Theoretical study of carrier-envelope phase effects on the 3D momentum distribution of H_2^+ dissociation fragments

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Synopsis The carrier-envelope phase (CEP) of few-cycle laser pulses can be used to control the strong-field dynamics of atoms and molecules. To study CEP effects in H_2^+, we have solved the time-dependent Schödinger equation including nuclear vibration and rotation as well as electronic excitation, only ionization is excluded. Including nuclear rotation is essential to obtaining results directly comparable with experiment such as the momentum distribution. We show that the momentum distribution is quite sensitive to the CEP.

Being the simplest molecule, H_2^+ has been an attractive candidate for studying molecular dynamics in intense laser pulses by both theorists and experimentalists for almost two decades. Since the time-dependent Schrödinger equation (TDSE) for H_2^+ can be solved accurately with some restrictions, the results should be directly comparable to experimental observations. This comparison, however, depends crucially on being able to analyze the time-dependent wave function. We present here a careful analysis of the momentum distribution of p and H following H_2^+ dissociation appropriate to most experiments.

To be measurable, carrier-envelope phase (CEP) effects require few-cycle pulses. The fact that such pulses for the common 785 nm Ti:S laser are much shorter than the free rotational period of H_2^+ has led many groups to neglect nuclear rotation in the theoretical analysis of CEP effects [1, 2]. Our results indicate that even a 5 fs pulse can populate a large number of rotational states which, in turn, continue to evolve freely as the fragments head to the detector. Including rotation is thus essential for predicting the momentum distribution of the fragments. The complex interference between the different angular momentum states also vary with other laser parameters such as intensity, wavelength, and CEP.

Figure 1(a) shows the distribution of the relative p+H momentum parallel to the linearly polarized laser field $P_{\|}$ and perpendicular to the field $P_{\perp}$. It shows a clear up and down asymmetry for a pulse length of 5 fs, wavelength of 785 nm, and intensity of 10^{14} W/cm^2. The angular distribution for a few CEP is shown in Fig. 1(b) and reveals only relatively weak CEP dependence. Figure 1(c), on the other hand, shows strong CEP effects in the up-down asymmetry, $A=2(P_{\mathrm{up}}-P_{\mathrm{down}})/(P_{\mathrm{up}}+P_{\mathrm{down}})$ where P_{up} (P_{down}) is the probability for being in the upper (lower) half plane. From these three panels, we see that there is strong CEP-dependent asymmetry and that it is most clearly revealed as a function of the relative p+H kinetic energy.

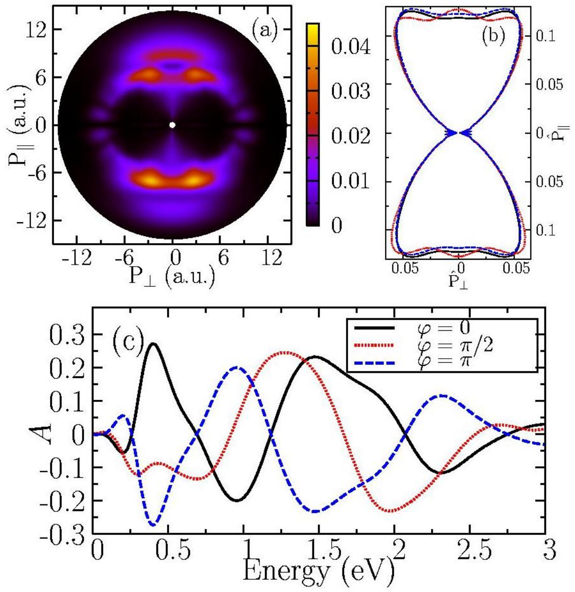

Fig. 1. (a) p+H relative momentum distribution for zero CEP (φ=0). (b) Angular distribution for the three CEP in (c). (c) Up-down asymmetry A as a function of p+H relative kinetic energy.

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References

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