Multiphoton ionization and stabilization of helium in superintense xuv fields

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Synopsis

We present calculations on multiphoton ionization of helium exposed to superintense xuv fields. In particular we scrutinize the role of the electron-electron interaction in the ionization and stabilization dynamics, and demonstrate how the single-particle picture breaks down at superstrong field strengths.

When exposing an atom to an intense laser, and increasing the intensity of the pulse to such a degree that the applied forces dominate over the Coulomb attraction, it is observed that the ionization probability does not increase accordingly, but rather stabilize, or start subsiding. This counterintuitive phenomenon is dubbed atomic stabilization, and has been subject to much research in the last two decades. (See for example [1] and references therein.)

In this work we present \textit{ab initio} calculations on multiphoton ionization of helium in superintense high-frequency fields obtained by solving the time-dependent Schrödinger equation in full dimensionality [2]. We look into the strong-field ionization dynamics of the atom, with particular emphasis on atomic stabilization, considering laser pulses of various central frequencies and durations. A comparison of the ionization yields obtained from the full calculations, including correlation, with corresponding results obtained from an independent-electron (IE) model, reveals that the validity of the latter breaks down at strong fields (see upper panel of figure 1). An analysis of the system equations in the so-called Kramers-Henneberger frame, the reference frame of a free (classical) electron moving in the field, shows that the electron-electron interaction plays a decisive role in this limit. As shown in the lower panel of figure 1, this is also manifested in the angular distributions for double ionization with equal energy sharing $E_1 = E_2 = (2\omega - I_p)/2$, where $\omega$ is the laser frequency and $I_p$ is the ionization potential. In contrast to the IE picture, where a symmetric double lobe would have been found, the distributions have a backward-forward asymmetry even at the highest field strength $E_0$. This clearly demonstrates the breakdown of the single-particle picture, which is tied to the fact that shake-up and shake-off processes cannot be properly accounted for in independent-electron models.

Figure 1. Upper: Ionization probabilities for a constant pulse duration of $2\pi$ a.u. for various frequencies and number of cycles. The dashed lines: IE calculations. Lower: Angular distributions for double ionization (6-cycles pulse) for three field strengths. The arrow indicates the direction of the first electron. Blue: $E_0 = 1$ a.u. Green: $E_0 = 10$ a.u. Red: $E_0 = 20$ a.u.

References

[1] M. Gavrila 2002 \textit{J. Phys B} \textbf{35} R147
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