An Introduction to Attosecond Pulses and Attosecond Physics

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The interaction of atoms with intense laser radiation leads to the generation of high-order harmonics of the laser field. In the time domain, this corresponds to a train of pulses in the extreme ultraviolet range and with attosecond duration. The physics of high-order harmonic generation (HHG) includes both the response of an atom to a strong laser field (atomic physics) and that of a macroscopic medium (nonlinear optics).

There is today an increased diversity of attosecond sources driven by a variety of lasers ranging from high energy lasers at low repetition rate to high average power lasers [1]. One of the reasons for this versatility is a scaling principle, which provides a general method for optimizing peak and average power of HHG sources, while maintaining the same conversion efficiency [2]. An orientation on the parameters that be reached will be presented.

As light pulses become shorter and more spectrally wide, their optical waveforms cannot be expressed as a product of temporal and spatial amplitudes, due to spatio-temporal couplings. This tutorial will discuss the temporal and spatial properties of attosecond pulses [3].

The short pulse duration and broad bandwidth of attosecond pulses allow the measurement of the phase and amplitude of an ionizing electronic wave packet using interferometric techniques. We will describe in particular the RABBIT (reconstruction of attosecond beating by two-photon transition) method [4], which enables us to combine high temporal and spectral resolution.

Attosecond pulses are used to study ultrafast photoemission dynamics in a variety of systems. We will concentrate on ionization of atoms both in a flat continuum [5] as well as close to resonant autoionization states [6,7]. In the first case, the dynamics is extremely fast, with a time scale of tens of attoseconds, while in the second case, the dynamics is typically several femtoseconds. This tutorial will present different temporal analysis of the photoionization process including a reconstruction of the density matrix [8].

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