Attosecond Physics

Séminaire général du Département de Physique de l'École Polytechnique

Fundamental processes in atoms, molecules, as well as condensed matter are triggered or mediated by the motion of electrons inside or between atoms. Electronic dynamics on atomic length scales tends to unfold within tens to thousands of attoseconds (1 attosecond [as] = 10^{-18} s). Recent breakthroughs in laser science are now opening the door to watching and controlling these hitherto inaccessible microscopic dynamics.

The key to accessing the attosecond time domain is the control of the electric field of (visible) light, which varies its strength and direction within less than a femtosecond (1 femtosecond = 1000 attoseconds). Atoms exposed to a few oscillations cycles of intense laser light are able to emit a single extreme ultraviolet (xuv) burst lasting less than one femtosecond [1,2]. Full control of the evolution of the electromagnetic field in laser pulses comprising a few wave cycles [3] have recently allowed the reproducible generation and measurement of isolated sub-femtosecond xuv pulses [4], demonstrating the control of microscopic processes (electron motion and photon emission) on an attosecond time scale. These tools have enabled us to visualize the oscillating electric field of visible light with an attosecond "oscilloscope" [5], to control single-electron and probe multi-electron dynamics in atoms [6,7], molecules [8] and solids [9]. Recent experiments [10] hold promise for the development of an attosecond x-ray source, which may pave the way towards 4D electron imaging with sub-atomic resolution in space and time.

[1] M. Hentschel et *al.*, *Nature* **414**, 509 (2001); [2] R. Kienberger et *al.*, *Science* **291**, 1923 (2002); [3] A. Baltuska et *al.*, *Nature* **421**, 611 (2003); [4] R. Kienberger et *al.*, *Nature* **427**, 817 (2004); [5] E. Goulielmakis et *al.*, *Science* **305**, 1267 (2004); [6] M. Drescher et *al.*, *Nature* **419**, 803 (2002). [7] M. Uiberacker et *al.*, *to be published*; [8] M. Kling et *al.*, *Science* **312**, 246 (2006); [9] A. Cavalieri et *al.*, *to be published*; [10] J. Seres et *al.*, *Nature* **433**, 596 (2005).

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