Highlighting the role of dipole matrix elements in strong field molecular dissociation: vibrational suppression in H_2^+

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Synopsis H_2^+ in an intense laser field shows stabilization against dissociation. We show that this stabilization can trivially be caused by the dipole matrix element coupling, without the need to summon other complex strong-field mechanisms such as vibrational trapping.

Typically, high vibrational (v) states of H_2^+ dissociate easily when exposed to an intense laser field by the absorption of one photon. Calculations, however, indicate that under the right laser conditions H_2^+ displays a counterintuitive stabilization against dissociation, e.g. [1]. A mechanism used to explain this stabilization phenomenon is vibrational trapping where an H_2^+ wavepacket is momentarily trapped in a laser-induced potential well — sheltering the H_2^+ population from dissociation.

At this conference we raise awareness of an alternative source of dissociation suppression, resulting from merely the amplitude of the H_2^+ dipole matrix elements that show a strong v dependence. Importantly, we find that the dipole matrix elements can explain some stabilization phenomena that had previously been interpreted by invoking the elaborate trapping mechanism.

Figure 1 demonstrates the H_2^+ suppression from its dipole matrix elements. Panel (a) shows the H_2^+ dissociation probability P_D for each v state calculated by solving the three-dimensional time-dependent Schrödinger equation (TDSE) for 45 fs, 4×10^{12} W/cm^2 pulses at 395 nm. For comparison the result from first order time-dependent perturbation theory (scaled) is also shown. Clear dips in P_D are observed for v=7, 9 and 10. These dips appear in the Franck-Condon averaged kinetic energy release (KER) distribution in Fig. 1(b) near 2.1, 2.4 and 2.6 eV, respectively.

Using a coincidence three-dimensional momentum imaging technique that we have developed in conjunction with a crossed laser–ion-beam experimental setup, we are able to observe this suppression effect as evident in the experimental KER distribution in Fig. 1(d), for 40 fs, 3×10^{13} W/cm^2, 395 nm pulses. By a fitting procedure, we retrieve the relative $P_D(v)$ values as plotted in Fig. 1(c) and obtain qualitative agreement with the theory, shown in Fig. 1(a), confirming the role of the H_2^+ dipole matrix element suppression in its intense-field dynamics.

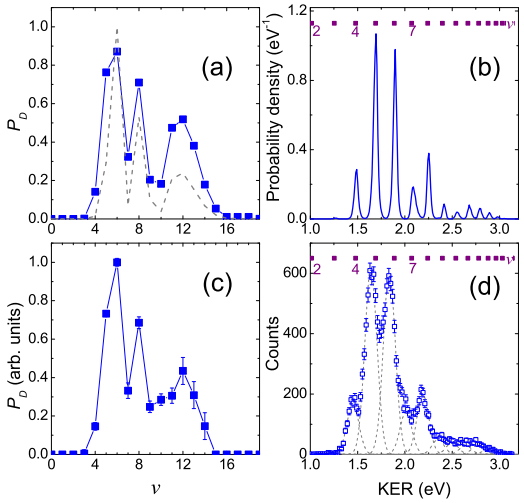

Fig. 1. (a) Calculated $P_D(v)$ of H_2^+ (points: TDSE calculation; dashed curve: perturbation theory), and (b) corresponding Franck-Condon averaged KER distribution. (c,d) same as (a,b) but experimental. For laser conditions, see text.

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References

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