High Harmonic Generation in Laser Plasma Interaction

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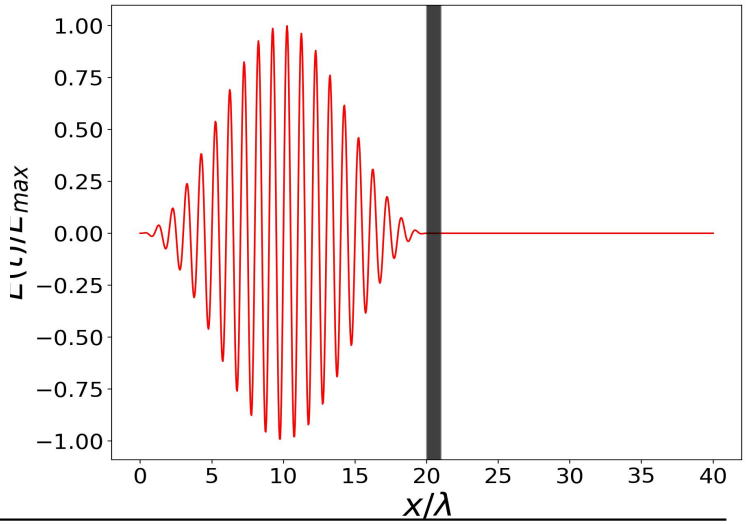
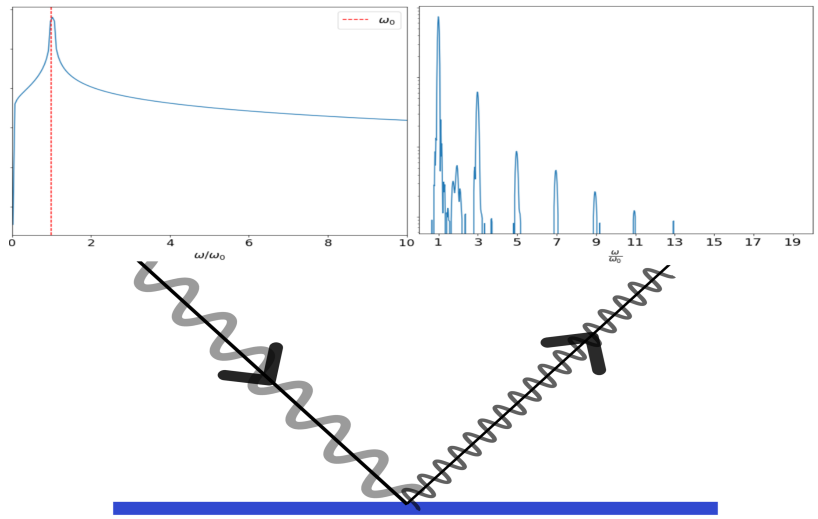
Introduction

Interaction of light with matter at ultra high light intensity gives access to novel physical regimes which are barely, if at all, explored in lab.

- 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.[3]





