PHYS-724 **Ultrafast Phenomena**

Vacat .

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

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

Postponed to Fall 2022

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.

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
- Minhaeng Cho â## Two dimensional optical spectroscopy
- Ultrafast Dynamics in Molecules, Nanostructures and Interfaces
- Peter Hamm â## Mukamel for dummies