The Role of Polarization for Bound States in Strong Fields

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As matter interacts with ultrastrong fields, the bound electrons in ion states are both polarized and Stark shifted. The unprecedented range of laser intensities from 10^{15} to 10^{24} Wcm^{-2} can take the interaction from the neutral atom to a bare nucleus.

We have used a single active electron approximation to calculate the polarization and Stark shifted binding energy for ultraintense lasers interacting with highly charged ions across the periodic table from beryllium to uranium at intensities up to 10^{22} W cm^{-2}. The calculated response with atoms from beryllium to uranium shows induced dipole and Stark shifts as significant as 0.1 e a_0 and 50 E_h.

Tunneling ionization is fundamental to the physics of attosecond science, high harmonic generation, multielectron rescattering ionization, and other phenomena in strong fields. Applying the findings to tunneling ionization reveals that the impact of polarization and Stark shifts on the ionization rate are significant but counteracting. The opposing role of polarization and Stark shift resolve a longstanding question on how field-free derivations of the tunneling response have been quantitatively successful in high-intensity experiments.

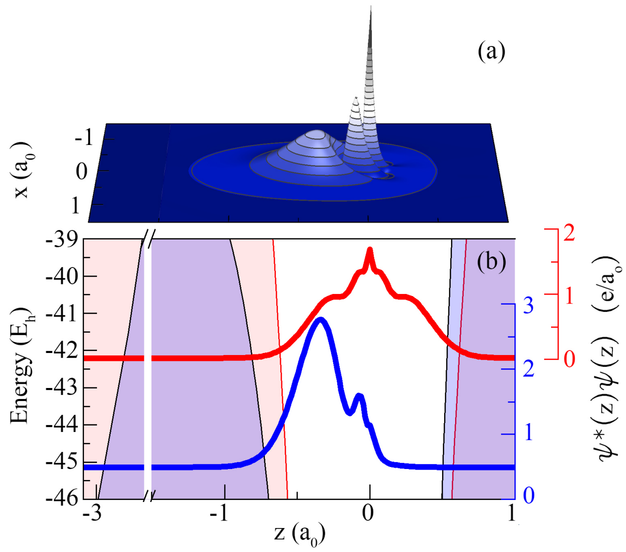

Figure 1: Wave function magnitude $|\psi(x,0,z)|$ (a) in the $y = 0$ plane for the Kr^{25+} outermost electron in an external electric field (intensity) of 12.4 $E_h\, e^{-1}\, a_0^{-1}\ \hat{z}$ (5.4×10^{18} W cm^{-2}). The electron probability $\psi(z)^*\psi(z)$ is shown (b) field free (red, upper bold line) and along the 12.4 $E_h\, e^{-1}\, a_0^{-1}\ \hat{z}$ field direction (blue, lower bold line). The $\psi(z)^*\psi(z)$ probability (right y-axis) is shown offset to indicate the binding energy of -42.2 E_h field free and -45.1 E_h in the field. The binding ion potentials for the Kr^{25+} outermost electron ion with no external field (red, thin line, light fill to x-axis) and in an electric field of 12.4 $E_h\, e^{-1}\, a_0^{-1}\ \hat{z}$ (blue, thin line, dark fill to x-axis) are also shown in (b)

Using a scaling relationship the results can be generalized to give the induced electric dipole for any species across an intensity range from 10^{15} to 10^{22} Wcm^{-2}. When scaling with the ion charge and principal quantum number, the polarized wave functions reveal a common polarization response that can be used to predict the dipole moment for highly charged ions across the periodic table and intensity range from 10^{15} to 10^{22} Wcm^{-2}.

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