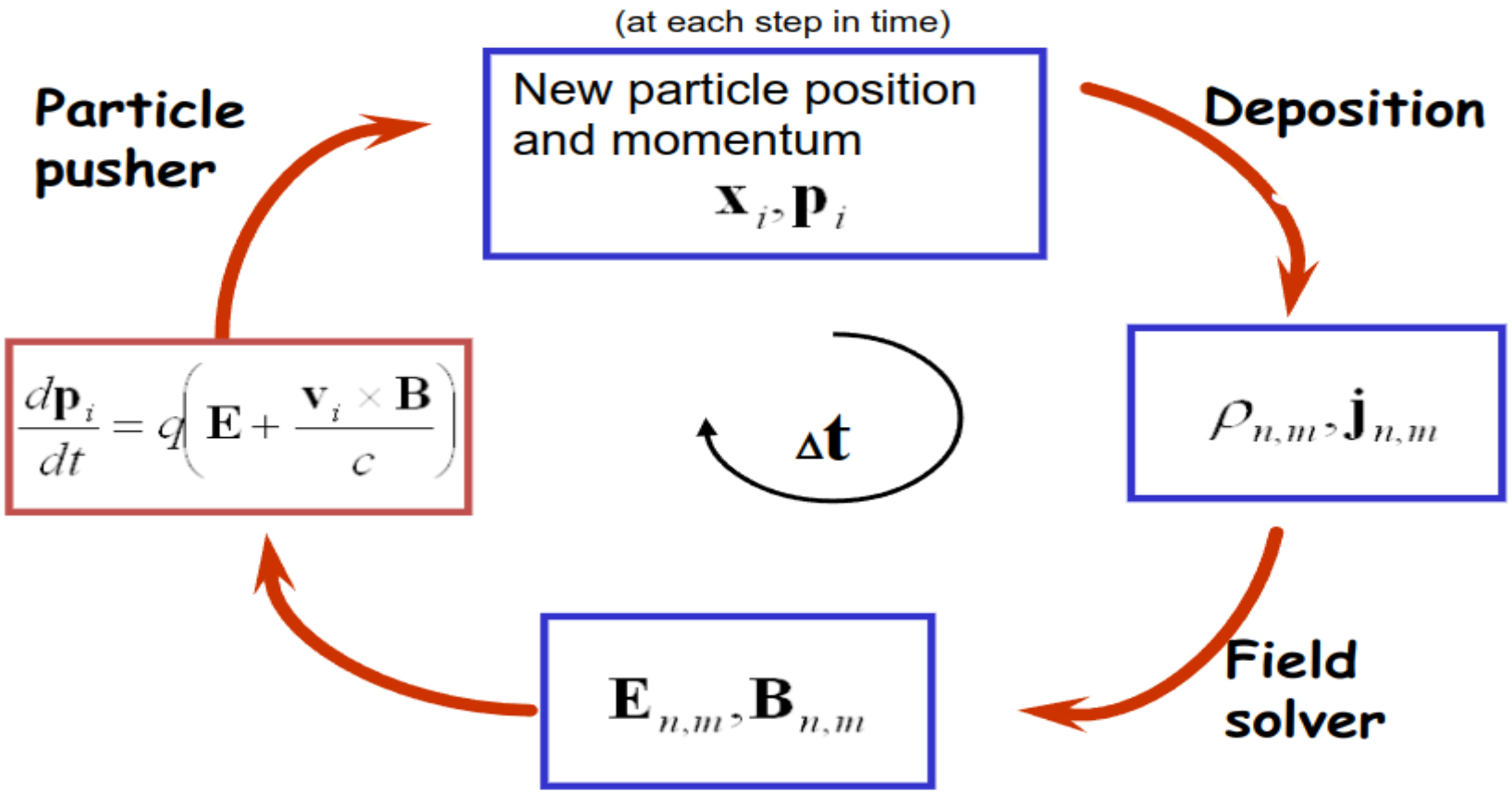
[1] *Henri Vincenti* 10.1103/physrevlett.123.105001

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

[3] *R. Lichters et al* 10 . 1063 / 1 . 871619

PIC Cycle

The simulation uses *EPOCH*[4] which implements a particle in cell algorithm.



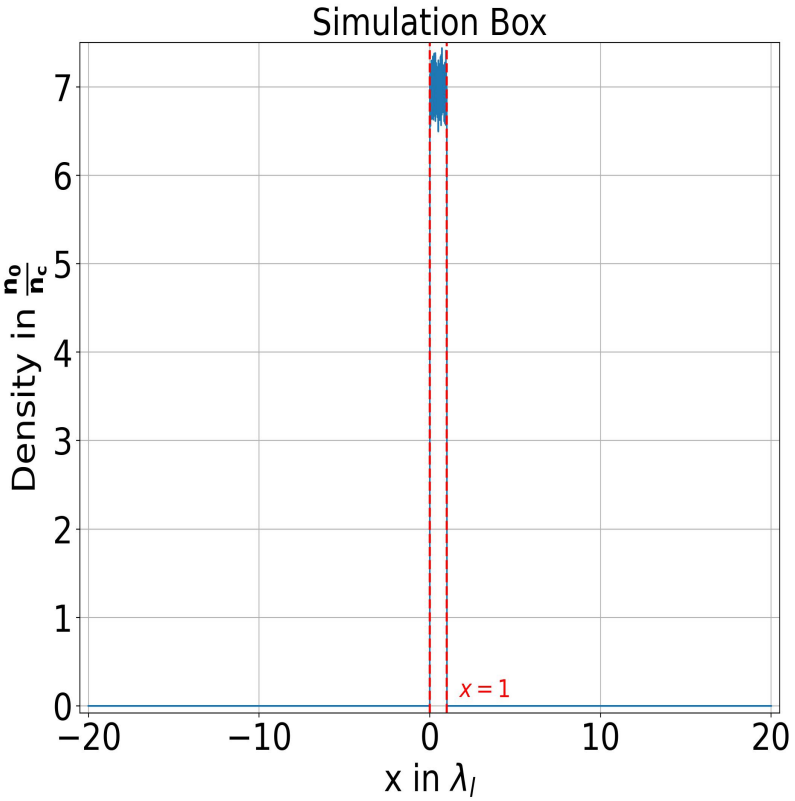
- Interaction of laser pulse with plasma
- Effect of relativistic laser pulse

