-linear optics

**Expected results:**

The student shall be capable of formulating original questions upon reading an article in ultrafast science

**Teaching Methods:**

Interactive lectures

Group activities in the classroom

Homework

**Reference textbooks:**

- O. Svelto, Principles of Lasers, Springer, New York, ISBN 978-1-4419-1301-2
- U. Keller, Ultrafast Lasers - A Comprehensive Introduction to Fundamental Principles with Practical Applications, Springer International Publishing, eBook ISBN 978-3-030-82532-4, 2021

**Learning verification methods:**

Oral presentation on a selected topic & discussion on the overall program

Notes

This course may be of interest to PhD students in the Schools of Engineering and Physical Chemistry