Correlated electron and nuclear dynamics in strong field photoionization of H^+_2

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Correlated electron and nuclear dynamics in strong field photoionization of H_2^+

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Synopsis We present a theoretical study of H_2^+ ionization under strong femtosecond pulses by using a method designed to extract correlated 2D photoelectron and proton kinetic energy spectra. There appear two different ionization mechanisms in which electrons and nuclei do not share the energy in the same way. Electrons produced in multiphoton ionization share part of their energy with the nuclei, leading to energy-conservation fringes in the 2D spectra. In contrast, tunneling electrons lead to fringes whose position does not depend on the proton kinetic energy. This suggests that the correlation between electron and nuclear dynamics in strong field ionization is more complex than expected.

The interaction of atoms and molecules with intense infrared laser pulses has been the object of continuous research for more than two decades [1]. Strong fields can efficiently excite and ionize atoms and molecules. The electrons, which can be ejected following either multiphoton absorption or tunneling, can either directly reach the detector after having been repeatedly accelerated and decelerated by the field (direct electrons) or recollide with the ionic core within an optical cycle (rescattered electrons). In molecules, ideal experiments are those in which electrons and ions are detected in coincidence [2], since this provides information about how the energy is shared between them [3].

Here we present a theoretical study of H_2^+ ionization under strong femtosecond pulses by using a method designed to extract correlated (2D) photoelectron and proton kinetic energy spectra. The time-dependent Schrödinger equation is solved numerically on a grid in a non-Born-Oppenheimer calculation which includes one electronic dimension along the laser polarization direction and nuclear motion. The 2D spectra are then obtained with an extension of the resolvent operator method [4] to molecules.

We observe that electrons produced in multiphoton ionization share part of their energy with the nuclei, an effect that shows up in the 2D spectra in the form of energy-conservation fringes. In contrast, tunneling electrons lead to fringes whose position does not depend on the proton kinetic energy [5]. At high intensity, the two processes coexist and the 2D plots show a very rich behavior.

Our results suggest that the correlation between electron and nuclear dynamics in strong field ionization is more complex than one would have anticipated.

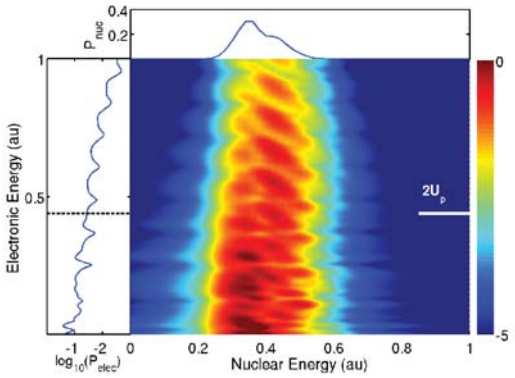

Figure 1. Correlated electron-nuclear kinetic energy spectrum for 400 nm and 4×10^{14} W/cm^2.

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