[4] *T D Arber et al* 10.1088/0741- 3335/57/11/113001

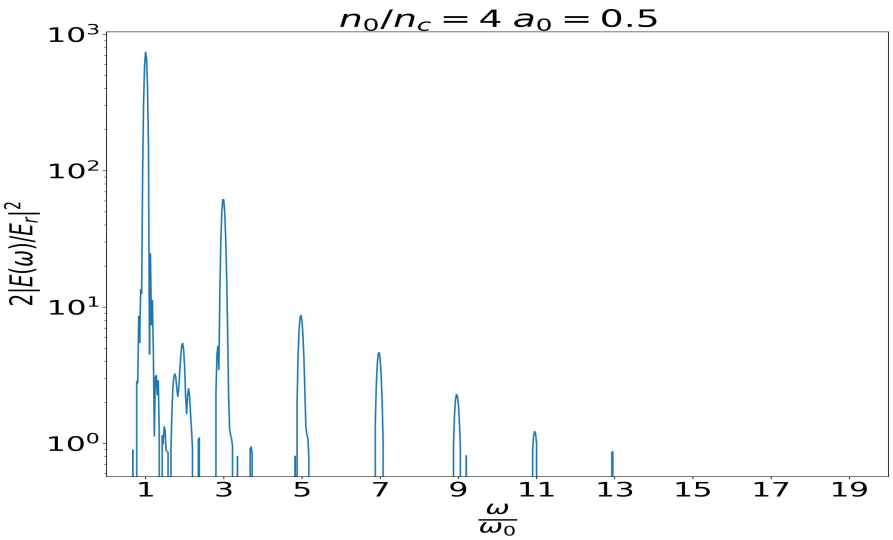
Simulation Details

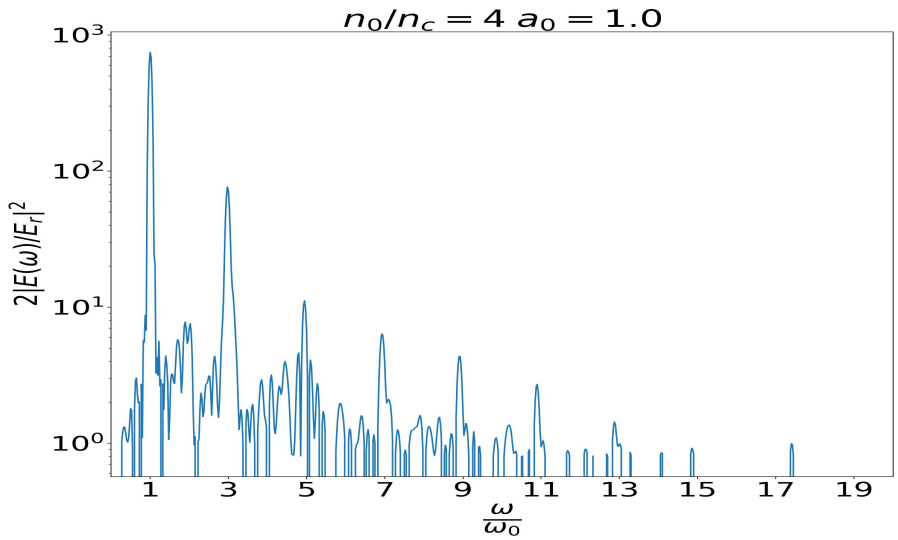
We want to study the effect of various plasma and laser parameters on the generated high harmonics. We performed some simulations in 1D3V. The parameters which are constant throughout the entire experimentation are these:

