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

John Emmons, Sean Buczek, K. Bartschat, and A. N. Grum-Grzhimailo

Department of Physics and Astronomy, Drake University, Des Moines, IA 50311, USA

Institute of Nuclear Physics, Moscow State University, Moscow 119991, Russia

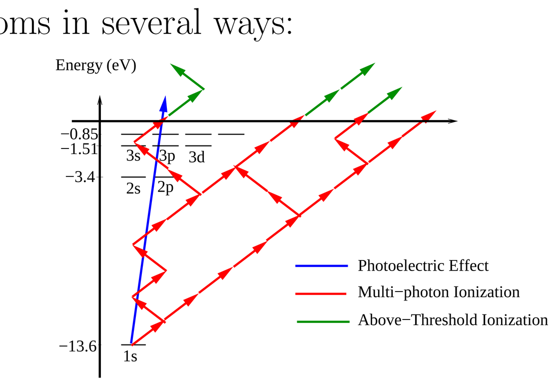
Research Supported by the United States National Science Foundation under PHY-1068140

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.

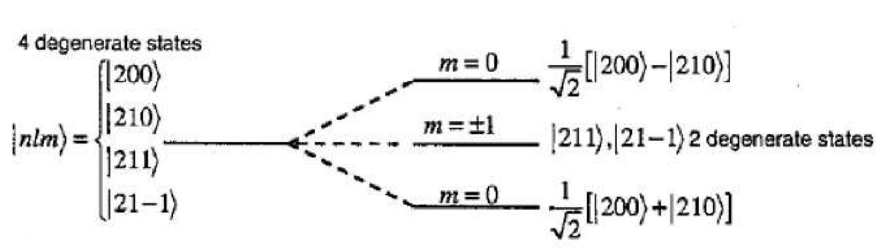
Introduction and Motivation

- 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

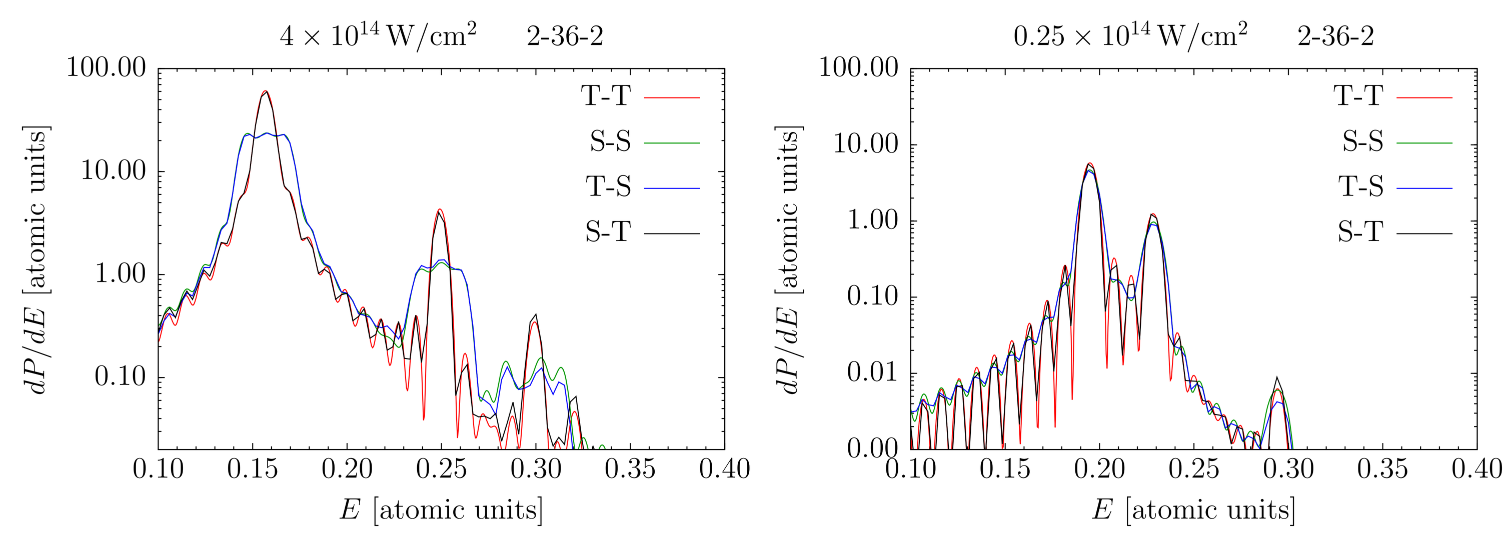


FIG. 1: LEFT: **0.350 AU** frequency plot with highest intensity RIGHT: **0.350 AU** frequency plot with lowest intensity

