Pulse-shape Effects on the Autler-townes Doublet in Strong-field Ionization of Atomic Hydrogen

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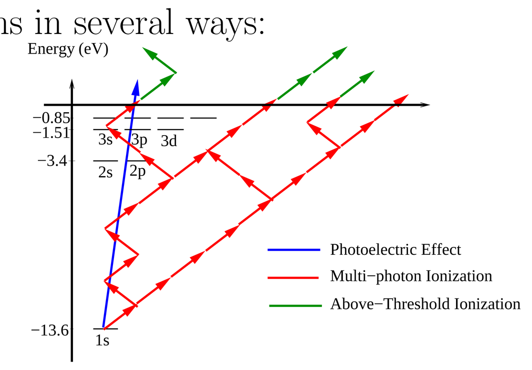
Abstract

We have applied a newly developed parallelized computer code to treat the ionization of atomic hydrogen by a strong laser pulse. In particular, we studied the effect of the pulse shape, as well as the peak intensity and the central wavelength, on the theoretical results for the so-called Autler-Townes doublet. While the splitting is well known for the quasi-static case, the *dynamic (time-dependent)* Stark effect studied here is much less understood. The strong dependence on the laser pulse found in this work is not only surprising, but may also be a limiting factor for calibrating absolute laser intensities.

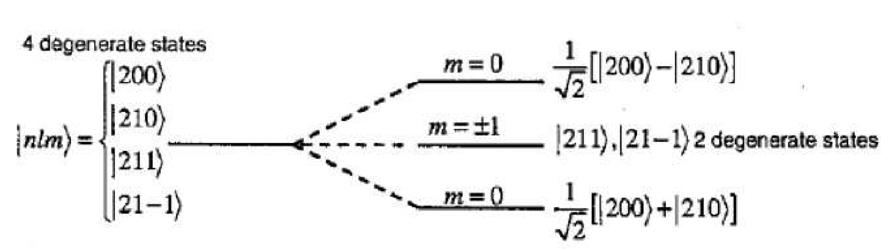
Introduction and Motivation

- Very short and intense laser pulses can be used to study the details of (valence) electron interactions in atoms and molecules.
- Typical laser intensities in this field range from 10^{12} to 10^{15} W/cm^2.
- **10^{14} W/cm^2 is a million billion times stronger than the radiation that the Earth receives from the Sun directly above us on a clear day.**
- Such intensities can rip electrons away from atoms in several ways:
  - **Multi-photon ionization**
  - **Above-threshold ionization**
  - **Field (tunnel) ionization**



The Stark Effect

- The Stark effect splits up the energetically degenerate (for fixed n) energy levels in atomic hydrogen by the interaction with a strong external electric field.
- The energy splitting is proportional to the electric field strength.
- For linearly polarized light, we can "see" only the two $m = 0$ levels.
- These levels form the "Autler-Townes" doublet in the energy spectrum of the ejected electron.
- We investigate this doublet in two-photon ionization, where the central frequency of the laser is tuned in such a way that it either hits (0.375 a.u. $= 10.2$ eV) or just misses (0.350 a.u.) the $1s \to 2s, 2p$ resonance transition as as stepping stone.
- Also, **we vary the splitting by ramping on/off the pulse.**