- Particles per cell: 100
- Number of cells: 16000
- Pulse duration $= 20\tau$ ($\tau \approx 3.3fs$)
- Simulation time $= 40\tau$
- Wavelength $\lambda_l = 1\mu m$
- Intensity of laser for $a_0 = 1$ is $I = 1.37 \times 10^{18} W/cm^2$
- Some parameters are varied to study their effect on the generated high harmonics.

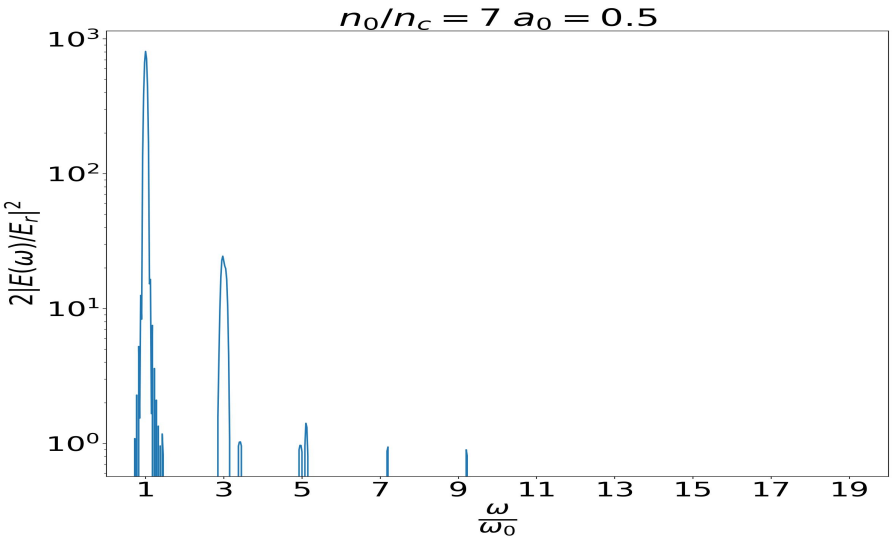


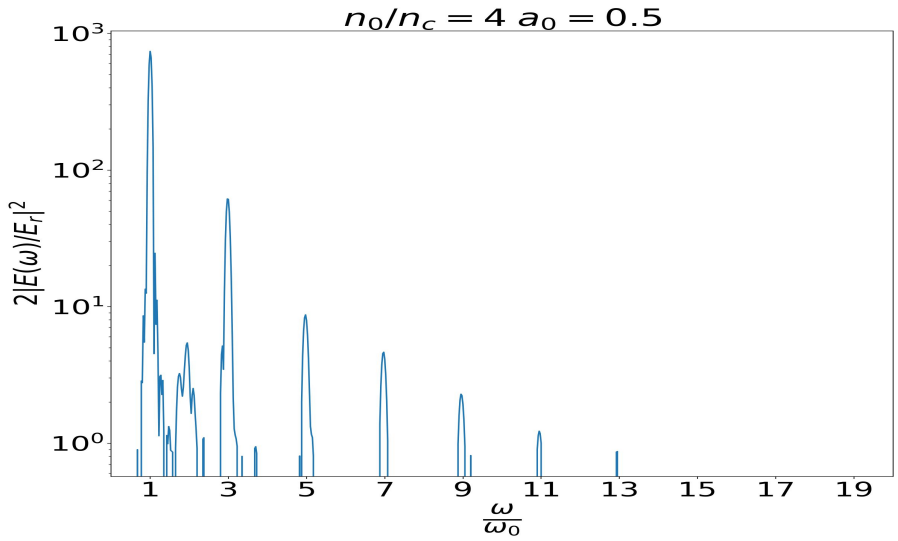
Effect of Laser Intensity





Effect of Plasma Density





Effect of Laser Envelope

1. Sine Sqaured

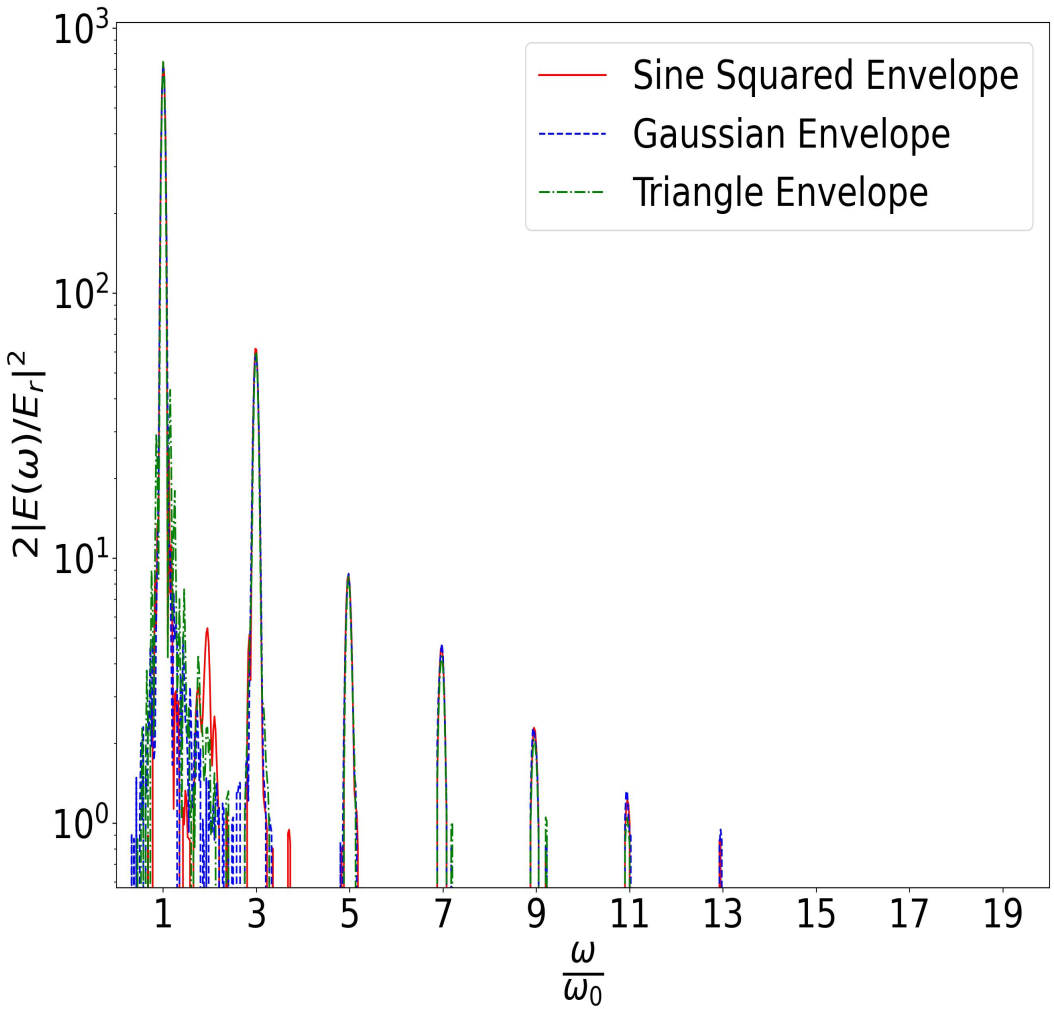
$$P(t) = \begin{cases} \sin^2(\pi t/T) \text{ for } 0 \leq t \leq T \\ 0 \quad \text{otherwise} \end{cases}$$

