High Harmonic Generation in Laser Plasma Interaction

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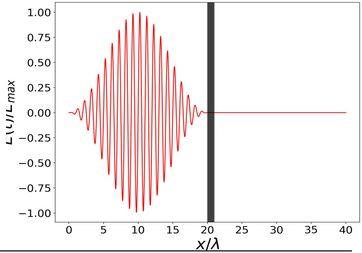
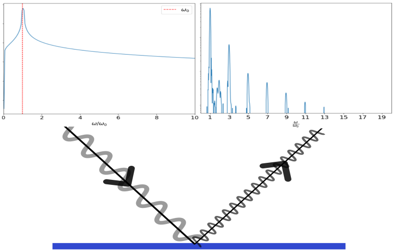
Introduction

Ultra high light intensity interactions with matter provide an opportunity to investigate new physical phenomena that have yet to be explored or have been only minimally explored in laboratory settings.

- Intensity of $10^{23}\ W/cm^2$ has been reached experimentally.[1]
- QED at $I = 10^{25} W/cm^2$. Schwinger field at $I = 10^{29} W/cm^2$.[2]
- Plasma is overdense if $\omega < \omega_p$.
- Harmonics are generated by interaction of laser with overdense plasma.





[1] *Henri Vincenti* 10.1103/physrevlett.123.105001

[2] *Jin Woo Yoon et al* 10.1364/OPTICA.420520

Summary of Work Done in the Previous Semester

- Interaction of highly intense laser pulse with overdense and underdense plasma
- Change in effective critical density of plasma for relativistic laser pulse
- The oscillations of plasma surface.
  - Oscillations increases with increase in intensity
  - Surface oscillations have even harmonics
- Study of high harmonics generation in laser plasma interaction (normal incidence)
  - Only odd harmonics are generated
  - A resonance at $n_0/n_c = 4$ is observed
  - Increasing intensity and pulse duration increases number of harmonics
  - No effect due to envelopes

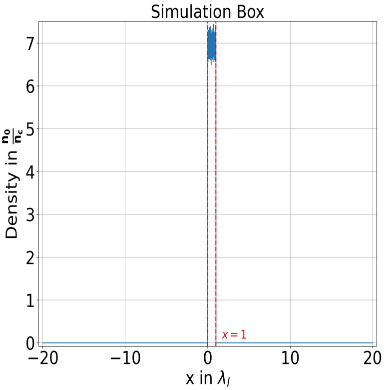
What Now?

- Effect of Super Gaussian (SG) envelopes on the generated high harmonics
- Oblique incident and p- and s-polarized laser
- Selection rules for p- and s-polarized laser

Simulation Details

We want to study the effect of super Gaussian envelope on the generated high harmonics. We performed some simulations in 1D3V. Here are some parameters:

- Particles per cell: 100
- Number of cells: 16000
- Wavelength $\lambda_l = 1\mu m$
- Pulse duration $= 20\tau$ ($\tau \approx 3.3fs$)
- Simulation time $= 40\tau$
- Intensity of laser for $a_0 = 0.5$ is $I = 3.425 \times 10^{17} W/cm^2$
- The density to critical density ratio is $n_0/n_c = 4$



We also performed simulations with p- and s-polarized laser incidence at oblique angle.

Oblique Incidence: Transformations

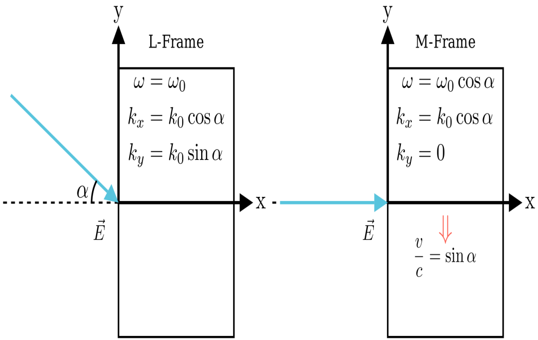
- We follow Bourdier[3] to make a transformation which lets us simulate oblique incidence in 1D.

For p-polarization

$$\mathbf{E}_L = E_0(-\sin\alpha\hat{x} + \cos\alpha\hat{y})$$
$$\mathbf{E}_M = E_0\cos\alpha\hat{y}$$
$$c\mathbf{B}_L = E_0\hat{z}$$
$$c\mathbf{B}_M = E_0\cos\alpha\hat{z}$$

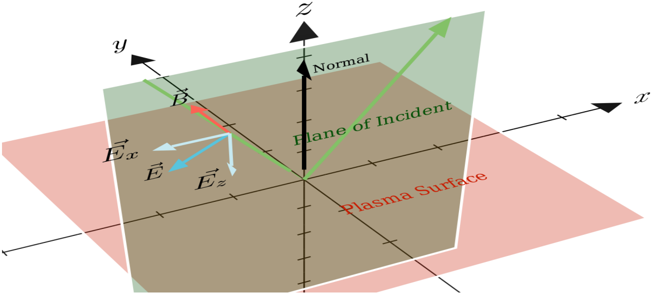
For s-polarization

$$\mathbf{E}_L = E_0\hat{z}$$
$$\mathbf{E}_M = E_0\cos\alpha\hat{z}$$
$$c\mathbf{B}_L = E_0(\sin\alpha\hat{x} - \cos\alpha\hat{y})$$
$$c\mathbf{B}_M = -E_0\cos\alpha\hat{y}$$



