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 presentation
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 ultrafast spectroscopy and introduce the basic theory to understand ultrafast (10-16 - 10-9 s) phenomena in chemistry, biology and condensed matter physics.

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, as well as using short electron pulses) are available.
The fastest dynamics that are accessible with state-of-the-art experiments are the motion of electrons in the attosecond regime (10-18-10-16 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, tracking of radiative and non-radiative electron relaxation pathways in biological systems, as well as charge carriers dynamics in materials.
The course addresses technological and theoretical aspects, and in the last part a few examples from literature will be studied:

1. Principles of femtosecond laser system

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

2. Time-resolved spectroscopy methods

- Transient absorption (pump-probe) spectroscopy and fluorescence up-conversion
- Non-linear optical methods (4-wave mixing, photon echo, transient grating and multidimensional spectroscopies)
- 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
- Density matrix formalism
- Liouville-space pathways

- Correlation functions

4. Examples: Photon-Echo spectroscopy, Biological electron an energy transfer, Solvation dynamics, charge carriers in materials, etc.…

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

Picosecond, femtosecond, attosecond, chemistry, biology, materials, spectroscopy, pump-probe, Nonlinear optics, X-rays, electrons, pulsed X-ray sources (synchrotrons, X-ray free electron lasers), ultrashort electron pulses.

Learning Prerequisites

Required courses

Quantum mechanics
Molecular Physics-Condensed matter physics-physical chemistry

Expected student activities

Read an article in ultrafast science and formulate his/her own questions

Resources

Ressources en bibliothèque

- Saleh & Teich â## Fundamentals of Photonics
- Peter Hamm â## Mukamel for dummies
- Ultrafast Dynamics in Molecules, Nanostructures and Interfaces
- Minhaeng Cho â## Two dimensional optical spectroscopy