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Numerical Modeling of Laser Wakefield Acceleration using the PIC code Smilei

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Acceleration of charged particle has been one of the most fascinating areas of research and it has numerous applications ranging from high energy physics to medical sciences. The traditional particle accelerators are of very large size and demands huge installation and operational costs. But after the pioneer work of Tajima and Dawson in 1979 [1], a new concept has emerged which worked very well to accelerate charge particles in the plasma using the field created by laser. Such scheme of particle acceleration is known as laser wakefield acceleration. The advent of ultra intense lasers has made this technique very promising. This particle acceleration scheme uses laser as a driver and plasma as a driven medium. The acceleration gradient produced by laser-plasma interaction is thousand times more than conventional accelerator [2]. Laser wakefield acceleration enables us to create small-size particle accelerators with low operational cost.

The interaction of ultra-intense laser with plasma results in various kinds of instabilities and it is important to understand the nature of these instabilities to produce particle acceleration. The particle-in-cell (PIC) simulation technique is one of the most important mechanisms to study the dynamics of laser-plasma interaction. It offers much better visualization and enables us to perform the studies which are not possible analytically. Researchers use the results produced by simulation to benchmark and scale the actual experiments. Here we have used particle-in-cell simulation code 'Smilei' [3] to model the laser wakefield acceleration. Smilei is a fully relativistic electromagnetic PIC code available as an open source. In the present work, we considered a linearly p-polarized Gaussian laser pulse with intensity $I = 5.8 \times 10^{19} \frac{W}{cm^2}$, $a_0 = eE_0/m_e c\omega_0 = 0.85\sqrt{I_{18}(W/cm^2)\lambda_{\mu m}^2}$ where I_{18} is laser intensity in the order of 10^{18} W/cm^2, $\lambda_{\mu m}$ is the laser wavelength in μm, a_0 is the laser pulse amplitude, E_0 is the electric field associated with laser pulse and ω_0 is the laser pulse angular frequency. We used pulse duration of laser as $21.3\,fs$ at FWHM (in intensity), beam width $10\,\mu m$ at FWHM, laser wavelength $\lambda = 0.8\,\mu m$. We considered electron density profile of the form $\frac{1}{1+exp\left(\frac{|x-x_0|-w_x}{L_x}\right)} n_{0max}$ in underdense plasma with thickness of $10\,mm$, where $n_{0max} = 10^{19}\,cm^{-3}$, $x_0 = 5000\,\mu m$, $w_x = 4700\,\mu m$, $L_x = 50\,\mu m$. Ions are taken to be fixed in whole simulation. Simulation box size was taken as $120\,\mu m \times 64\,\mu m$, cell size as $0.05\,\mu m \times 0.4\,\mu m$ and duration of simulation as $4\,ps$. Figure 1 shows the accelerating field at different times. In the coming time, we shall also calculate the energy gain attained by the electron bunches.

References

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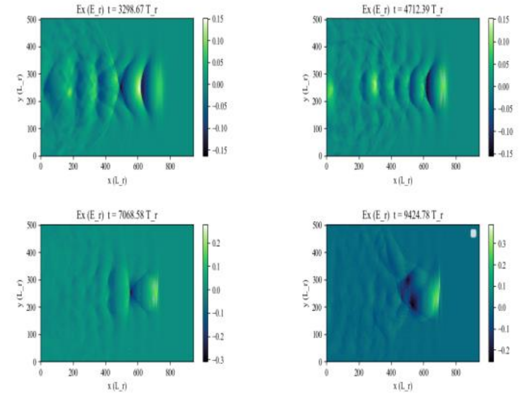

Fig.1: Accelerating field E_x (E_r) with different time $t = 3298.67\,T_r, 4712.39\,T_r, 7068.58\,T_r$ $9424.78\,T_r$ where E_x and t are normalized with E_r and T_r.