2. Gaussian

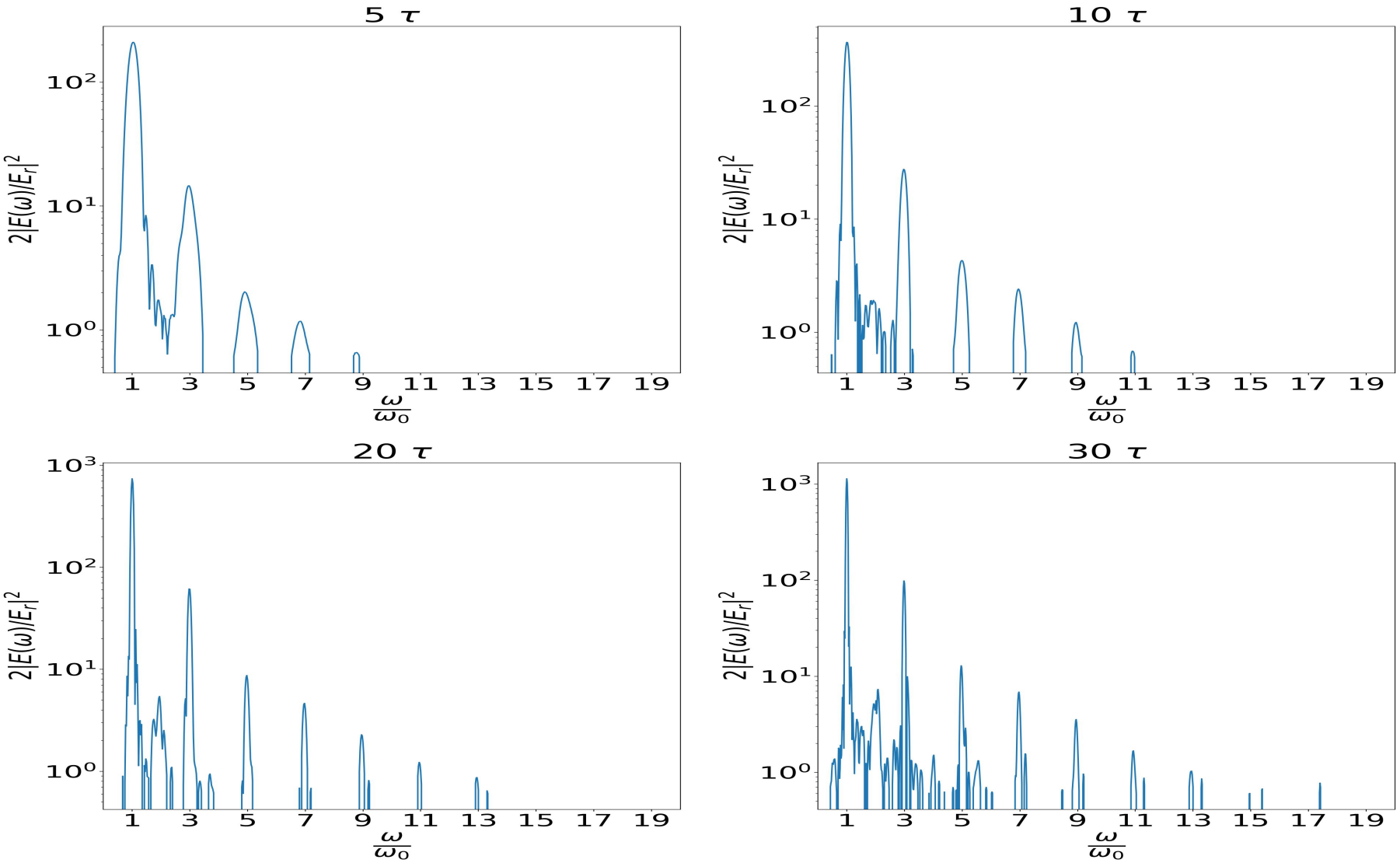
$$P(t) = \begin{cases} e^{\frac{-(t-T/2)^2}{2(0.2T)^2}} \text{ for } 0 \leq t \leq T \\ 0 \quad \text{otherwise} \end{cases}$$