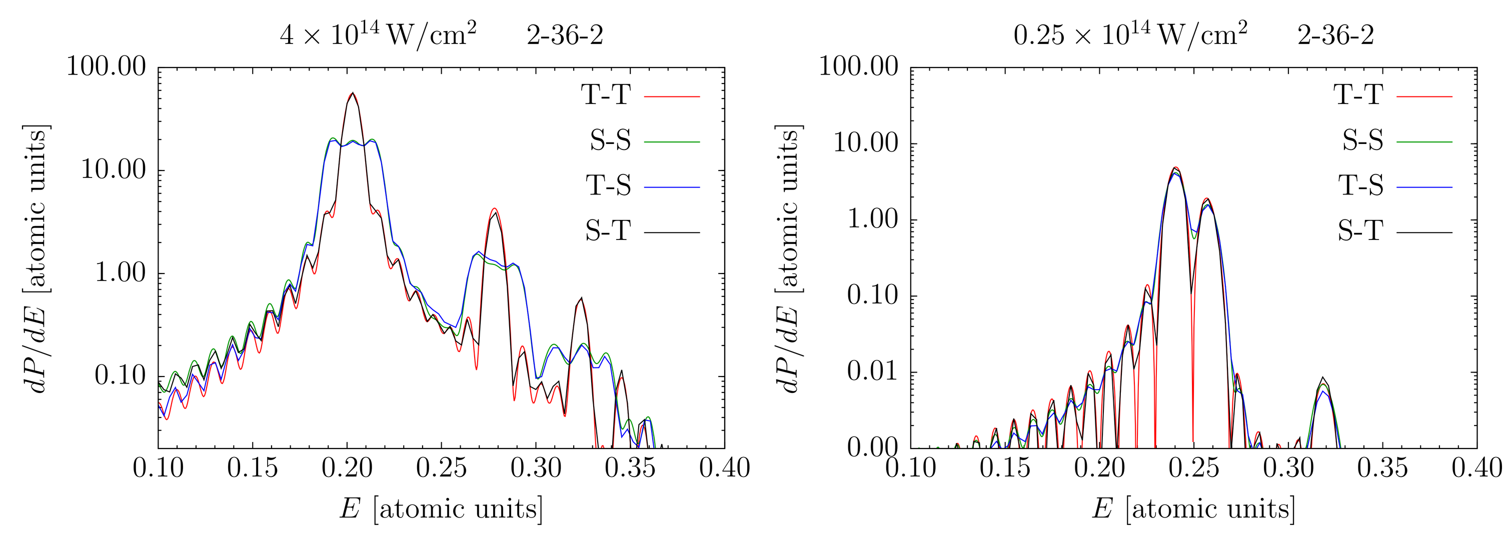
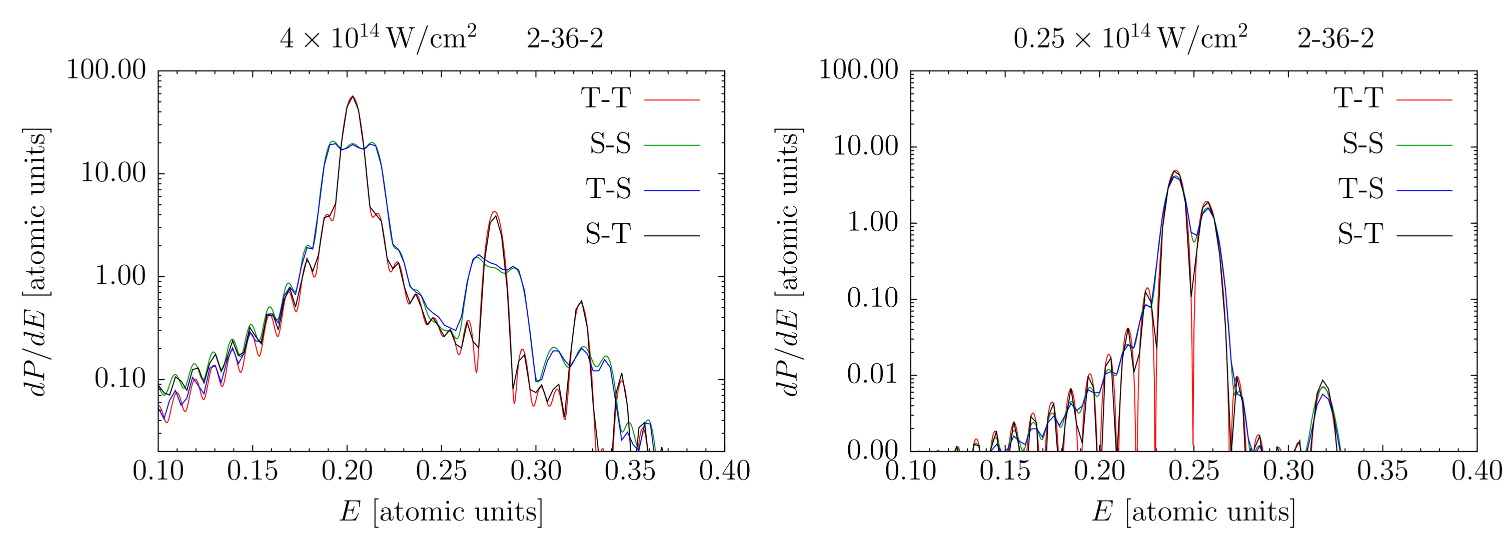
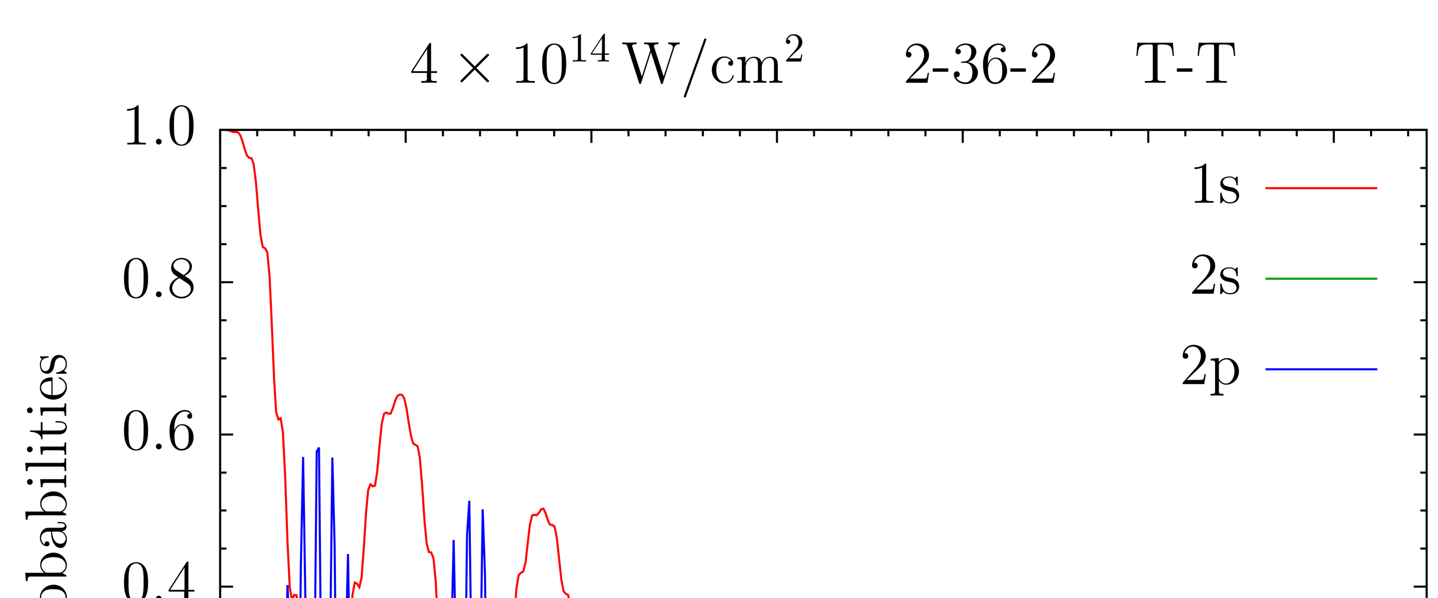
