





# Pulse-shape Effects on the Autler-Townes Doublet in Strong-Field Ionization of Atomic Hydrogen

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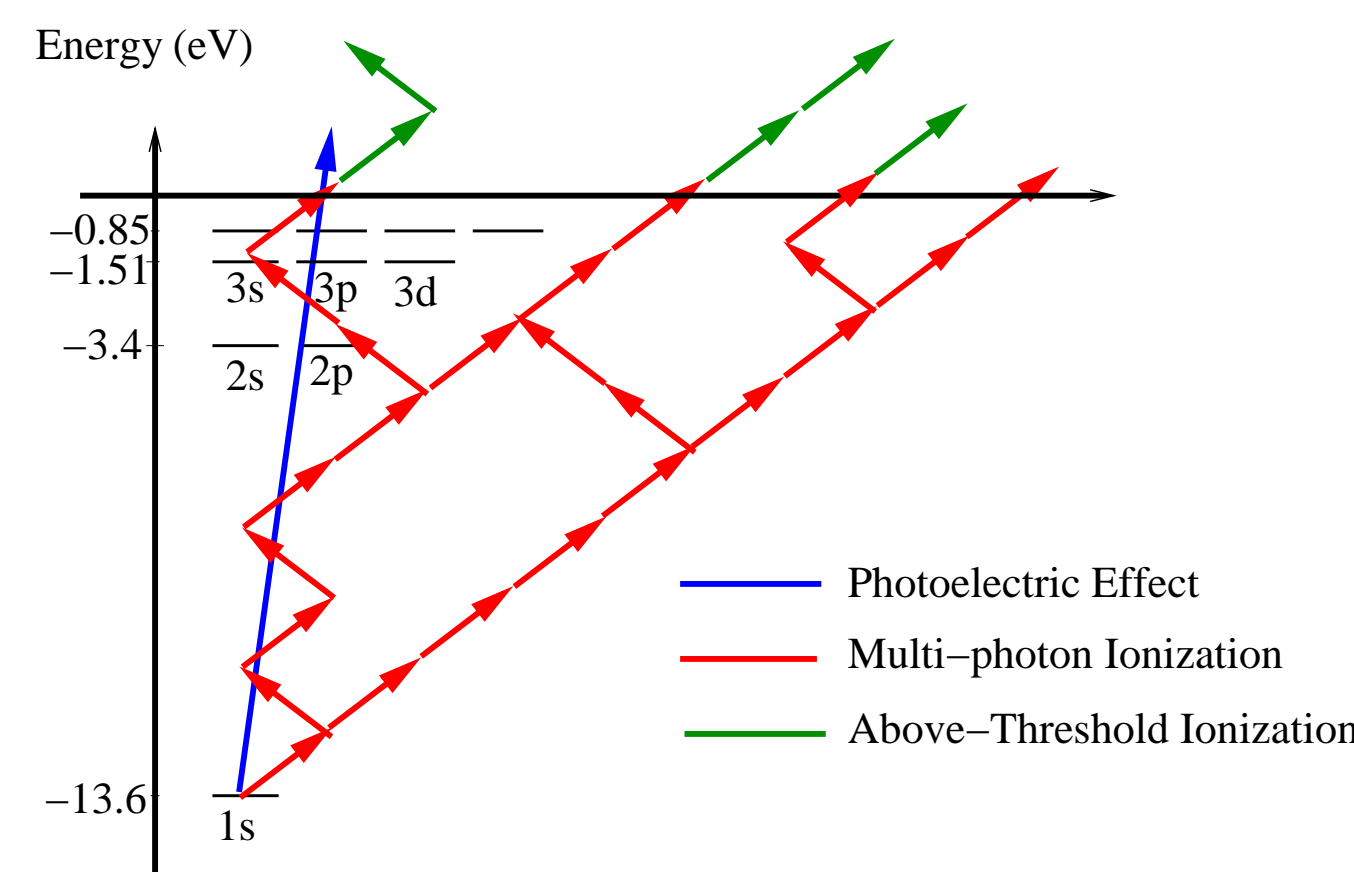
Research Supported by the United States National Science Foundation under PHY-1068140

## Abstract

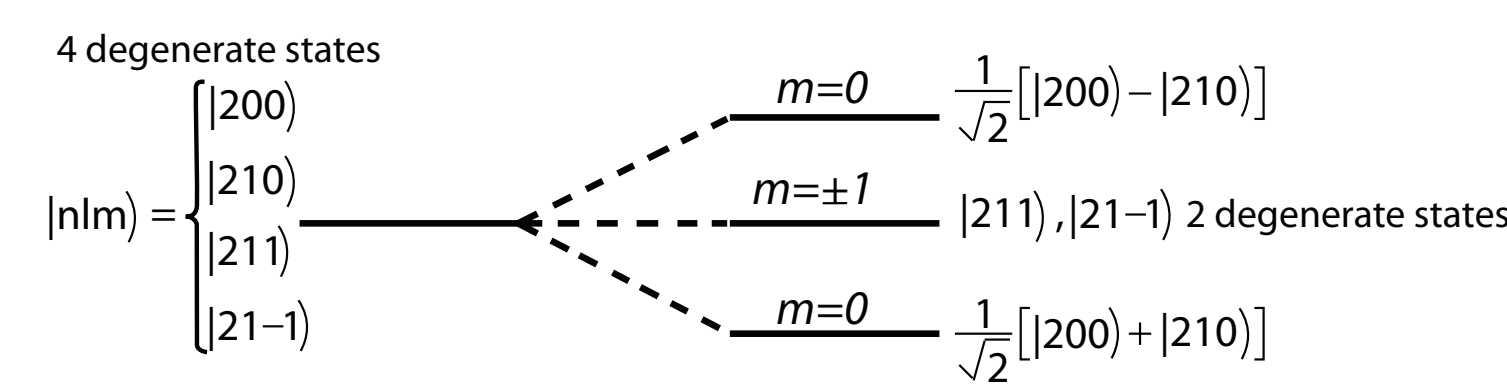
We have applied a newly developed parallelized computer code to treat the ionization of atomic hydrogen by a strong laser pulse. In particular, we studied the effect of the pulse shape, as well as the peak intensity and the central wavelength, on the theoretical results for the so-called Autler-Townes 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<sup>2</sup>.
- $10^{14}$  W/cm<sup>2</sup> 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. =  $9.5$  eV) the  $1s \rightarrow 2s, 2p$  resonance transition as as stepping stone.
- Also, we **vary the splitting by ramping on/off the pulse.**

