Essential conditions for dynamic interference

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Synopsis We work out the parameter window where the general phenomenon of dynamic interference — a non-linear feature of the photo-effect in atoms or molecules exposed intense high-frequency pulses — occur. This theory is backed up by full numerical calculations of photo-electron spectra of hydrogen for photon frequencies as large as 1 keV.

Dynamic interference (DI) has been predicted to occur for the photo-effect in intense laser pulses [1] as available in existing and upcoming Xray free-electron laser machines. Thereby, non-linear behavior does not emerge as higher-order process (a. k. a. above-threshold ionization), but rather through dynamical Stark shifts that induce a double-slit-like interference in time and manifests as structures in the photo-electron spectra. In contrast to published claims [1, 2], dynamic interference does not occur for ground-state hydrogen in VUV pulses as shown in Fig. 1a.

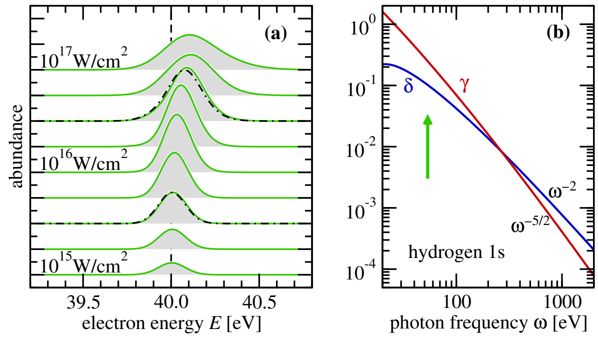

Figure 1. **(a)** Photo-electron spectra for 1s-hydrogen exposed to 10 fs pulses showing a dynamic Stark shift, but no DI. **(b)** Dimensionless parameters δ and γ characterizing the dynamic Stark shift and depletion, respectively, shown as the function of frequency ω [3]. The green arrow marks the frequency $\omega = 53.6$ eV used in the left panel and in previous publications [1].

Although the process being non-perturbative, we could fully disentangle system and pulse properties allowing for predictive statements about the visibility of the effect by means of electronic structure calculations without performing any cumbersome numerical propagation [3]. The decisive quantity is the ratio of the dynamic Stark shift Δ and ionization rate Γ, which both depend on the frequency. Figure 1b shows the corresponding dimensionless quantities $\delta = \Delta/E_{\rm pond}$ and $\gamma = \Gamma/E_{\rm pond}$, respectively, for the hydrogen ground-state.

By means of this analysis we predict DI to occur for the 1s-state only in the Xray regime ($\sim$ 1 keV) and for the excited 2p-state also for VUV frequencies ($\sim$ 12 eV). We proof this by the numerical propagation of the time-dependent Schrödinger equation (TDSE), cf. Fig. 2 for the VUV case.

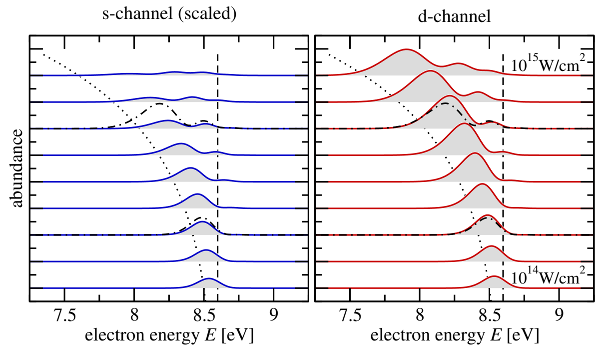

Figure 2. Photo-electron spectra for 2p-hydrogen exposed to 10 fs pulses showing DI in both continuum channels [3].

The solution of the TDSE in the keV-range requires a dedicated propagation method [4], which will be presented.

References

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