Sideband and streaking regimes in two-color photoionization by twisted X-waves in strong infrared fields

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Synopsis The photoionization by short twisted XUV pulses (X-waves) is investigated in the presence of an intense infrared beam within the S-matrix formalism. It is demonstrated how sidebands are affected by the twist of the ionizing pulse as the pulse duration increases.

During the past decade, the generation of attosecond laser pulses enabled experimental studies of electron dynamics in atoms. In particular, the photoionization by XUV pulses in the presence of an additional strong low-frequency laser field has attracted much interest. Such a setup allows, for example, to extract timing information about the ionization process and to characterize the participating laser pulses. Here, we explore this photoionization if the plane-wave XUV pulse is replaced by a twisted X-wave that carries additional orbital angular momentum (OAM).

Detailed studies of the excitation and ionization by twisted light have revealed that selection rules of both bound-bound and bound-free transitions are modified [1, 2]. However, the presence of an additional plane-wave infrared field also affects the continuum states accessible to the photoelectron and hence leads to the formation of sidebands in the recorded spectra [3]. A question of particular interest is how these sidebands are modified and how the streaking regime arises if the duration τ_X of the twisted pulse is shortened to the order of the infrared cycle length T_{IR}. For plane-wave pulses, this transition is displayed in Fig. 1. For $\tau_X < T_{IR}$, the photoelectrons appear at a definite time in the infrared field and are streaked to the same energy. The energy-differential ionization probability therefore exhibits a single peak in the streaking regime (red curve). If τ_X is increased, the interference of photoelectrons entering the infrared field at different times leads to the formation of sidebands ($\tau_X > T_{IR}$, blue curve). It was recently demonstrated that the angular distribution of photoelectrons in the transition regime provides information about the initial atomic state [4].

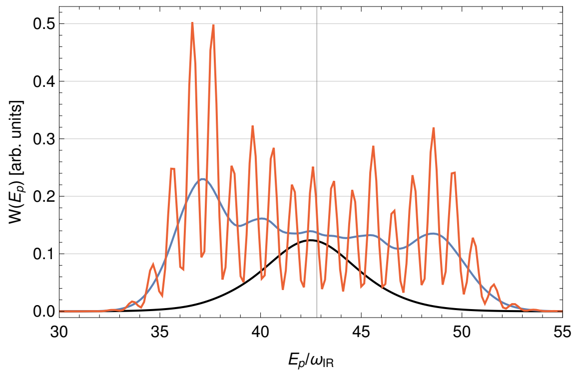

Figure 1. Energy-differential ionization probability $W(E_p)$ for three durations τ_X of the ionizing XUV pulse with photon energy $\omega_X = 80$ eV. Red curve: sideband regime for $\tau_X = 7$ fs; black curve: streaking regime for $\tau_X = 1$ fs; blue curve: transition for intermediate $\tau_X = 3$ fs. The central black line marks the position of the XUV photoline without infrared field. Further laser parameters are $\lambda_{IR} = 800$ nm, $I_{IR} = 10^{13}$ W/cm^2 and $I_X = 10^9$ W/cm^2. Black and blue curves are magnified by a factor of 2.

In this contribution, we discuss how the two-color ionization process is affected by the OAM of the X-wave. More specifically, we investigate the streaking and sideband regimes and the transition from one to the other with increasing X-wave pulse duration.

References

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