3. Triangular

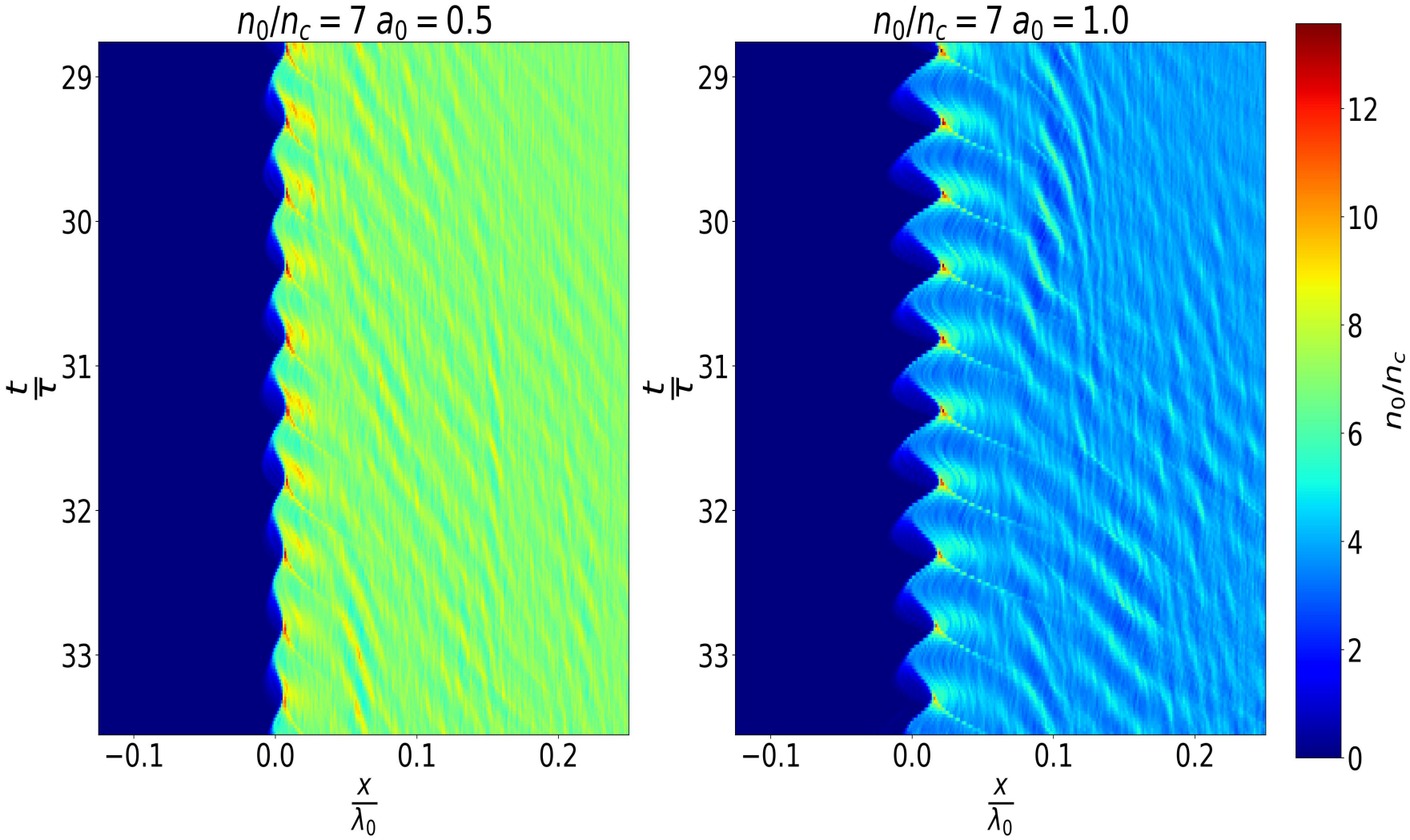
$$P(t) = 2\times \begin{cases} t/T \text{ for } 0 \leq t \leq T/2 \\ 1 - t/T \text{ for } T/2 \leq t \leq T \\ 0 \quad \text{otherwise} \end{cases}$$



