Attosecond ionization time delays from atoms, molecules to solid surfaces

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Attosecond photo ionization delays have been first measured in my group in the multi-photon / strong field regime in 2008. Since then it has been a strong research effort and we have extensively studied the dynamics of ionization/photoemission from atoms, molecules and solids in regimes ranging from tunnel-ionization to single-photon ionization. In the simplest case, when the electron is promoted into a flat (non-resonant) continuum by direct laser-assisted single photon ionization, the measured delay after absorbing a single XUV photon is related to the group delay of the departing electron wave packet induced by the ionic potential and laser field, respectively. This delay is also referred to as the Wigner delay. This is however not the case for tunnel ionization. More recently our work in the gas phase revolved around fundamental aspects of ionization in the vicinity of autoionizing states. We could demonstrate in collaboration with Anne L'Huillier that not only the phase of the photoelectron wave packet is significantly distorted in the presence of resonances, but that this distortion depends on the electron emission angle. In H_2, on the other hand, we obtained the first experimental evidence for the importance of the coupled electron-nuclear motion for the attosecond ionization dynamics confirmed by a complete *ab initio* theoretical study with the group of Fernando Martín. Further studies on CO with an asymmetric Coulomb potential revealed that the accumulated phase of the escaping electron wave packet is not only energy- and molecular orientation dependent, but can give insight into the mean position of the ionization within the CO molecular potential. This dependence is unique to the molecular photoionization process and has been supported by two different theoretical models by S. Patchkovskii's and A. Landsman's groups. And finally our experiments on attosecond photoemission dynamics from a Cu(111) surface showed that the effective mass is a valid concept within our temporal resolution of 350 as and travel distances of only 5-7 Å.

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