Plots

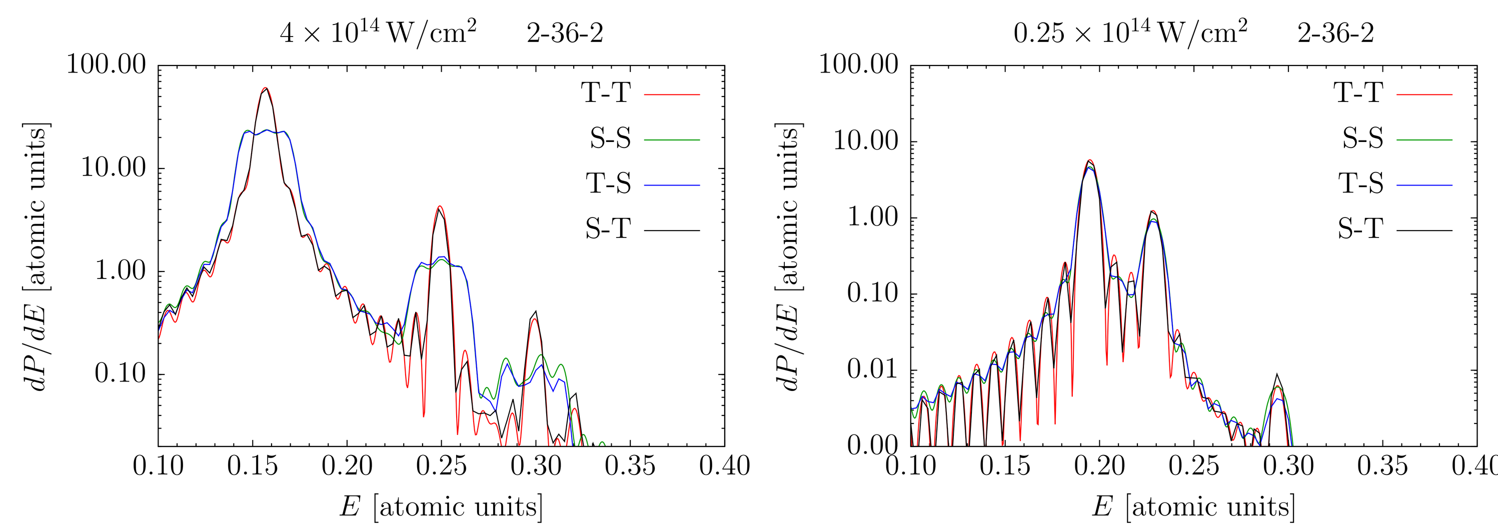


Fig. 1: LEFT: **0.350 AU** frequency plot with highest intensity RIGHT: **0.350 AU** frequency plot with lowest intensity

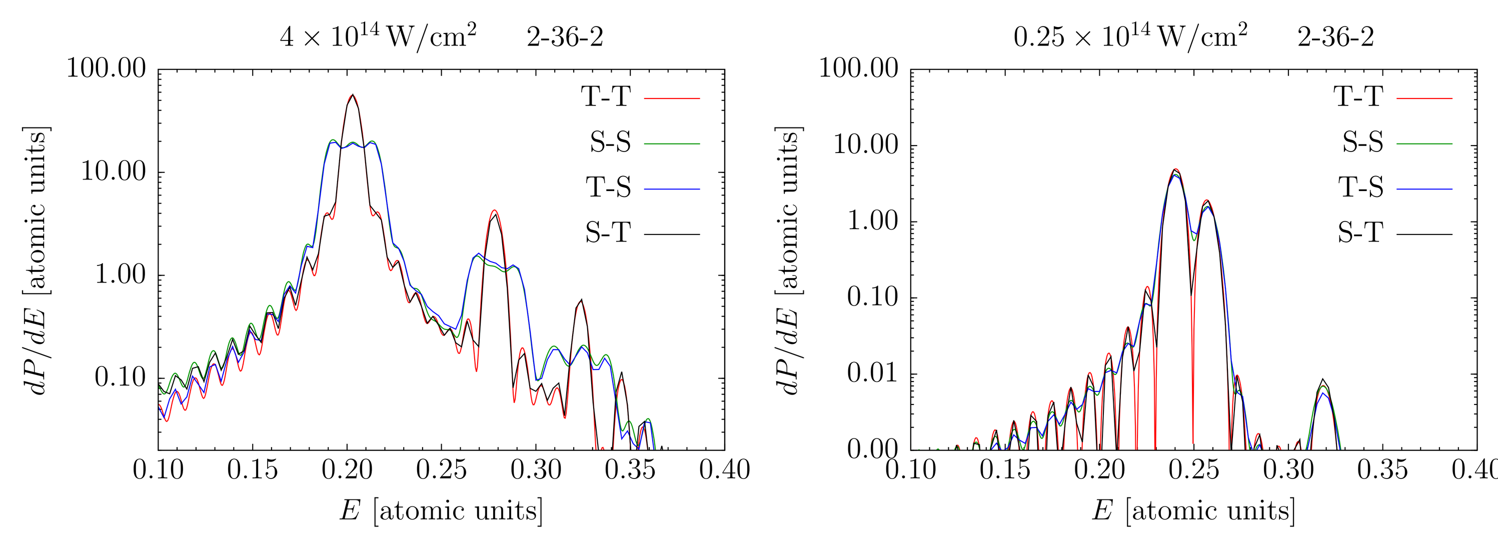


Fig. 2: LEFT: **0.375 AU** frequency plot with highest intensity RIGHT: **0.375 AU** frequency plot with lowest intensity

