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Transverse electron momentum distribution in strong field ionization: transition from tunneling to over the barrier ionization regimes.

I.A.Ivanov[*1], **A.S.Kheifets**[†2]

[*] Center for Relativistic Laser Science, Institute for Basic Science (IBS), Gwangju 500-712, Republic of Korea

[†] Research School of Physics and Engineering, The Australian National University

Synopsis We study transverse electron momentum distribution (TEMD) in strong field atomic ionization driven by laser pulses with varying ellipticity. We show, that the TEMD in the tunneling and over the barrier ionization regimes evolves in a qualitatively different way when the ellipticity parameter describing polarization state of the driving laser pulse increases.

The current understanding of strong field atomic ionization is based on the pioneering work by Keldysh which introduced the distinction between the multiphoton and tunneling ionization regimes. A finer distinction arises when one realizes that the Keldysh theory in its original form is not applicable for very high field strengths exceeding the over the barrier ionization (OBI) limit. Despite the fact that underlying physics is very different in the two regimes (a classically forbidden trajectory for tunneling and a classically allowed trajectory for OBI), the energy spectra and electron angular distributions as given by these two theories are not dissimilar. This makes it often difficult to distinguish the two regimes in the experiment [1].

We show, that the TEMD distributions are qualitatively different in the tunneling and the OBI regimes. In the tunneling regime, TEMD exhibits a cusp-like structure due to the Coulomb focusing effect at $p_\perp = 0$ for linear polarization and a Gaussian-like structure predicted by the Keldysh theory for circular polarization. We studied this transition from the cusp-like to the Gaussian structures in detail in the tunneling regime [2], and interpreted this transition as a gradual diminishing of the role of the Coulomb effects with a growing ellipticity of the laser pulse. Further study of the role of the Coulomb focusing effects has been reported in [3]. Behavior of the TEMD in the vicinity of the point $p_\perp = 0$ can described by means of an expansion:

$$\ln W(p_\perp) \approx B + A|p_\perp|^\alpha \; . \qquad (1)$$

For the TEMD $W(p_\perp = 0)$ to have a cusp $V(p_\perp = 0)$ should have an infinite derivative of some order, the gaussian behavior of the TEMD predicted by the Keldysh theory corresponds to $\alpha = 2$.

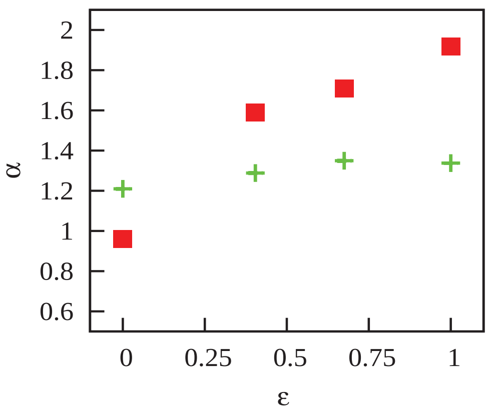

Figure 1. The fitting parameter α in Eq. (1) as a function of the ellipticity parameter ϵ for Ar (red) boxes and Ne* (green) crosses.

In Figure I we show behavior of α- parameter as a function of the the ellipticity parameter of the driving laser pulse for Ar (field intensity of 4.8×10^{14} W/cm^2, well below the OBI limit) and metastable Ne atom (field intensity of 2×10^{14}, which is above the OBI threshold).

For the Ar atom, the α parameter grows with ϵ reaching the value close to 2 for circular polarization, similar to the behavior we observed for the tunneling ionization of hydrogen [2]. For the metastable Ne* atom, the α parameter remains essentially flat, indicating that a cusp-like behavior is present for all ϵ in the range from linear to circular polarization.

References

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[1]E-mail: igor.ivanov@anu.edu.au
[2]E-mail: a.kheifets@anu.edu.au