I need to decide what to focus on in this work. There is a lot of information out there about the laser, different regimes. Do I fully derive the cold-fluid plasma equations

1 Cold Fluid Equations

In treating a plasma mathematically as a fluid, we must consider that the fluid particles will also have to obey the Maxwell equations. This means that the well known Navier-Stokes equation has to be modified to include additional terms. In a simple model, where the electron motion is confined to motion in the x direction, and $T = 0$ and $B = 0$, the full equations needed to describe the cold plasma is given by:

$$\boldsymbol{\nabla} \cdot \mathbf{E} = 4\pi e(n_i - n_e) \tag{1a}$$

$$mn_e \left(\frac{\partial \mathbf{v}_e}{\partial t} \right) = -en_e\mathbf{E} \tag{1b}$$

$$\frac{\partial n_e}{\partial t} + \boldsymbol{\nabla} \cdot (n_e \mathbf{v}_e) = 0 \tag{1c}$$

$$\tag{1d}$$

With an small incident electric field, we can linearize the equations about equationbrium:

$$\begin{aligned} &\mathbf{E} \rightarrow \mathbf{E_0} + \mathbf{E_1} \\ &n \rightarrow 0 + \delta n \\ &\mathbf{v} \rightarrow \mathbf{v_0} + \mathbf{v_1} \end{aligned}$$

Only keeping terms to first order, and assuming that the perturbations vary sinusoidally, this gives us the disperion of Langumir waves in a cold plasma.

$$\omega = \left(\frac{ne^2}{m_e \epsilon} \right)^{1/2} = \omega_p, \tag{2}$$

with e as the electron's charge, m_e the electron's mass, n is the number density of electrons in the medium, and ϵ is the permativity of the plasma.

2 Laser-Driven Plasma Waves for Particle Acceleration and X-Ray Production

The nonlinear case is where $a_0 = e\mathbf{A}(m_e c^2)^{-1} > 1$. Transfering to a frame moving at the same rate as the phase veloctiy of the packet, $t \to \tau$, $z - v_g t \to \xi$, and assuming that the pulse doesn't evolve, we can get Poisson's equation:

$$\frac{\partial^2 \phi}{\partial \tau^2} = k_p^2 \left(\frac{n_e}{n_{e0}} - 1 \right) \tag{3}$$

The relativisitic factor then becomes:

still need to be able to derive this . . .

$$\gamma = \frac{\gamma_\perp^2}{1 - \beta_z^2} \tag{4}$$

I think I may just show a figure for the non-linear case. The equation is hard to look at and understand. Cite heavily.

3 Laboratory Visualization of Laser-Driven Plasma Accelerators in the BUbble Regime

4 Injection in Plasma-Based Electron Accelerators

5 Experimental Programs

6 Texas

Should include figure from the Texas people.

Using chirped-pulse-amplification (CPA), extremely high peak power can be achieved by modern ultra-fast laser. CPA works by first creating an ultrashort pulse using a mode-locked laser (such as Ti:Sapphire). The pulse energy is fairly small to begin with[1]. To avoid damage to the amplification stage, the pulse is given a 'chirp' in the frequency domain: the simplest example of this is to send a pulse down an optical fibre, where the dispersion will naturally broaden the pulse in time. Once the pulse has been stretched out, the peak power will decrease, and the pulse can be safely sent through a laser-amplification stage, typically with a gain between 2-100 per pass. Once the pulse has been safely amplified, it can be re-compressed, using a technology such as parallel grating compressor. The whole process can increase the peak power from $10^3\,\mathrm{W}$ to $10^{14}\,\mathrm{W}$, as in the Texas PetaWatt Laser at UT-Austin.

With laser peak power this high, it can easily ionize a solid target– creating the plasma that it will be propogating through. In the Texas setup, the laser pulse is incident on a gas-cell, where it will create the co-propogating density wave by 'blowing out' the electrons from the region of the laser pulse.

This will set-up the longitudinal electric field that acts to accelerate the electrons. The electrons will be accelerated for the duration of the glass cell, and then be expelled into free space.

There is an array of sensors to measure the incoming electrons. First, they pass through a magnetic field, which bends them with a radius of curvature $r = mv/(eB)$. The slower moving electrons will be bent more, hitting an imagining plate. The faster moving electrons will continue on, largely undeflected. They are incident on two imagining plates: the first is a high-sensitivity plate that picks up medium energy electrons ($E > 0.5\,\mathrm{GeV}$) that have been energery dispersed (not well collumate), the second imagining plate is the one that picks up the well-collumated electron beam at $E \approx 2\,\mathrm{GeV}$. Additionally, tungsten posts are placed at various places downsteam of the exit aperature. These posts will cast shadows on the imaged plates, and simple geometry can be used to reveal the trajectory of the electron beam.

make this rela-tivisitic

[1]Typically around $10^{-9}\,\mathrm{J}$, with duration $\tau = 10^{-12}\,\mathrm{s}$ to $10^{-14}\,\mathrm{s}$, for peak powers of $10^3\,\mathrm{W}$ to $10^5\,\mathrm{W}$

7 SLAC

8 Europe

9 Future Work

The initial results in 2004 by [][][] where very promising, and progress is being made at an accelerated rate. However, it is still difficult to understand the minutia of the dynamics of LPA. This is due to the highly non-linear nature of the process. To make further progress, advances need to be made in three catagories: first, finer control over the laser parameters needs to be established, the pulse duration, pulse shape, pulse energy; second, better imaging and diagnostic technologies need to be developed so that the pulse can be imaged in situ; third, more work needs to be done on the theoretical side so that experimentalists have an idea of what knobs to twist.