Multiphoton radiative recombination of electron assisted by a laser field

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In the presence of an intensive laser field the radiative recombination of the continuum electron into an atomic bound state generally is accompanied by absorption or emission of several laser quanta. The frequencies of emitted photons represent an equidistant pattern $\Omega_m = (m + \eta)\omega$ with the spacing equal to the laser frequency ω (m is an integer). The laser assisted recombination (LAR) represents important mechanism of high-energy photoproduction in laser plasma (along with two other processes, high harmonic generation and laser-stimulated bremsstrahlung). It did not receive a proper attention in the literature, although its importance was indicated before [1].

We study the distribution of intensities in the photon spectrum employing the Keldysh-type approximation, i.e. neglecting interaction of the incident electron with the atomic core in the initial continuum state. The Keldysh model [2] is standardly employed in the theory of laser-field-induced above-threshold ionization (ATI) where transitions has under-barrier character, i.e., can occur only at complex-valued time. The emission time emerges in the quantum theory through the saddle points when the time integration is carried out in the semiclassical (adiabatic) approximation [3]. The important physical distinction of LAR from ATI is that for a part of the photon spectrum the emission can occur classically, i.e. at real time. Therefore the scale of emitted photon frequencies is subdivided into classically allowed and classically forbidden domains. Further, in the classically allowed domain the regimes of fast, $p_{\|} > F/\omega$, and slow, $p_{\|} < F/\omega$, photoelectron should be distinguished, as illustrated by Fig. 1(a,b). Here $\mathbf{F}$ is the amplitude of electric field strength in laser wave, $\mathbf{p}$ is the photoelectron translational momentum, $p_{\|}$ is its component parallel to $\mathbf{F}$. For each regime the schematic plots Fig. 1(a,b) show the instantaneous kinetic energy of electron $\frac{1}{2}\Pi_{\|}(t)$, where $\Pi_{\|}(t) \equiv p_{\|} + (F/\omega)\sin\omega t$ is the electron momentum with account for the quiver motion in the laser field. As time t varies, the function $\frac{1}{2}\Pi_{\|}(t)$ oscillates in the interval that covers the emitted photon energies Ω_m allowed for population classically. Outside this interval only nonclassical (tunneling) population is possible. The plot (a) shows that in the classically allowed domain each value of the photon energy Ω_m is passed twice during the laser field period T if the electron is fast ($p_{\|} > F/\omega$). In the slow electron regime ($p_{\|} < F/\omega$) the classically allowed domain of Ω_m is subdivided into two regions, see the plot (b). The photons with higher Ω_m are again emitted in the double-passage mode, whereas the lower values of Ω_m are passed four times per the laser field cycle.

Some representative cross sections for *spontaneous* emission of photons with frequency Ω_m are shown for fast, Fig. 1(c), and slow, Fig. 1(d), electron regimes. The highest intensities

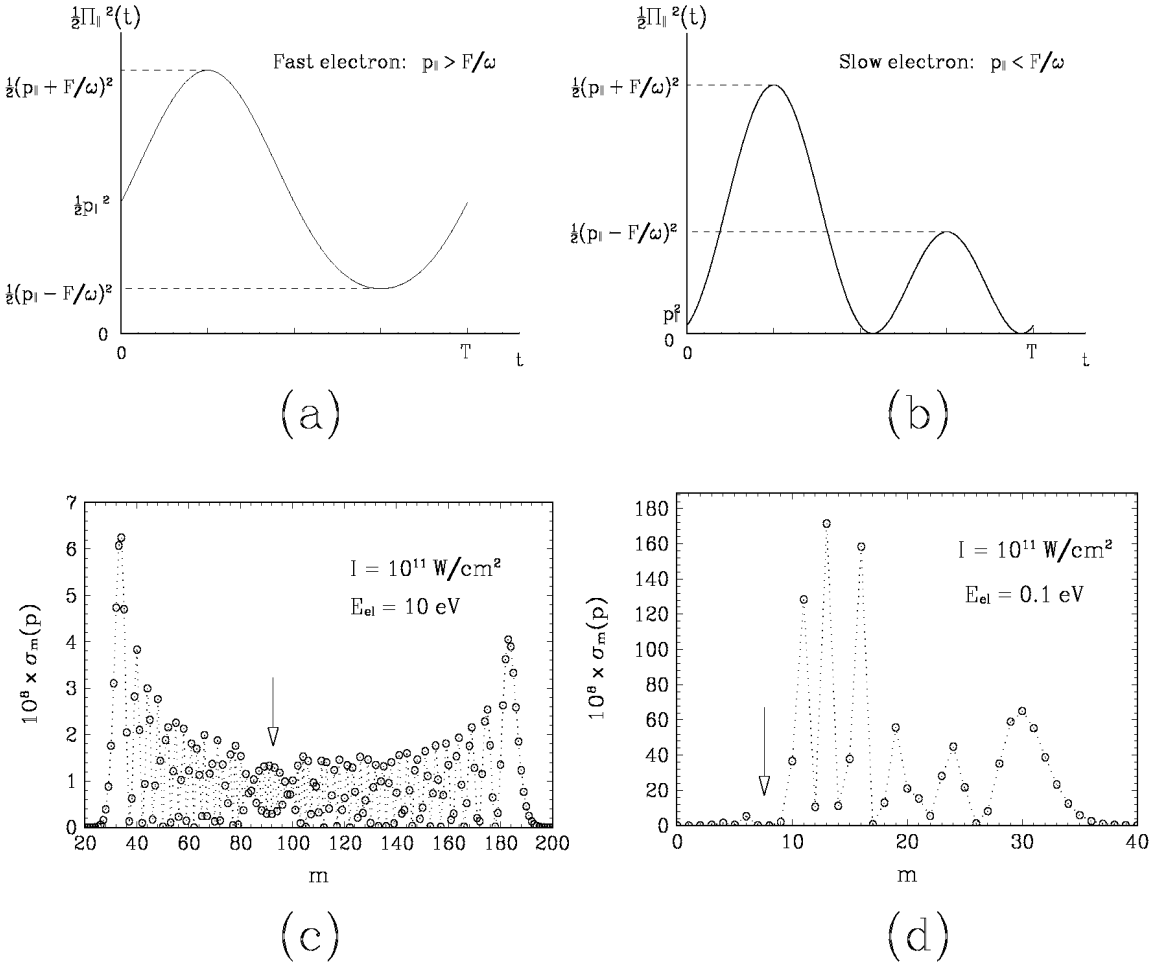

Figure 1: Regimes of fast and slow electron in the laser-assisted recombination process (a-b) and cross section $\sigma_m(p)$ (c-d) for laser-assisted recombination of the electron with the energy $E_{\rm el}$ to the bound state in H^- ion for the laser field intensity I and frequency $\omega = 0.043$ a.u. As $I \to 0$ the spectrum shrinks to the single line with the position indicated by vertical arrow.

correspond to emission frequencies close to the edges of the classically allowed domain.

For the weak laser field the photon spectrum shrinks to a single line; as the laser intensity I increases, the spectrum broadens. The *total* cross section of electron recombination summed over all emitted photon channels *exhibits negligible dependence on intensity* I.

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