Plasma Accelerator Physics Term Project

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Laser Wakefield Acceleration Near the Critical Density

Abstract

Using EPOCH 1D electromagnetic particle-in-cell code, we will investigate the efficiency and energy scaling laws of Laser Wakefield Acceleration (LWFA) with respect to laser intensity and plasma density near the critical density.

Intro:

In conventional Laser Wakefield Acceleration (LWFA) a high intensity laser pulse with a pulse width of $\tau_L = \frac{1}{2}\lambda_p$ (resonant width) passes through an underdense plasma with a group velocity (v_g) and phase velocity (v_{ph}) near the speed of light ($v_g \approx v_{ph} \approx c$). This excites an electrostatic wake field behind the laser pulse. The electrostatic wake has a group velocity of zero ($v_{gw} = 0$) and a phase velocity near the speed of light ($v_{ph} \approx c$) because of the laser's group velocity. The phase velocities near the speed of light allow for the excited wakes to be coherent, long lasting, and stable from thermal instabilities. Electrons are then trapped in the wake and accelerated to high energies.

Until recently, it was thought that LWFA could only be stable in rarefied gas or highly underdense plasmas. Conventional LWFA has an energy scaling of:

$$\Delta E \propto \frac{a_0^2\, n_c}{n_e}$$

Where ΔE is the energy gain by the accelerated particle, $a_0 = \frac{e|E_0|}{m\omega_L}$ is the normalized laser field magnitude, $n_c = \frac{\epsilon_0 m \omega_L^2}{e^2}$ is the critical density, and n_e is the electron plasma density.

In undedense plasma the n_c/n_e term is very large but as we change $n_e \rightarrow n_c$ the terms cancel out.

Here, using EPOCH particle-in-cell method we will explore how LWFA behaves near the critical density and see if we can obtain an energy scaling formula near the critical density: $n_e \approx n_c$. We will plot out ΔE vs n_e and ΔE vs a_0 for near critical densities.