Interaction of Laser Pulse With Plasma

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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.[1]

- Intensity of laser in order of $10^{23}\ W/cm^{-2}$ has been reached experimentally.[2].
- QED effects starts acting at intensity above $10^{25} W/cm^{-2}$.
- Intensity level of $10^{29} W/cm^{-2}$ corresponds to the Schwinger field.

Here, we study the generation of high harmonics of the incident laser pulse by its interaction with overdense plasma.

- Plasma is overdense if its density is so high that it reflects the incident laser pulse.
- The em field of the incident laser pulse drives relativistic oscillations in the plasma electrons which results in the generation of high harmonics.
- Simulations are performed to study the effect of some plasma and laser parameters on high harmonics generation.
- Oscillations of the plasma surface is also studied.

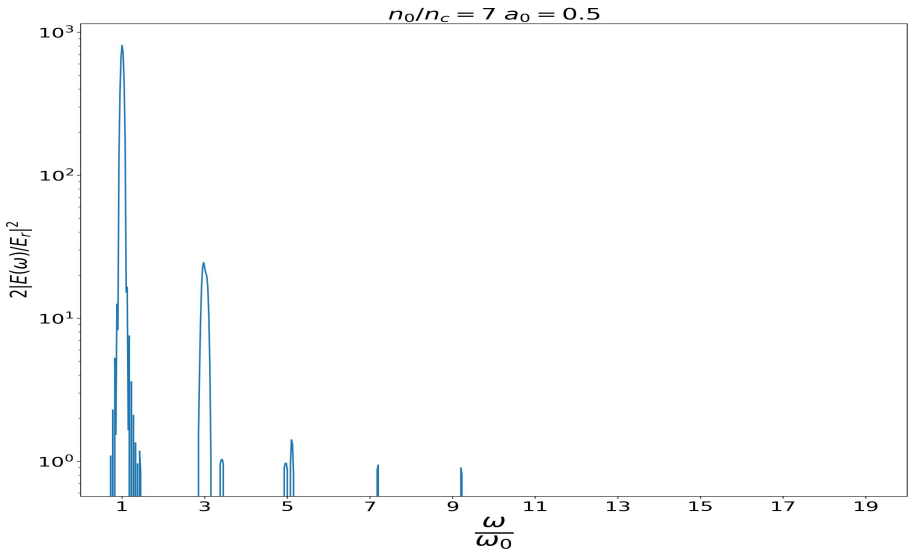
Simulation Parameters

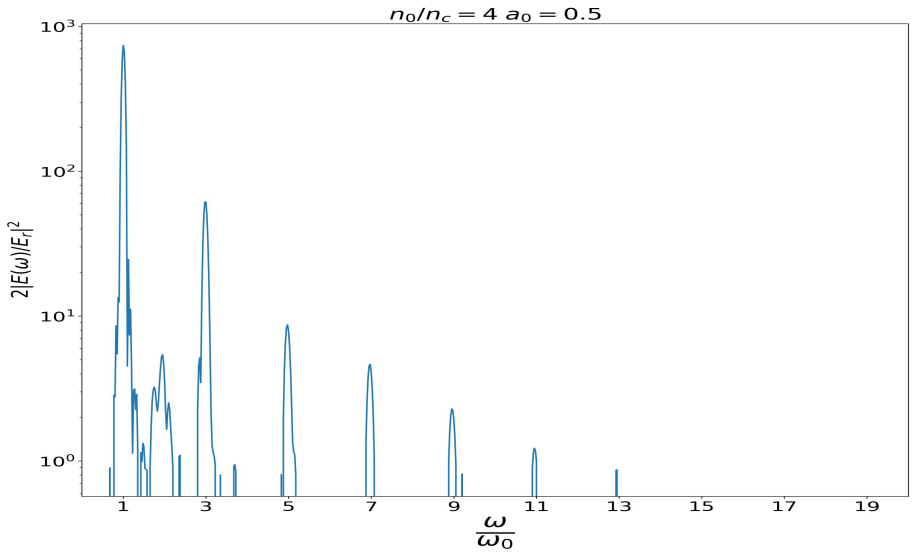
The simulation uses *EPOCH*, a parallised, second order and fully relativistic implementation of particle in cell algorithm.[3] The current simulation is performed in 1D3V only. We want to study the effect of various plasma and laser parameters on the generated high harmonics. The parameters which are constant throughout the entire experimentation are these:

