Attoclock

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Ultrafast solid-state lasers enabled the world's most accurate clocks – the optical clock and the attoclock. In collaboration with Dr. Telle (PTB, Braunschweig), we pioneered self-referencing frequency comb stabilization from modelocked lasers [1], introduced and made first feasibility demonstrations for several novel techniques to measure and stabilize the carrier envelope offset phase (i.e. CEO phase or CEP) fluctuations – for example we proposed the f-to-2f heterodyne technique which is being used today.

Novel time-resolved attosecond streaking techniques such as energy streaking [2, 3], the attoclock [4, 5, 6] and interferometric techniques based on RABBITT [7] are currently being applied in an attempt to answer very fundamental questions in quantum mechanics, such as how fast can light remove a bound electron from an atom or a solid? Furthermore, the question of how long a tunneling particle spends inside the barrier has remained unresolved since the early days of quantum mechanics.

The stabilized frequency comb enabled us to invent the attoclock: a powerful, new, and unconventional tool to study fundamental processes in quantum mechanics – with attosecond accuracy using 1000 times longer laser pulses. We have established the attoclock to measure the electron tunneling time for the first time in 2008 [4, 5]. Since then we improved the signal-to-noise ratio in our measurements and revealed a real and not instantaneous tunneling time [6]. The matching theoretical model predicts a strong implications on the investigation of electron dynamics in attosecond science, because a significant delay must be taken into account about when the electron hole dynamics begin to evolve.

Furthermore, the attoclock revealed that the standard model of strong field ionization, where the initial step consists of ionization by tunneling and the second step is Newtonian movement in the laser field, needs to be refined: the larger the atomic polarizability, the more important it becomes to account for the Stark shift of the energy levels and the deformation of the ion potential by the induced dipole [8]. For double ionization of argon we found that the ionization time of the first electron is in good agreement with the model predictions, whereas the ionization of the second electron occurs significantly earlier than predicted [9] and the two electrons exhibit some unexpected correlation.

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