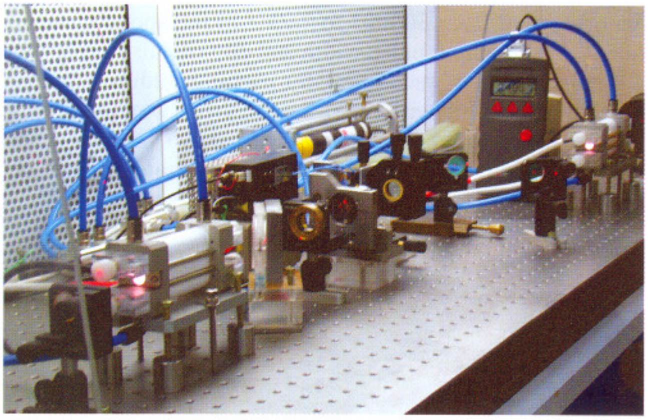

Fig. L.4.5: Photograph of the system in operation

Reported by: by: R. Sundar (email: sundhu@rrcat.gov..in) , K R. Ranganathan, P.Headoo and Dr. S. M. Oak

L.5: 3D simulation of relativistic electrons from laser driven wakefield acceleration

Activity on 3D simulation of laser based wakefield acceleration of electrons was started in Sep. 2006 at Laser Plasma Division, RRCAT, in collaboration with Laser & Plasma Technology Division of BARC, Mumbai, where a general-purpose serial Particle-in-Cell (PIC) code PICPSI-3D existed. This code has been upgraded at RRCAT to facilitate study on laser based electron acceleration. Recent simulation results have shown mono-energetic electron beam at ~23 MeV, with an energy spread of ±7.5 MeV for a plasma density of $3.5x10^{19}$ cm^{-3}.

Laser wake-field acceleration (LWFA) of electreons has drawn considerable attention due to the possibility of developing a compact table-top accelerator. High intensity laser pulses propagating through an under-dense plasmas are known to produce accelerating field of upto ~1 TV/m over a few millimeters, which have been used worldwide to accelerate electrons to an energy up to 170 MeV. At RRCAT, we have also experimentally demonstrated mono-energetic electrons with low divergence (<10 mrad) with good monochromaticity ($\Delta E/E<10\%$). [For more details, please see; S. R Bobbili *et al., New J. Phys.,* 12, 045011, (2010)].

Simulations provide insight into the internal dynamics of the laser-plasma interaction, to optimize LWFAs and to explain electron injection and self-consistent acceleration. Several codes like VLPL, OSIRIS, VORPAL are in use for such studies and the behaviour predicted by these codes has been subsequently verified in experiments. Using our code PICPSI-3D, we have studied the interaction of intense laser pulse with preformed plasma, and the subsequent evolution of the plasma and the field parameters.

In our simulation, a laser pulse of intensity ~ 1.5×10^{19} W/cm^2 (a_0=10), and 18 fs pulse duration, focussed to a Gaussian spot of 10 m in to a plasma of uniform density $3.5x10^{19}cm^{-3}$ was taken. Each macro-particle consisted of 78,368 particles. The plasma consisted of $7x10^7$ macro-particles and was inside a simulation box of volume $25\times25\times260$ μm^3, with a mesh-size of 0.2 m. The total number of mesh-cells was 2.03×10^7, resulting in approximately 3.5 macro-particles per cell. The code was run for 11000 time-steps, with each time-step being 0.0962 fs. Since the laser period ($c\tau$ = 5.4 μm) was equal to the plasma wavelength (λ_p= 5.4 μm), the acceleration was expected to be in the bubble regime of acceleration. For this plasma density, the dephasing length was ~255 μm, the critical power for self-focusing was 0.8 TW, and the expected maximum electron energy was 46 MeV.

The run took ~72 days to simulate as a stand-alone job on our workstation. In Fig. L.5.1, one clearly observes growth of a bubble after 1600 time-steps (~154 fs). The bubble breaks at 4000 time-steps (384 fs), resulting in the launch of electrons inside the bubble. At 6800 time-steps (654 fs), the electron energy spectrum starts to show a peak. The electron energy spectra in Fig. L.5.2 shows observation of monoenergetic electron beam at ~23 MeV, with an energy spread of ±7.5 MeV.

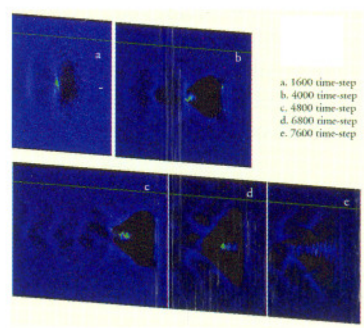

Fig. L.5.1: Electron density plot.

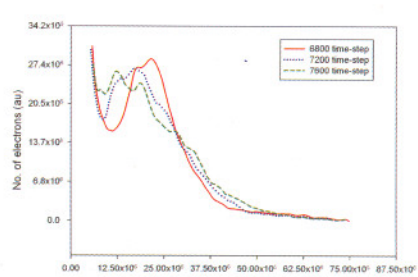

Fig. L.5.2: Electron energy spectrum.

Reported by: Ajit Upadhyay (ajitup@rrcat.gov.in), K. Patel (BARC) and P. A. Naik