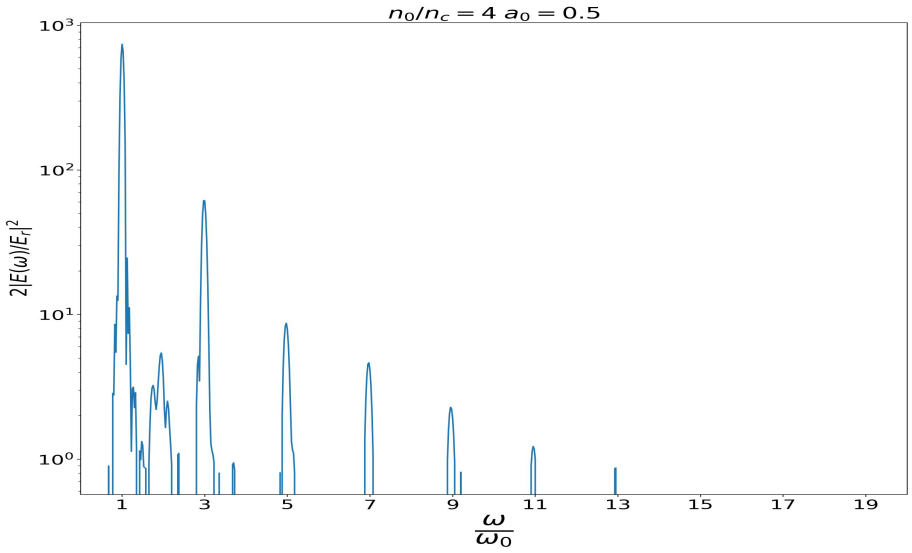
- The simulation box extends for $40\lambda_l$ (from $-20\lambda_l$ to $20\lambda_l$), $\lambda_l = 1\mu m$
- Number of cells is 16000 and the plasma is placed at $x = 0$ and with a thickess of λ_l. There are 100 particles per cell.
- Pulse duration is $T = 20\tau$ and simulation is run till $T_{end} = 40\tau$. τ is time period of laser pulse $\approx 3.3fs$

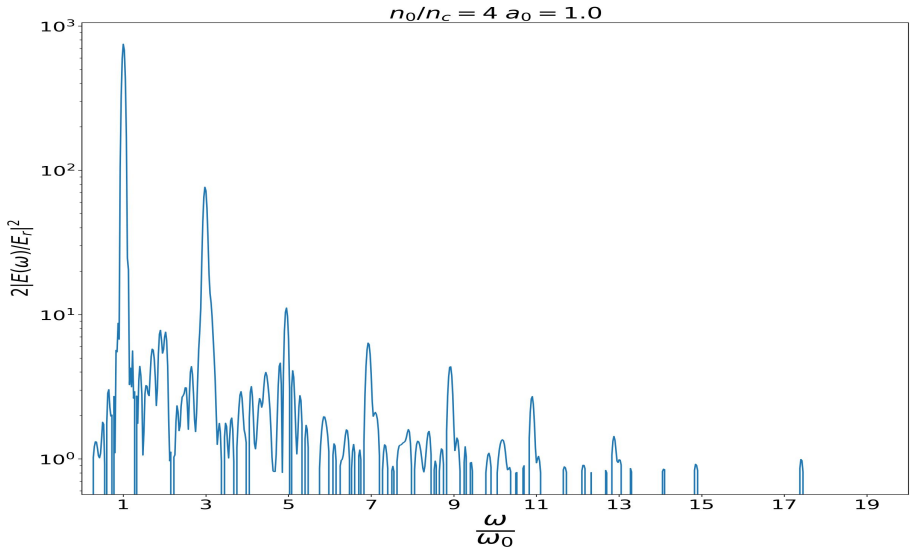
Some parameters are varied to study their effect on the generated high harmonics. These parameters and their effect on the harmonics are discussed in the next section.