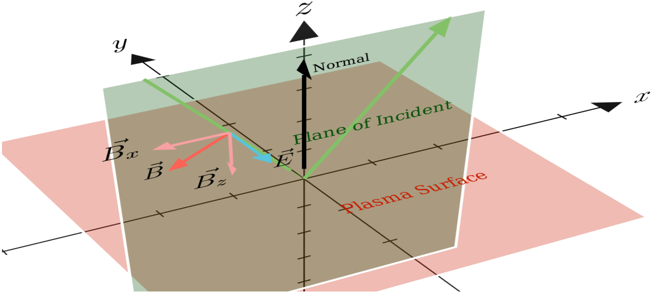
[3] *Bourdier,A.* 10 . 1063 / 1.864355

p- and s- Polarized Laser: Selection Rule



p-Polarization

p-Polarized: Even, Odd
s-Polarized: None



s-Polarization

p-Polarized: Even
s-Polarized: Odd

Results: SG Envelope

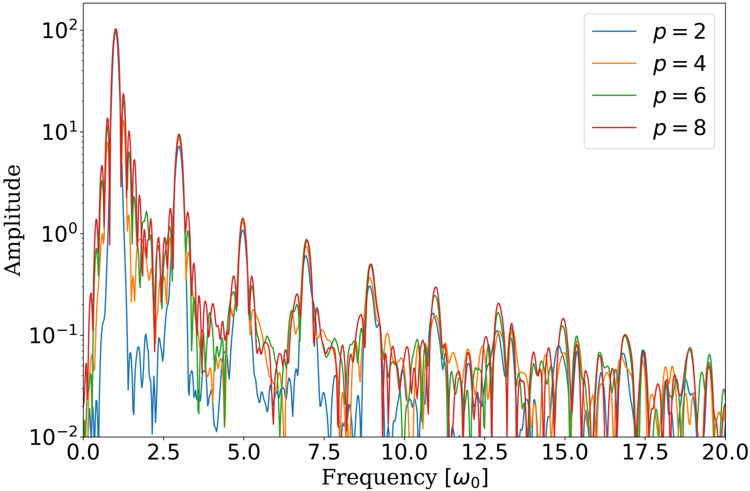


Figure: The spectrum of SG envelopes with power 2,4,6, and 8 is shown in a sigle plot. A small increase in the peak amplitude is observed with increasing power.

Results: p-Polarized Laser

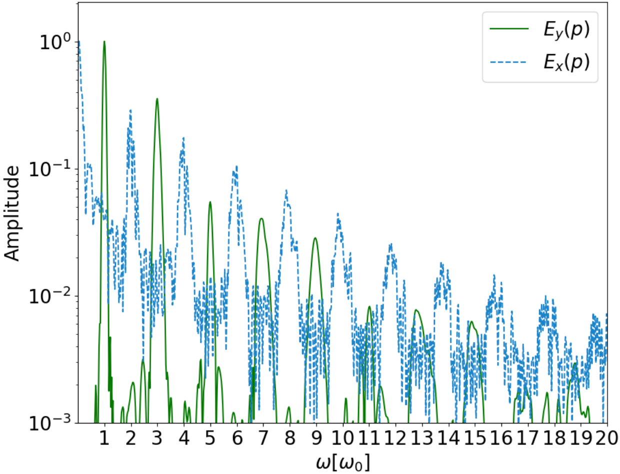


Figure: Spectrum of HHG for p-polarized light. Simulation parameters are $\alpha = \pi/4$, the density is $n_0 = 7n_c$ and $a_0 = 4$

Results: s-Polarized Laser

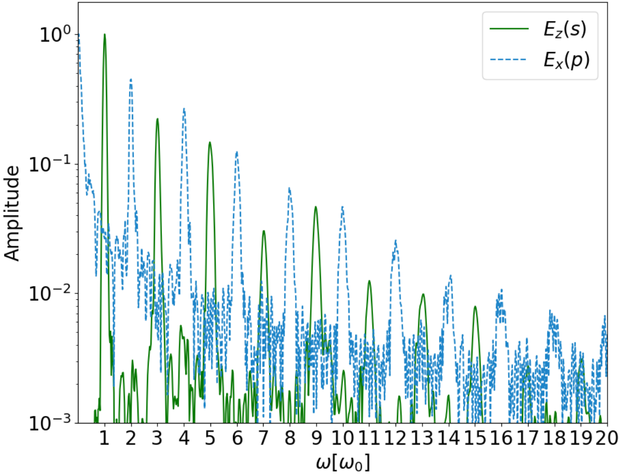


Figure: Spectrum of HHG for s-polarized light. Simulation parameters are $\alpha = \pi/4$, the density is $n_0 = 7n_c$ and $a_0 = 4$

Current Status and Future Plan of Work

Current Status

- A brief overview of HHG generation in laser plasma interaction
- SG envelopes have very little effect on the generated harmonics
- For p-polarized laser, even and odd p-polarized harmonics.
- For s-polarized laser, odd s-polarized harmonics and even p-polarized harmonics.

Future Plan of Work

- Study oblique incidence and polarization more rigorously.
- Do 2D simulations.
- Compare it with the 1D results.

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