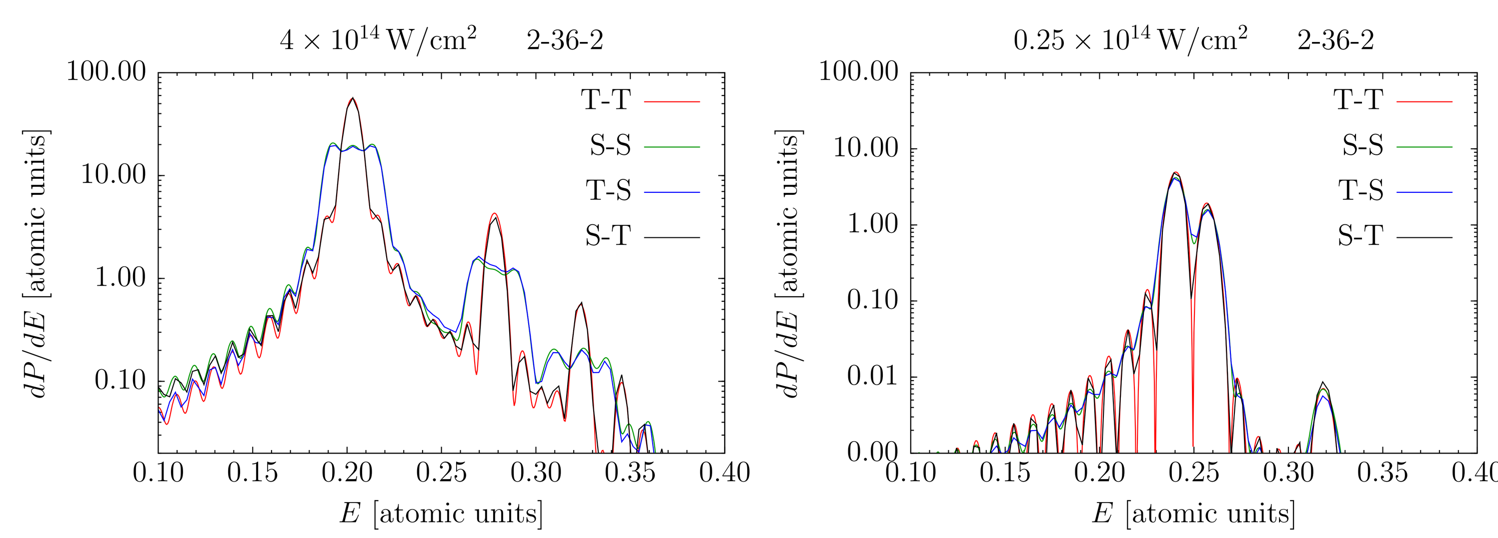


Fig. 3: LEFT: **0.375 AU** frequency plot with highest intensity RIGHT: **0.375 AU** frequency plot with lowest intensity

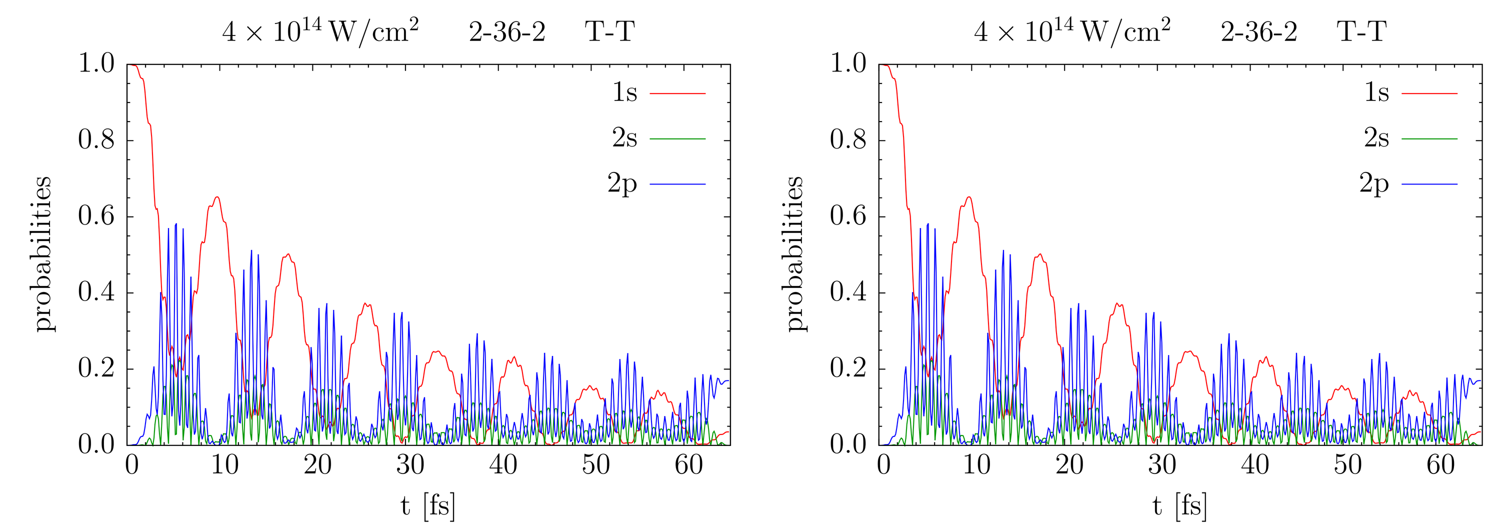


Fig. 4: LEFT: **0.350 AU** frequency RIGHT: **0.350 AU** frequency

- **Logarithmic time complexity** when sufficiently scaled. Time to completion depends on the maximum depth of the file system (i.e. most nested directory or file).
- Degenerates to linear time complexity in the worst case (same as Tree-walk).

Our Test Case

Results and Discussion

References