

**Coordinator:** Giulia F. Mancini

**Year:** A.A. 2021/2022 (activated every other year)

**Hours:** 20 hours of frontal lectures

**Language:** English

**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 into 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) Q-switching & Active and passive mode-locking, (iv) Pulse duration and pulse shape measurements, (v) Pump-probe measurements and noise.

**Program & contents:**

1. Principles of femtosecond laser systems
  - Overview of laser oscillators and pulse amplification
  - Parametric generation and amplification
  - Pulse measurement/characterization
  
2. 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)
  
3. Theory (no, or minimal, pre-existing knowledge is required)
  - Non-linear optics

**Expected results:**

The student shall be capable of formulating his/her own creative questions upon reading an article in ultrafast science

**Learning pre-requisites:**

A basic knowledge of Photonics and Spectroscopy are recommended

**Teaching methods:**

- Interactive Lectures

- Guest lectures\*. Within the module “Hot topics in ultrafast science”, 3 seminars will be held by guest lecturers who are internationally recognized experts in:
  - Ultrafast Electron Microscopy
  - Ultrafast Spectroscopy
  - Ultrafast Science at Free-Electron Lasers and synchrotrons

**Exam:**

- Oral presentation

**Literature:**

- Saleh, B. E. A., Teich, M. C., Fundamentals of Photonics, John Wiley & Sons, Inc., 1991
- U. Keller, Ultrafast Lasers - A Comprehensive Introduction to Fundamental Principles with Practical Applications, Springer International Publishing, eISBN 978-3-030-82532-4, 2021
- O. Svelto, Principles of Lasers, Springer International Publishing, e-ISBN 978-1-4419-1302-9

**Additional Notes:**

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