Effect of Plasma Density and Laser Intensity









Effect of Laser Envelope

1. Sine Sqaured

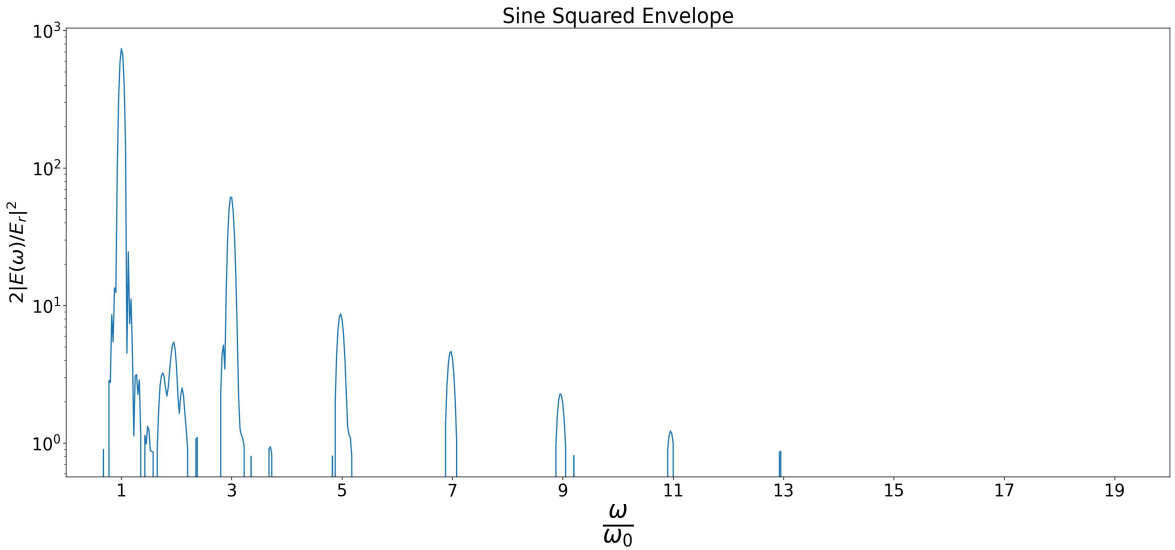
$$P(t) = \begin{cases} \sin^2(\pi t/T) \text{ for } 0 \leq t \leq T \\ 0 \quad \text{otherwise} \end{cases}$$

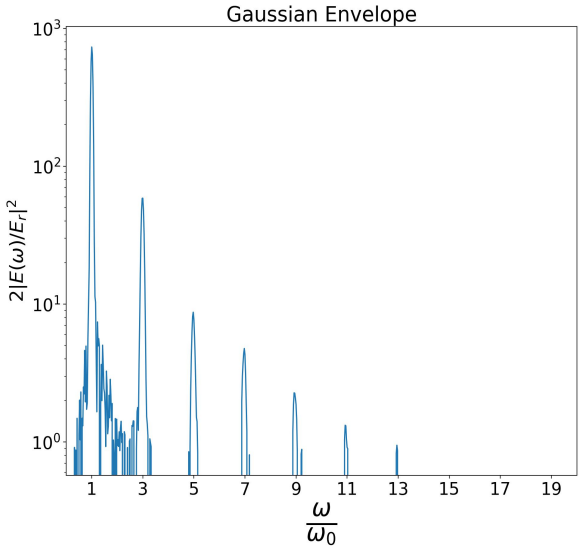
2. Gaussian

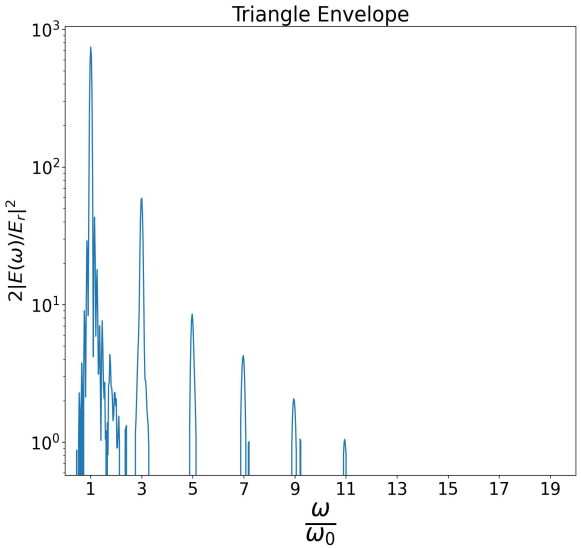
$$P(t) = \begin{cases} e^{\frac{-(t-T/2)^2}{2(0.2T)^2}} \text{ for } 0 \leq t \leq T \\ 0 \quad \text{otherwise} \end{cases}$$

