L.7: Multi-MeV quasi-mono-energetic electrons from laser- solid interaction

Ultra-intense laser - matter interaction is being investigated extensively for the past several years world-wide to generate high quality relativistic electron beams from compact and low cost setups involving table-top terawatt titanium sapphire laser systems delivering femtosecond duration pulses. Generation of stable quasi-mono-energetic electron beams have been demonstrated using the laser wake-field acceleration scheme in under-dense plasmas produced from a gas jet, a gas filled capillary, or laser ablated plasma plumes from solid targets. Energetic electrons can also be produced from laser-solid interaction, either through acceleration by plasma waves excited by resonance absorption process or by acceleration in the direct laser field. However, the resultant electron beam typically has large divergence angle (> 40°) and continuous energy distribution (100 % energy spread). In addition, the electron acceleration mechanism and consequently the direction of the electron emission critically depends on various interaction parameters like laser incident angle, intensity, polarization, and pre-pulse. Here, we report generation of well directed collimated multi-MeV quasi-mono-energetic electron beam from the interaction of ultra-short ultra-intense laser pulse interaction with solid target surface at grazing incidence angle >80° and optimizing the interaction conditions.

The experiment was performed using the 10 TW Ti:sapphire laser system at Laser Plasma Division of RRCAT. The system delivered p-polarized, 45 fs duration laser pulses at 800 nm. A schematic diagram of the experimental set-up is shown in Fig. L.7.1. The laser beam was focused at a grazing incidence angle of <10° (i.e. >80° with the normal) on the surface of a bulk carbon target (1 mm thick strip) near its front edge to a $1/e^2$ spot radius of ~7 μm, resulting in a peak intensity 5×10^{18} W-cm^{-2}. An electron beam was produced along the target surface direction which was detected by an integrating current transformer and also by a Gd_2O_2S:Tb phosphor screen coupled to a 16-bit charge couple device (CCD) camera. The electron beam energy was measured by deflecting the beam in the magnetic field of a compact permanent rectangular dipole magnet with effective magnetic field of 0.14 T over 50 mm length kept before the phosphor screen.

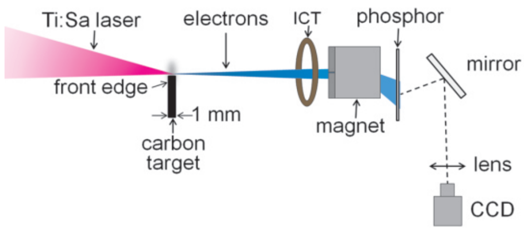

Fig.L.7.1: A schematic of the experimental setup

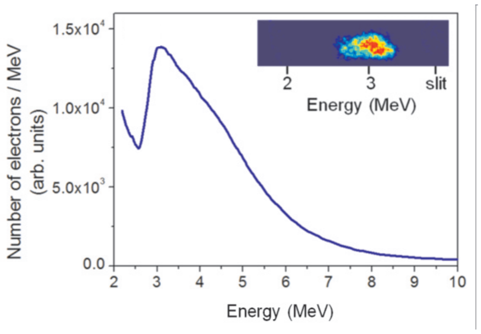

Fig.L.7.2: Energy spectrum of the collimated electron beam showing quasi-mono-energetic peak. Image of the energy dispersed electron beam recorded on the phosphor screen is shown in the inset.

The electron beam produced along the target surface direction genarally had large divergence and broad energy distribution with maximum energy upto 10 MeV. However, under optimum interaction conditions, once in a while, a collimated electron beam was observed. The divergence of the electron beam at FWHM was 3° and the spectrum showed a quasi-mono-energetic distribution with a peak at ~3 MeV, as shown in Fig.L.7.2. The quasi-mono-energetic electron beam had a charge of about 100 pC and estimated normalized emittance of about 1πmm.mrad. The quality of the electron beam was critically dependent on the laser pre-pulse due to amplified spontaneous emission (ASE). The effective intensity of the ASE pre-pulse on the target was about 10^{12} W-cm^{-2}. The quasi-mono-energetic electron beam was observed only for the shortest ASE pre-pulse of ~1 ns duration. As the duration of the ASE pre-pulse pedestal was increased beyond about 2 ns, the collimated, quasi-mono-energetic beam completely dissappeared. The dependence on pre-pulse suggested that the scale-length of pre-plasma produced on the target plays a vital role in the generation of the high quality relativistic electron beam. We infer that the electrons generated through JxB heating will be guided along the target surface by the quasi-static electromagnetic fields on the surface and accelerated by resonant interaction with the intense electric field of the reflected laser pulse via betatron oscillations.

Generation of intense multi-MeV quasi-mono-energetic surface electron beam could be of significance for studies related to fast ignition of inertial confinement fusion targets. Further, having potential of high repetition rate operation, this technique of multi-MeV quasi-mono-energetic electron beam generation in future could be useful in number of practical applications. For more details, please refer to *B. S. Rao et al., Appl. Phys. B 120, 149, 2015.*

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