L.1 : High-quality stable electron beams from laser wake-field acceleration in high density plasma

Laser wake-field acceleration (LWFA) in plasma medium using table top, high-power, femtosecond duration laser pulses is a promising alternate technique to the conventional radio-frequency based acceleration technology. LWFA provides extremely high accelerating electric field of ~100 GV/m and therefore has potential for development of compact high energy electron accelerators. However, in order to be useful for potential applications, the LWFA accelerators should be stable and provide electron beams with low divergence, energy spread, pointing variation and without any low energy background electrons for high signal to noise ratio in the electron beam/ x-ray interaction studies and to reduce the unwanted, potentially hazardous bremsstrahlung radiation. In order to generate such beams, the self-injection process must be stable and time duration of injection must be much shorter than the laser pulse transit time through the plasma. At Laser Plasma Division, RRCAT we have been able to generate high-quality, stable electron beams from a self-injected LWFA in a new parameter regime. The electron beam has virtually background free quasi-mono-energetic distribution with average peak energy ~35 MeV.

The 10 TW, 45 fs duration Ti:sapphire laser pulses were focused using an f/5 off-axis parabola on a supersonic He gas jet. The peak power of the laser pulse on the target was ≅3 TW, considering E_L=145 mJ contained in the focal spot, and assuming a Gaussian temporal profile. The peak intensity in the focal spot was estimated to be $I_L=2P_L/\pi\omega_0^2=2\times10^{18}$W/cm^2 ($a_0\cong1$). After scanning the plasma density and fine tuning of the laser focus position in the gas jet, at plasma density, n_e 5.8×10^{19} cm^{-3}, a highly reproducible and stable electron beam was observed.

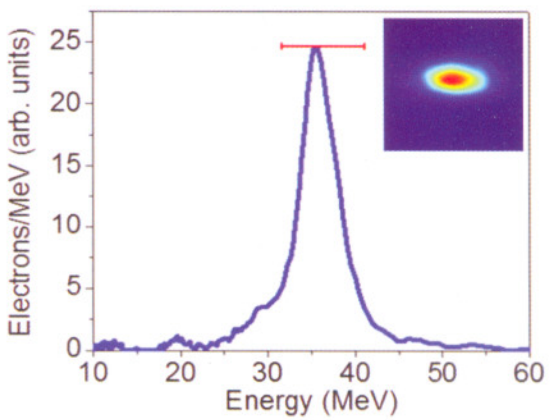

Fig.L.1.1: Energy spectrum of a typical electron beam. The inset shows the transverse profile of the electron beam.

A spatial profile of the electron beam and its energy spectrum are shown in Fig. L.1.1. The FWHM divergence of the electron beam was $\Delta\theta_X = 13.1^{+4.6\,-2.0}$ mrad in the horizontal direction and $\Delta\theta_Y = 7.2^{+2.8\,-0.7}$ mrad in the vertical direction. The errors shown are the root-mean-square (RMS) deviations from the average value. The RMS pointing deviation from the mean pointing angle of the electron beam in horizontal and vertical directions was $<\theta_X>=$ 12.3 mrad and $<\theta_Y>=$ 7.6 mrad, respectively. The average charge of the electron beam was estimated to be $3.8^{+2.8\,-1.2}$ pC. Fig. L.1.2 shows the distribution of the energy of the electron beam produced in a series of shots. The electron beam energy is highly reproducible with a quasi-mono-energetic peak value E_{peak} = $35.6^{+3.9\,-2.5}$ MeV. The high quality electron beam generation indicates a near threshold self-injection and acceleration of electrons in the laser wake-field excited in the "blowout" regime. The experimental results open a way for application of energetic electron beams produced with small laser facilities which are now widely available. (For more details, please refer to B. S. Rao et al., Phys. Rev. Spec. Topics Accel. Beams 17, 333, 2013).

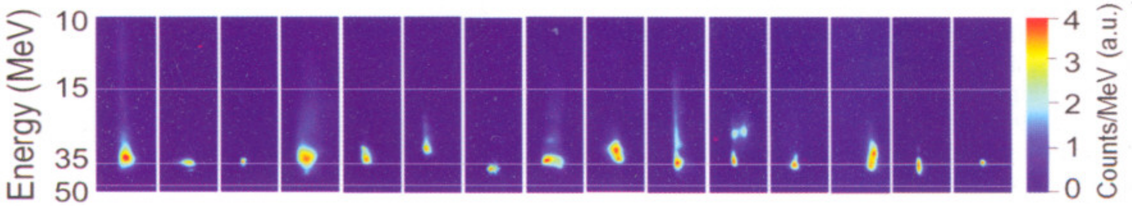

Fig.L.1.2: Energy spectrum of the quasi-mono-energetic electron beam from He gas-jet target recorded in 15 consecutive shots.

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