DYNAMICS OF HYDROGEN MOLECULAR ION FRAGMENTATION IN INTENSE FEW-CYCLE INFRARED LASER PULSES

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Central to our understanding of the response of generic molecules to intense ultrashort laser pulses is a comprehensive knowledge of the reaction dynamics of the H_2^+ molecular ion and its isotopic compatriots, HD^+ and D_2^+. These molecules make for tractable targets due to their simple three-body structure, providing a much sought-after test case for current theory.

In recent studies we have employed the use of a molecular ion beam for the laser interaction. This method holds many advantages over more traditional stationary target experiments which prepare the H_2^+ target by ionizing a neutral H_2 molecule in the same laser pulse. First, formation of the H_2^+ ion in an isolated source [1] removes the pre-requisite requirement of high intensity for the initial formation step (i.e. $H_2 \rightarrow H_2^+$) allowing studies to be performed over a much broader range of intensity spanning the low intensity limit. It further serves to populate a well-defined distribution of vibrational states, following the fast electron-impact ionization of H_2 in the source, hence removing any uncertainties which might arise from this otherwise unknown parameter.

Perhaps most important for the present work is the non-stationary nature of the target. The initial momentum of the H_2^+ molecules in the laboratory frame allows for straight-forward detection of both the neutral and ionic fragments. Recently, we have taken advantage of this ability by developing a coincidence three-dimensional imaging system [2] tailored to provide kinematically complete momentum information, in the center-of-mass frame, of the correlated fragment particles. That is, we measure the reaction channels:

$$H_2^+ + nh\nu \rightarrow H^+ + H \qquad (1)$$

and

$$H_2^+ + nh\nu \rightarrow H^+ + H^+ + e^- , \qquad (2)$$

where $nh\nu$ symbolizes the strong interaction with the laser field. Application of a small electrostatic field in the interaction region (see Figure 1) temporally separates the ionic particles from the neutrals enabling ionization events, pathway (2), to be isolated from dissociation events, pathway (1).

At this conference we will provide additional details on how we perform the measurements and extract the three-dimensional momentum vectors of the particles. Further, we will describe recent results where we apply our method to the interaction of few-cycle (< 10 fs) laser pulses (795 nm) with the H_2^+ ion. Our results show a clear dependence of the fragmentation structure on the temporal duration of the laser pulse used, highlighting new aspects of the response of the H_2^+ molecular ion in a sub-vibrational period laser pulse.

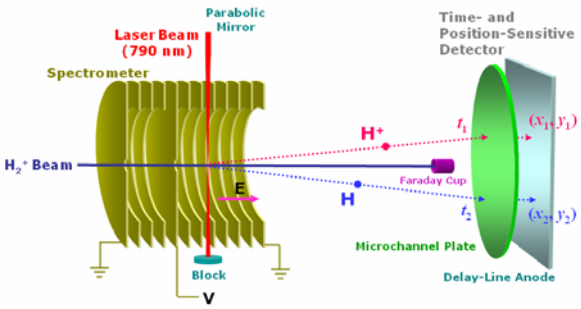

FIG. 1. Schematic of the spectrometer and detection system used for coincidence 3D imaging of H_2^+ break-up in intense laser fields.

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References

[1] Here we use an electron cyclotron resonance (ECR) source.

[2] I. Ben-Itzhak, P. Q. Wang, J. F. Xia, A. M. Sayler, M. A. Smith, K. D. Carnes, and B. D. Esry, Phys. Rev. Lett. **95**, 073002 (2005).