Above-threshold detachment of Si^- by few-cycle femtosecond laser pulses

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The recent adiabatic saddle point approach of Shearer and Monteith [1] is extended to multiphoton detachment of negative ions with outer half-filled np^3 subshells. This theory is applied to investigate strong field photodetachment dynamics of Si^- ions exposed to few-cycle femtosecond laser pulses, without taking into account the rescattering mechanism. The present theory can be modified to take into account the spatiotemporal intensity distribution of the laser focus and saturation effects. To date, there are relatively few studies on photodetachment cross sections for Si^- in the literature [3-5]. The aim of the present work is to provide for the first time, detailed information on strong field photodetachment dynamics of Si^- by mid-infrared femtosecond laser pulses.

This study focuses on numerical calculations for mid-infrared few cycle laser pulses with wavelengths of 1340 nm and 1985 nm at intensities of 1.4×10^{12} W/cm^2 and 3.5×10^{12} W/cm^2. In this work as in [1] we assume an ir laser with frequency ω, polarized along the $\hat{\mathbf{z}}$ axis, whose time-dependent vector potential is given by,

$$\mathbf{A}(t) = A(t)\hat{\mathbf{z}} = A_0 \left[\sin^2\left(\frac{\omega t}{2N}\right)\sin(\omega t + \alpha)\right]\hat{\mathbf{z}}. \tag{1}$$

At higher intensities of order 10^{13} W/cm^2, the present few-cycle regime fails and we need to use an infinitely long flat pulse to describe the photodetachment process accurately. This may be due to the fact that the Keldysh parameter has only a well defined meaning in the long pulse limit [6]. In this case we consider the intensity of 7.6×10^{13} W/cm^2 and take the laser field $\mathbf{F}(t)$ to be defined as,

$$\mathbf{F}(t) = F(t)\hat{\mathbf{z}} = [F\cos\omega t]\,\hat{\mathbf{z}}. \tag{2}$$

The calculations involve summation over channels with different values of $m = 0, \pm 1$ simulated separately and with the statistical averaging of channels associated with the three final triplet atomic states, $^3P_2$, $^3P_1$ and $^3P_0$ of Si respectively.

Analysis of electron momentum distribution probability maps reveal a remarkably detailed concentric-ring structure of above threshold detachment. This is attributed to electronic quantum wave-packet interference effects.

Above threshold detachment of photoangular distributions (PADs) as functions of laser intensity and wavelength near channel closings are also investigated and found to be sensitive to initial-state symmetry as in [1-2].

Additionally it is observed that the profile of the photoelectron emission spectra calculated within the current few-cycle laser pulse regime is strongly influenced by the carrier envelop phase (CEP), thus indicating it is a powerful tool for extracting information about the mechanism underlying photodetachment of Si^-on a femtosecond time scale.

References

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