Photoionization yield of atomic hydrogen using intense few-cycle pulses

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Synopsis

We present experimentally measured photoionization yields of atomic hydrogen as a function of laser intensity for few-cycle laser pulses. Comparison of data with exact ab-initio simulations produce better agreement than analytical theories and enable accurate intensity calibration.

The interaction of intense few-cycle infrared laser pulses with matter is the fundamental process at the heart of attosecond and strong-field science \cite{1}. The complex, highly nonlinear dynamics that occur in the regime of few-cycle laser pulses necessitate accurate theoretical simulations in order to retrieve useful physical measurements and provide a sensible physical interpretation of the experimental data.

Strong-field ionization experiments involving atomic hydrogen (H) have been previously performed \cite{2,3}, however agreement with theory was predominately qualitative. Building on our earlier work, which obtained quantitative agreement at the 10\% level between simulations and measurements of photoelectron spectra in H \cite{4}, we now extend this scheme to measurements of the total photoionization yield.

The experimental apparatus consists of a few-cycle laser pulse interacting with an H beam. Our commercial “Femtolaser Compact Pro” laser produces linearly polarized, 6.0 fs, 800 nm central wavelength, \(\sim 150\) \(\mu\)J light pulses at a repetition rate of 1 kHz. The H beam is created by collisional dissociation of H\(_2\) in a radio-frequency discharge powered by a helical resonator. An off-axis parabolic mirror is used to focus the laser beam into the H beam, near the entrance to a \(\sim 10\) cm field-free time-of-flight mass spectrometer. We measure the H ion yield as a function of laser intensity for two different focal spot sizes of \(\sim 45\) \(\mu\)m and \(\sim 75\) \(\mu\)m.

Our data (Figure 1) have been fit to results from direct integration of the non-relativistic time-dependent Schrödinger equation (TDSE), and to results from the commonly used analytical tunneling theory of Ammosov-Delone-Krainov (ADK) \cite{6}. The figure illustrates a failure of the simpler model in describing the accurate ionization for even the simplest atomic system. Fitting the H yield with ab-initio theory is a simple method of accurately obtaining the intensity dependent yield for any other species present in the experiment.

![Figure 1](image)

**Figure 1.** Measured H yield (points) as a function of laser intensity with 6 fs pulses with a focal spot of \(\sim 45\)\(\mu\)m (a), and \(\sim 75\)\(\mu\)m (b). Fits to the TDSE simulations (solid line) \cite{5} has been used to calibrate the intensity scale. Corresponding predictions for the ADK simulations (dashed lines) are plotted alongside for comparison.

References


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