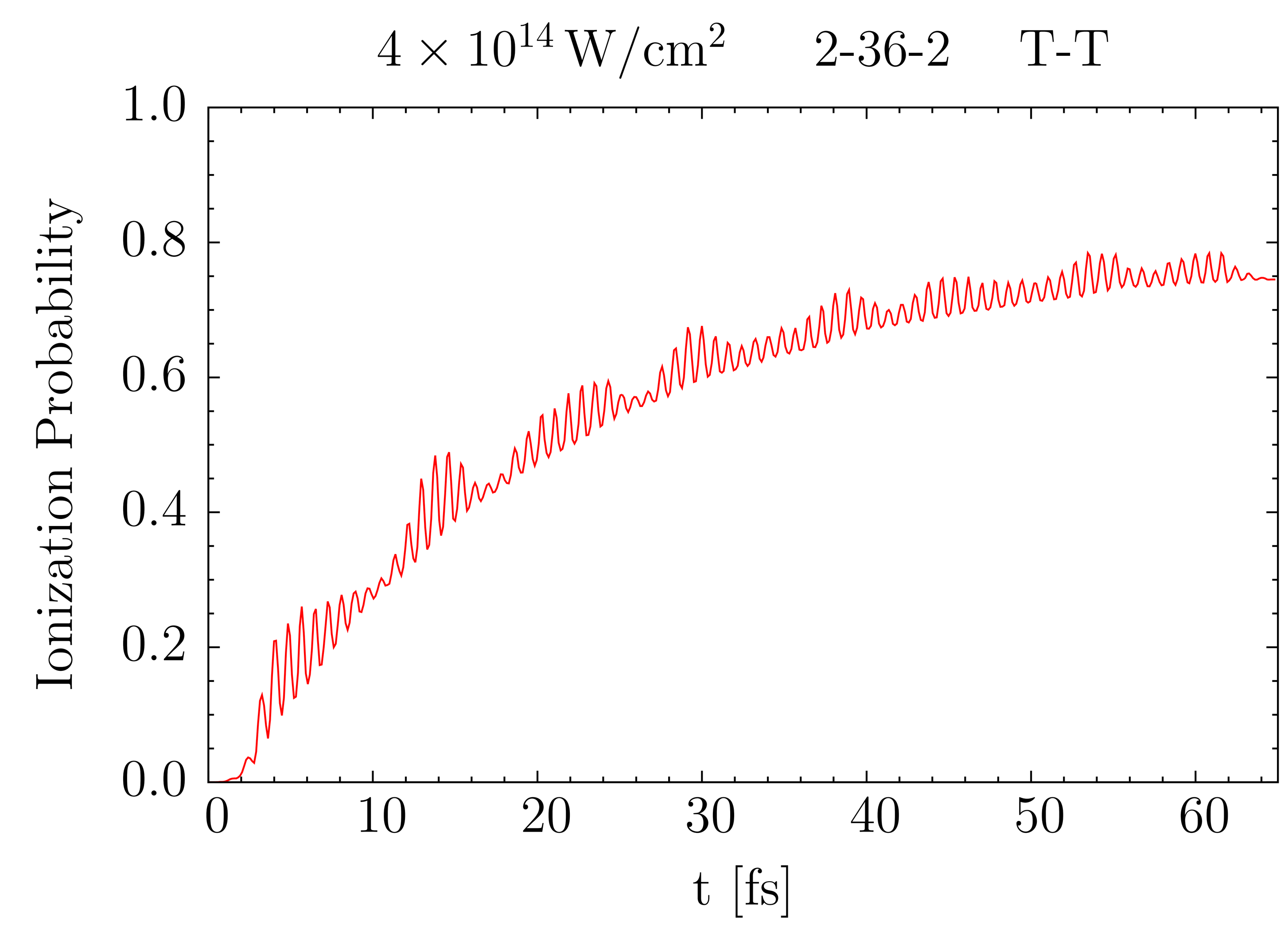


FIG. 2: LEFT: **0.375 AU** frequency plot with highest intensity RIGHT: **0.375 AU** frequency plot with lowest intensity







- **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