David Busto & Eva Lindroth Quantum Connection 2024: Attosecond Physics

In 2023, the Nobel prize in Physics was awarded for "experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter". In these lectures we will introduce how it is possible to generate pulses of attosecond duration and to use them to study electronic dynamics in matter on their natural time scale.

The lectures by David Busto (1,4,6) and Eva Lindroth (2,3,5) will connect to each other.

1) High-order harmonic generation and attosecond pulses The interaction of intense laser fields with atoms can lead to the generation of coherent radiation consisting of very high order harmonics of the fundamental laser field, and extending to the soft X-ray region. This lecture will introduce the process of high-order harmonic generation and discuss how it can be used to generated light pulses of attosecond duration (1 as = 10^{-18} s.). A review that provides a good introduction to high-order harmonic generation is *Introduction to macroscopic power scaling principles for high-order harmonic generation* `https://iopscience.iop.org/article/10.1088/0034-4885/67/6/R01/meta`

2) Time in quantum mechanical systems - especially the delay-concept. Many of you may have heard the quote from Wolfgang Pauli 1933: *We conclude that the introduction of an operator T must fundamentally be abandoned and that the time in quantum mechanics has to be regarded as an ordinary number*. But there are still many aspects of time that we can talk about. One of these is the photoionization *delay*. A good source for information is the Review of Modern Physics article *Attosecond chronoscopy of photoemission* `https://doi.org/10.1103/RevModPhys.87.765`

3) More about Delays and Phases - How to get phase information. Traditionally light-matter interaction leading to ionization was studied with weak light-fields and the main interest was ionization probability. The advent of intense coherent sources showed new processes such as *above threshold ionization*, where continuum electrons absorbs or emits photons, which later proved to be important in the attosecond metrology. An article which provides basic concepts is here *Strong-field approximation in laser-assisted dynamics* from American Journal of Physics (which publish articles on the educational and cultural aspects of physics) `https://doi.org/10.1119/1.1796791`

4) Attosecond photoelectron interferometry How do you experimentally measure processes that are orders of magnitude faster than the fastest electronics? This talk will introduce the basics of attosecond photoelectron interferometry before presenting some of its applications such as measuring delays in photoionization or observing the "birth" of photoelectron wave packets. A pedagogical introduction to photoelectron interferometry can be found in *Introduction to attosecond delays in photoionization* `https://iopscience.iop.org/article/10.1088/0953-4075/45/18/183001/meta`

5) Photoelectron interferometry from a theoretical perspective Here we will discuss the interplay between theory and experiment and touch about the complications that always arise when we have to describe a many-body system.

6) Attosecond physics and quantum information The last four years have seen the emergence of new research topics at the interface of attosecond physics and quantum information science such that as the generation of "giant" optical cat states, quantum state tomography of photoelectrons or controlling ion-photoelectron entanglement. This talk will cover some of the recent developments in the field. An interesting review of recent experimental and theoretical advances is *Quantum phenomena in attosecond science* `https://arxiv.org/html/2403.05482v1`