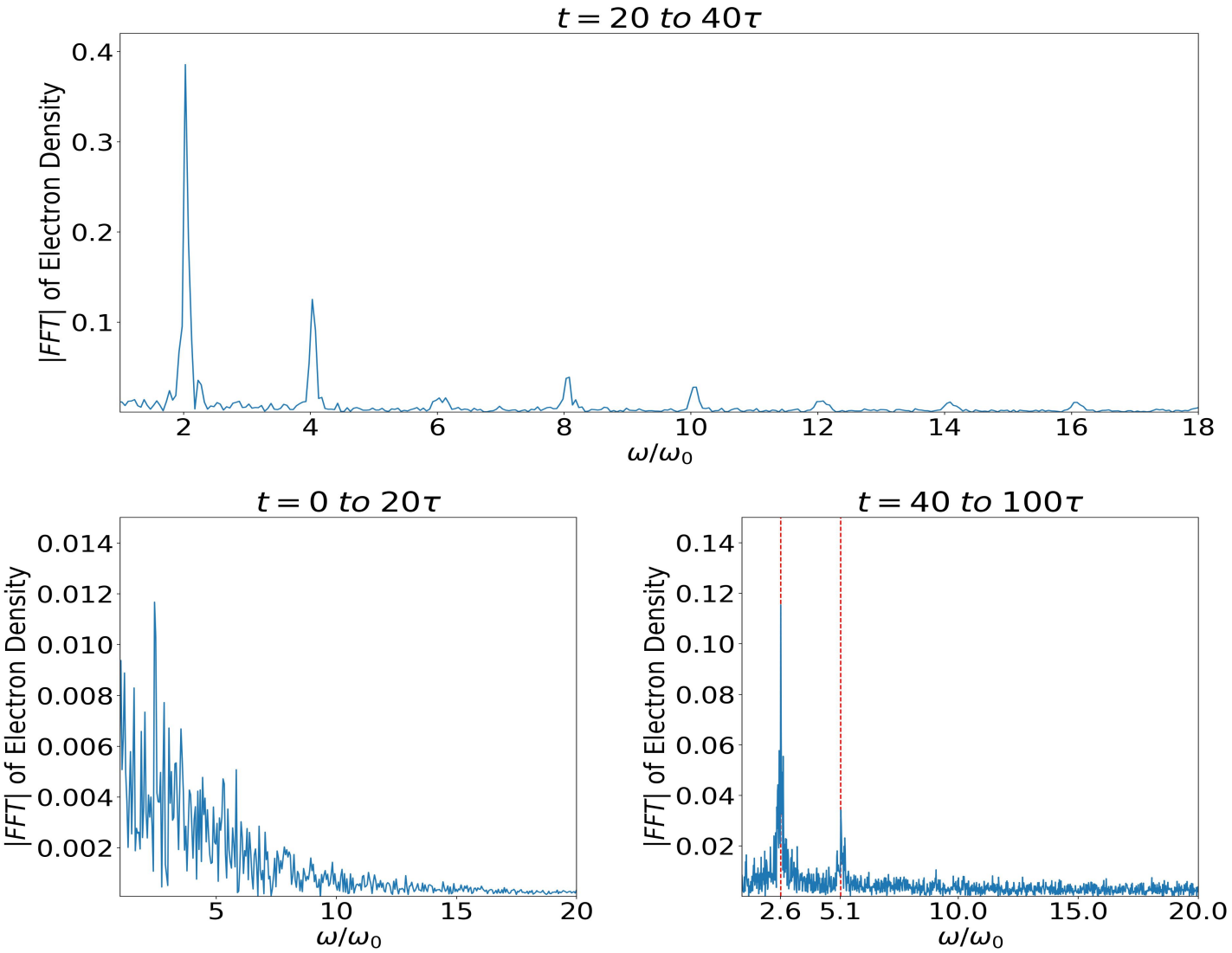
Effect of Pulse Length



Effect of Laser Intensity on Electron Oscillations



Frequency of the Oscillations



Current Status and Future Plan of Work

- Only odd harmonics are generated
- A resonance at $n_0/n_c = 4$ is also observed
- Increasing intensity and pulse duration increases number of harmonics
- No effect of the envelopes
- Even harmonics are generated in electron oscillations

Future plan of work is as follows:

- Effect of plasma density
- Oblique incidence
- Some more envelopes (Supergaussian, Laguere-Gaussian, etc.)
- Polarization