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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 [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 [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 [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, ~150 μJ 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 ~10cm 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 ~45 μm and ~75 μm.

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) [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.

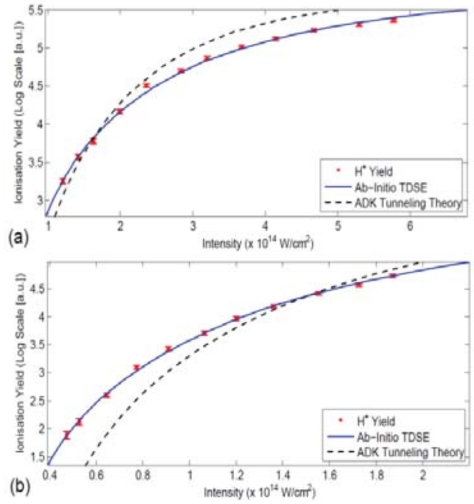

Figure 1. Measured H yield (points) as a function of laser intensity with 6 fs pulses with a focal spot of ~45μm (a), and ~75μm (b). Fits to the TDSE simulations (solid line) [5] has been used to calibrate the intensity scale. Corresponding predictions for the ADK simulations (dashed lines) are plotted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

References

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