## Numerical Method

- We start with the **Time-Dependent Schrödinger Equation**

$$\hat{H}\Psi = i\frac{\partial}{\partial t}\Psi \quad (1)$$

- In the **Length Form** of the electric dipole operator,

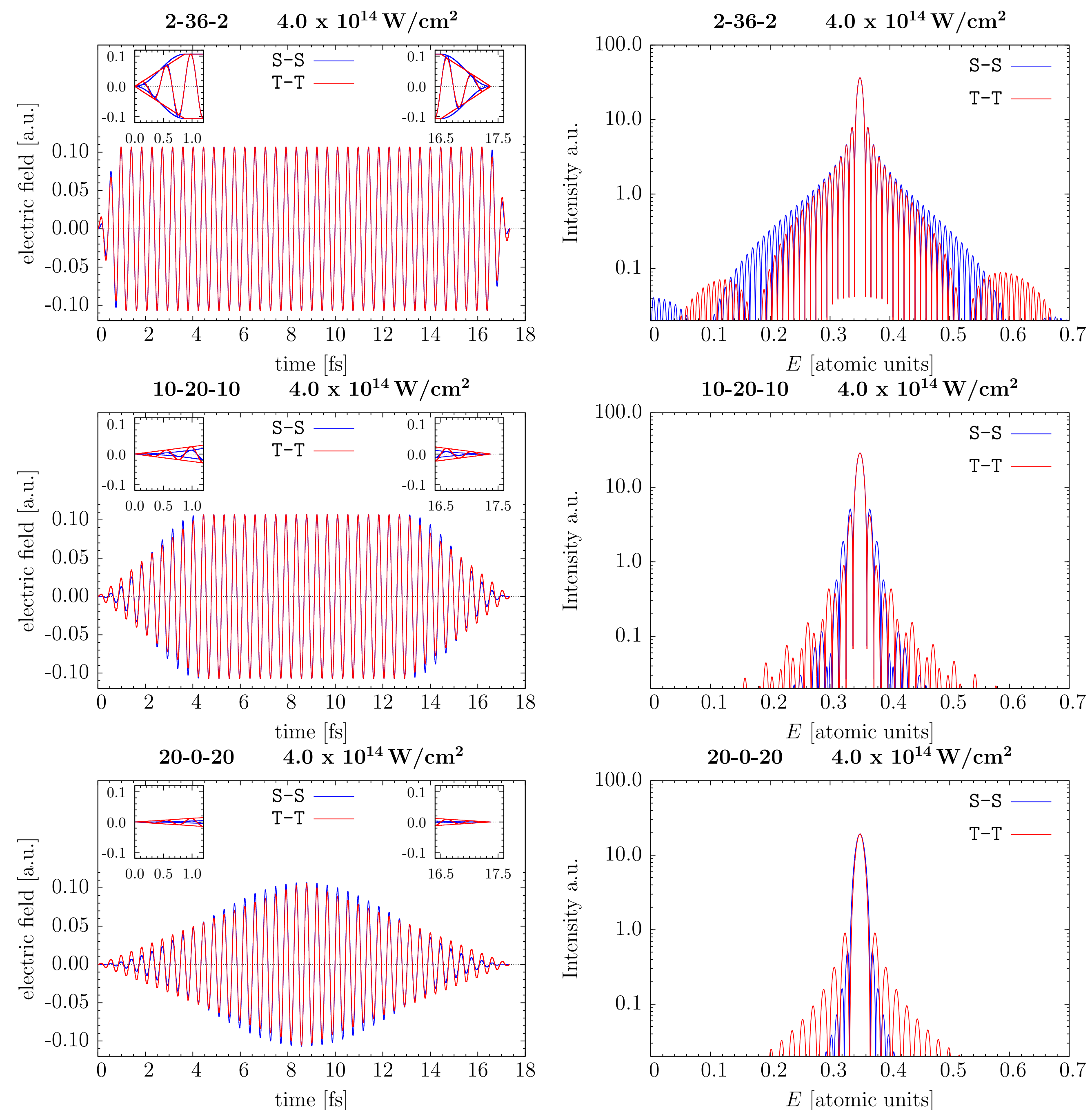
$$\hat{H} = -\frac{1}{2}\nabla^2 - \frac{1}{r} + r\cos(\vartheta)E(t) \quad (2)$$

- We propagate the initial wavefunction  $\Psi(\mathbf{r}, t=0)$  in time using **Finite Differences**.
- We use the **Crank-Nicolson Approximation**

$$\Psi(\mathbf{r}, t + \Delta t) \approx \frac{1 - i\hat{H}\Delta t/2}{1 + i\hat{H}\Delta t/2}\Psi(\mathbf{r}, t) \quad (3)$$

- This is an **implicit** method that allows for large timesteps.

## The Field



## Conclusions

## Results

