Attosecond Time Delay in Photoemission and Electron Scattering near Threshold

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Synopsis We study the time delay in the primary photoemission channel near the opening of an additional channel and compare it with the Wigner time delay in elastic scattering of the photoelectron near the corresponding inelastic threshold. The photoemission time delay near threshold is significantly enhanced, to a measurable 40 as, in comparison to the corresponding elastic scattering delay. This opens the possibility of studying threshold behaviour utilizing attosecond chronoscopy.

Attosecond time delay in atomic photoemission can provide an alternative route for observing threshold effects. The opening of a new channel corresponds to a branching point of the scattering amplitude in the complex energy plane because the number of physically available quantum states of the system changes. Hence, the behaviours present around such a branching point brings significantly richer information in comparison to any other regular energy point.

The time delay in photoemission is interpreted in terms of the Wigner time delay introduced for particle scattering in external potential [1]. It is a delay, or advance, of a particle travelling through a potential landscape in comparison with the same particle travelling in a free space. The Wigner time delay is calculated as an energy derivative of the scattering phase in a given partial wave. A similar definition is adopted in photoemission, where the time delay is related to the photoelectron group delay, and evaluated as an energy derivative of the phase of the complex ionization amplitude [2].

Here we report on the recently published work [3] where we investigated the time delay in the primary photoemission channel near the opening of an additional channel and compared it with the Wigner time delay in the elastic scattering of the photoelectron near the corresponding inelastic threshold. We do so by considering photodetachment from the H^- negative ion and comparing it with electron scattering on the hydrogen atom near the first excitation threshold. Additionally, we consider the equivalent processes on the He atom for the purpose of contrast and comparison.

Our numerical results are obtained within the convergent close-coupling (CCC) formalism [4]. In the case of He, all three calculated time delays closely approximate one another. This means that the independent electron Hartree-Fock basis represents both the scattering and ionization processes very accurately and correlations are negligible. In the case of H^-, above the $n = 2$ (10.2 eV) excitation threshold, both the photodetachment and elastic scattering amplitudes experience rapid growth of their phases. However, this growth is an order of magnitude larger in photodetachment in comparison with photoelectron scattering. This results in an order of magnitude enhancement of the photoemission time delay near threshold, reaching a readily measurable $\simeq 40$ as. We attribute this large deviation between the time delay in photoemission and electron scattering to the different lowest orders of interelectron interaction mixing the ground state and excitation channels.

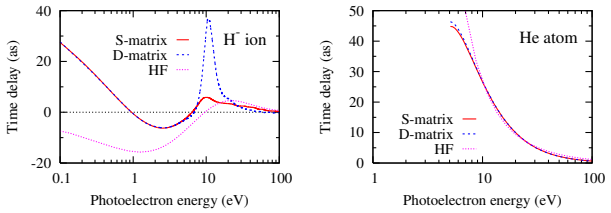

Figure 1. Left: The calculated time delay for the photodetachment of H^- labelled *D*-matrix (red), elastic scattering of an electron on H in the dipole singlet channel labelled *S*-matrix (blue), and this elastic scattering delay as calculated by a frozen core Hartree-Fock approach (cyan) [5]. Right: Equivalent, but for a He atomic target.

References

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