

PHYS-724

Ultrafast Phenomena

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Cursus	Sem.	Type
Advanced Manufacturing		Obl.
Photonics		Obl.
Physics		Obl.

Language of teaching	English
Credits	4
Session	
Exam	Oral
Workload	120h
Hours	56
Courses	28
Exercises	28
Number of positions	

Frequency

Every year

Remark

Every year / Fall

Summary

The course will cover fundamental concepts and recent developments in the field of time-resolved spectroscopy and introduce the basic theory to understand ultrafast (10-16 - 10-9 s) phenomena in condensed matter- and biological systems.

Content

For the study of electronic and structural dynamics in solids and (bio-) molecules in "real" time, a variety of time-resolved spectroscopic techniques (in the optical, THz, and X-ray region of the electromagnetic spectrum) are available. The fastest dynamics that are accessible with state-of-the-art experiments are the motion of electrons (10-16 s), vibrational motion of molecules (10-14 s), and electronic relaxation pathways (10-12 s). Examples include the breaking of interatomic bonds, vibrational dynamics in molecular systems, and tracking of radiative and non-radiative electron relaxation pathways in biological systems.

The course will try to address technological and theoretical aspects, and in the last part a few examples from literature will be studied:

1. Principles of femtosecond laser system
 - a. Overview of laser oscillators and pulse amplification
 - b. Parametric generation and amplification
 - c. Pulse measurement/characterization.
2. Time-resolved spectroscopy methods
 - a. Transient absorption (pump-probe) spectroscopy and fluorescence up-conversion
 - b. Multidimensional spectroscopy (Photon echo)
 - c. Attosecond spectroscopy using high harmonic radiation
 - d. Time-resolved X-ray absorption spectroscopy using synchrotron and XFEL radiation
3. Theory (no, or minimal, pre-existing knowledge is required)
 - a. Non-linear optics
 - b. Density matrix formalism
 - c. Liouville-space pathways
 - d. Correlation functions
4. Examples: Photon-Echo spectroscopy, Biological electron an energy transfer, Salvation dynamics...

Students are encouraged to bring up subjects/papers for discussion.

Note

Suggested reading:

- Saleh & Teich – Fundamentals of Photonics
- Series in Optics and Photonics: V. 8 – Ultrafast Dynamics in Molecules, Nanostructures and Interfaces
- Peter Hamm – Mukamel for dummies (<http://www.mitr.p.lodz.pl/evu/lectures/Hamm.pdf>)
- Minhaeng Cho – Two dimensional optical spectroscopy

Keywords

Ultrafast spectroscopy, Multidimensional spectroscopy, Optical Bloch Equations, High Harmonics Generation, Attosecond Spectroscopy, Femtosecond Lasers, Nonlinear optics.