Theory for ultrafast dynamical photoemission: cases of dressed continuum, dressed atom and dressed ion

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According to Einstein's photoelectric effect, the energy of an ejected photoelectron is determined by the difference between the photon energy and the binding potential of the atom: $E^{\text{kin}} = \hbar\omega - E^{\text{bin}}$, where $\hbar\omega > E^{\text{bin}}$. This fundamental relation is the basis for photoelectron spectroscopy, which has been sucessfully used to learn about many-body correlation effects in quantum systems, such as atoms and molecules, over the past half century [1]. In the case of intense ultrashort laser pulses the photoemission process becomes dynamical and the photoelectric equation must be modified. Intense laser pulses with small photon energy, $\hbar\omega \ll E^{\text{bin}}$ lead to *i)* multiphoton transitions and *ii)* dressing of the photoelectron continuum. Photoionization by a short-wavelength field, $\hbar\omega > E^{\text{bin}}$, into such a dressed continuum, which gains energy equal to the ponderotive energy, U_p [2], can lead to dynamical interference structures in the photonelectron distribution [3]. If the frequency of the short-wavelength light matches an atomic transition, $\hbar\omega = \Delta E_{ba}$, the atom will be dressed and it may undergo Rabi oscillations, with angular frequency Ω, provided that the field duration τ is sufficient: $\tau > 2\pi/\Omega$. In this case, the photoelectron distribution changes into an Autler–Townes doublet [4]. Depending on the intensity of the short-wavelength field, the atom can be photoionized from the resonant state, from the ground state, or from a coherent combination of both states, which opens up for studies of dressed-atom stabilization [5]. Alternatively, high-intensity short-wavelength lasers can be used to create dressing in the ionic system [6]. Currently, the photoelectric effect is gaining interest as a resource for quantum entanglement between massive particles (photoelectron and photoion) controlled by ultrashort laser pulses in atoms and molecules [7].

In this tutorial, I will review analytical models that can be used to study dynamical photoelectric effects in atoms including: *i)* dressing of the photoelectron continuum, *ii)* dressing of the neutral atom and *iii)* dressing of the ion with an entangled photoelectron.

References

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