3. Triangular

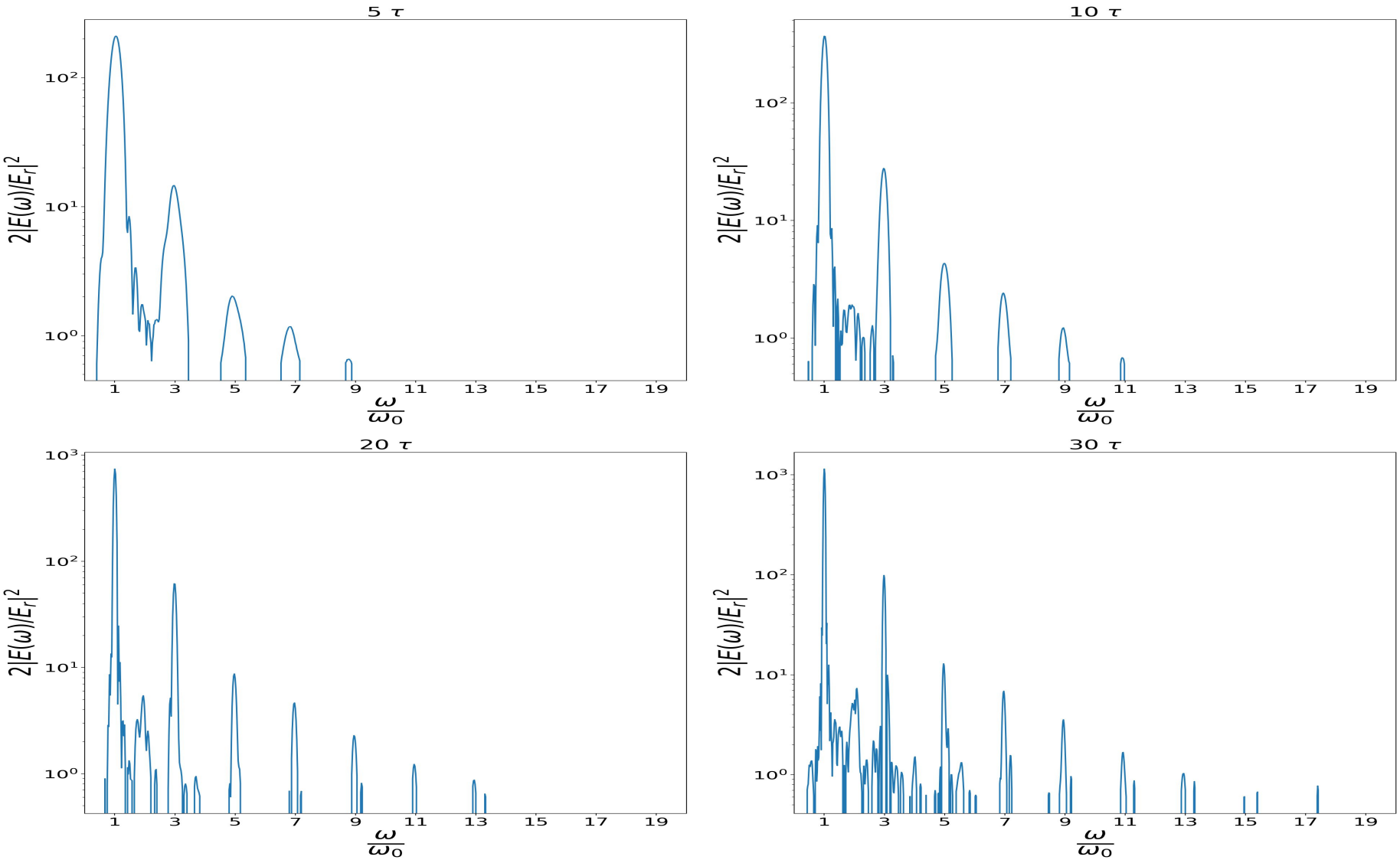
$$P(t) = 2\times \begin{cases} t/T \text{ for } 0 \leq t \leq T/2 \\ 1 - t/T \text{ for } T/2 \leq t \leq T \\ 0 \quad \text{otherwise} \end{cases}$$



