ALFRED MAQUET, Université Pierre et Marie Curie, Paris, France

Status of the time variable in quantum mechanics and the new generation of experiments with attosecond pulses of radiation

Whether time is a parameter or an operator in Quantum Mechanics is a long-standing question since the foundation of the theory. In fact, it remains open to decide if time is a parameter (as in classical mechanics) or a measurable quantity associated to a hermitian operator expressed in terms of dynamical variables. For years, the question remained rather academic and it attracted mainly the specialists' attention.

Things have changed first in the 1980s, with the related concept of "Tunnelling Time", i.e. how to measure "the time it takes a particle to tunnel through a potential barrier"? It turns out that no consensus has been reached yet on how to define such tunnelling times. It is in the 2010s, with the advent of sources of coherent radiation delivering "attosecond" (1 as = 10-18 s) pulses, that one has investigated photoionization in the time domain. At a fundamental level, this has opened the possibility to "clock" the response of a quantum system to the annihilation (absorption) of one photon.

We shall address some issues raised by this new generation of measurements and we shall present a theoretical analysis of recent experiments. These have evidenced the existence of attosecond time delays between the emission times of electrons ejected from different sub-shells in atoms, upon the absorption of one photon [1], [2].

[1] M. Schultze et al. "Delay in Photoemission", Science 328 1658-1662 (2010).

[2] K. Klünder et al. "Probing Single-Photon Ionization on the Attosecond Time Scale", Phys. Rev. Lett. 106, 143002 (2011).