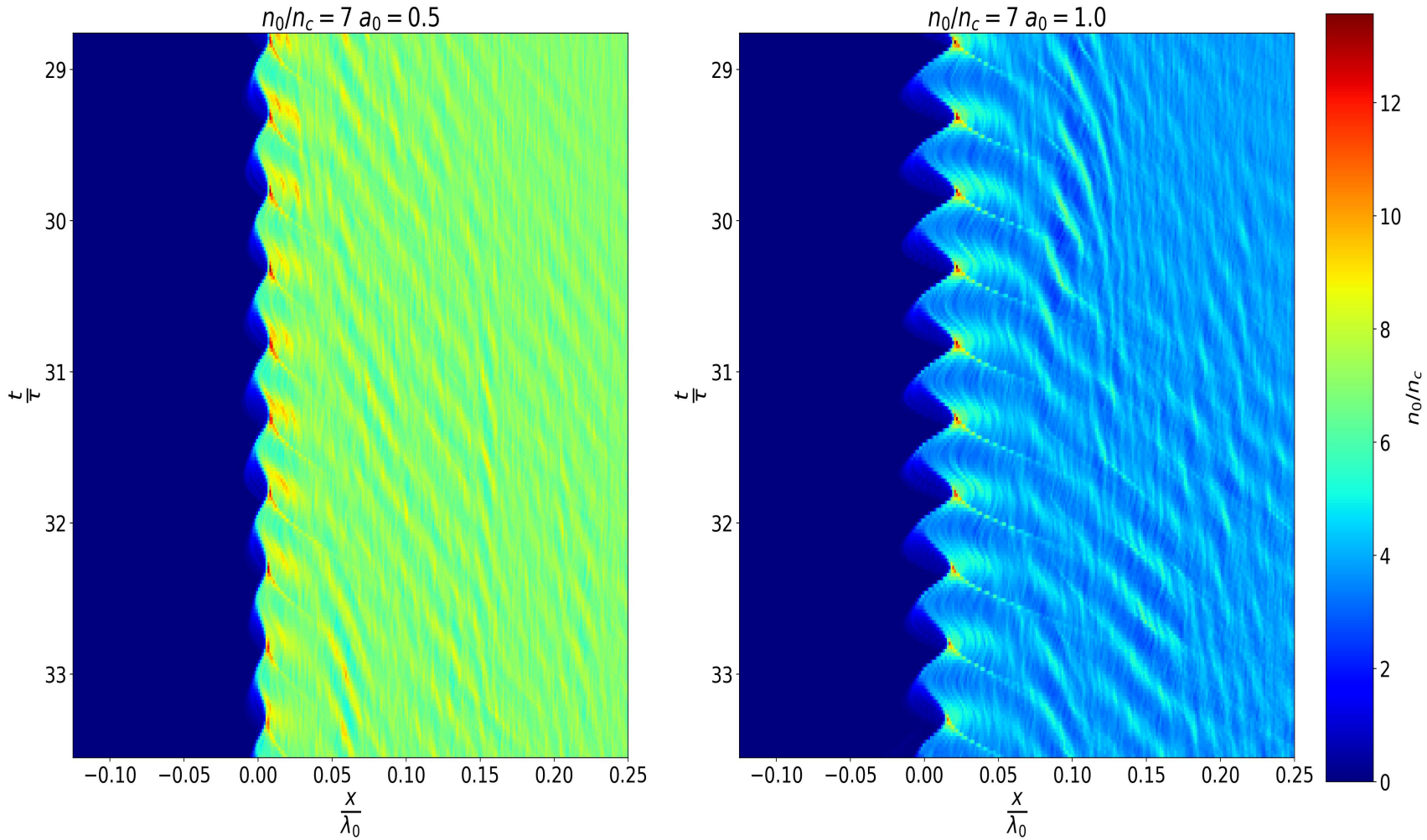




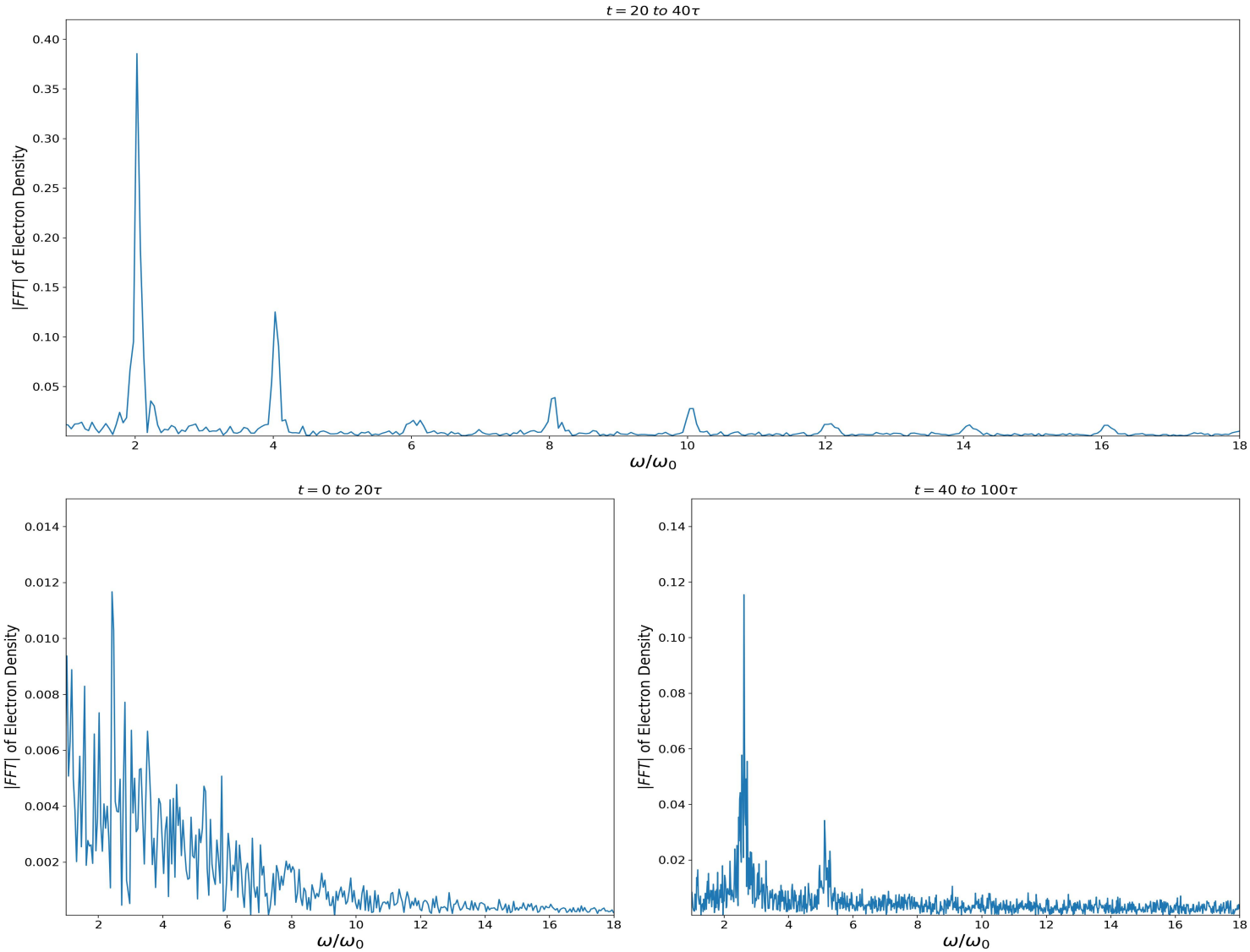
Effect of Pulse Length



Effect of Laser Intensity on Electron Oscillations



Frequency of Oscillations



Current Status and Future Plan of Work

The interaction of high intensity laser pulse with overdense plasma is investigated. During this, odd harmonics of the incident laser pulse is generated and the effect of variuos laser and plasma parameters on the hormonic generation is studied. Future plan of work is to study about the effects of some more parameters on the harmonics generation escpecially the effect of oblique incidence and different polarization of the laser pulse.

[1] Henri Vincenti. "Achieving Extreme Light Intensities using Optically Curved Relativistic Plasma Mirrors". In: *Physical Review Letters* 123.10 (Sept. 2019). DOI: 10.1103/physrevlett.123.105001. URL: https://doi.org/10.1103%2Fphysrevlett.123.105001.

[2] Jin Woo Yoon et al. "Realization of laser intensity over 1023 W/cm2". In: *Optica* 8.5 (May 2021), pp. 630–635. DOI: 10.1364/OPTICA.420520. URL: https://opg.optica.org/optica/abstract.cfm?URI=optica-8-5-630.

[3] T D Arber et al. "Contemporary particle-in-cell approach to laser-plasma modelling". In: *Plasma Physics and Controlled Fusion* 57.11 (Sept. 2015), p. 113001. DOI: 10.1088/0741-3335/57/11/113001. URL: https://dx.doi.org/10.1088/0741-3335/57/11/113001.