L.5: Fast electron transport in foil targets irradiated by ultra-short intense laser pulses

Understanding the mechanisms of fast electron generation in short-pulse laser-plasma interactions and its subsequent transport in the dense heated matter, is a subject of prime importance to understand the physics relevant to the acceleration of MeV ions, generation of ultra-fast x-ray sources, and the fast ignition approach to the inertial confinement fusion scheme. Various fast electron generation mechanisms have been proposed, such as resonance absorption, vacuum heating, and relativistic J×B heating. The fast ignition scheme relies heavily on the generation of fast electrons of energies in the MeV range to initiate ignition of the pre-compressed core of the fusion fuel pellet. However, the natural divergence of the fast electrons results into poor coupling of their energy to the core of the compressed fuel pellet to ignite the fuel efficiently. Therefore, a knowledge and control of the fast electron divergence during the propagation through solid density matter remains a key issue to the success of the fast ignition scheme.

A study has been carried out on fast electron transport in foil targets by measuring the K-α x-ray source size produced by the fast electrons at the rear surface of the foil by employing knife edge shadowgraphy technique. Fig. L.5.1 shows the spatial profile of the x-ray source at the rear surface of a Cu foil irradiated by 50 fs laser pulses at an intensity of ~1.3×10^{18} W-cm^{-2}. The FWHM diameter of the x-ray source derived from the first derivative of the intensity profile of the knife-edge, which was fitted with a Gaussian profile, was 155 µm (FWHM) in the horizontal direction.

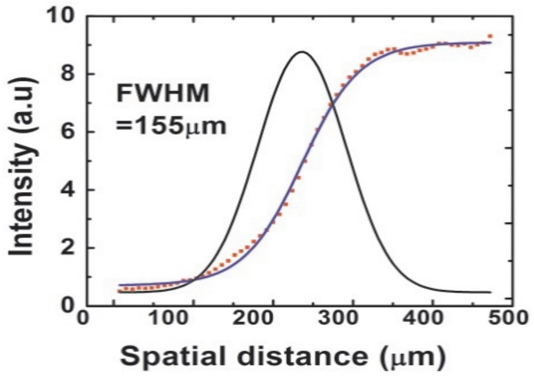

Fig. L.5.1: Spatial profile of x-ray source where the red points are experimental edge spread function, blue line is the Fermi fit, and black line is the final profile from derivation of the Fermi fit.

The x-ray source size at the rear was studied as a function of the laser pulse duration for a fixed fluence of 2×10^{5} J cm^{-2} (Fig. L.5.2). The source size decreases from 222 µm to 152 µm when the laser pulse duration was varied from 800 fs to 50 fs. This is due to the pinching of electrons by the self-generated mega-gauss magnetic field in the target at higher laser intensity. At low laser intensity, the magnitude of magnetic field is expected to be smaller and hence pinching will also be less, giving rise to a larger x-ray source size.

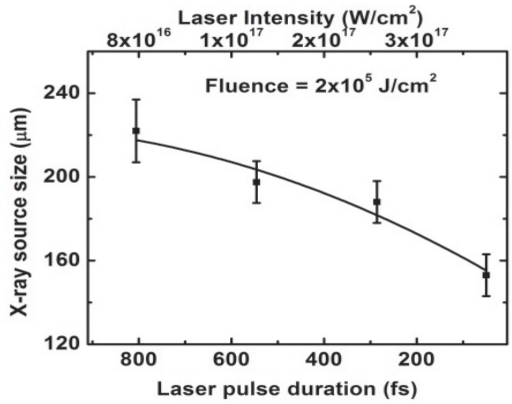

Fig. L.5.2: X-ray source size on the rear side of the foil as a function of the laser pulse duration.

It is important to quantify the divergence angle of the fast electron beam as it propagates through the foil. A multi-layered target was used for measurement of the fast electron beam divergence. It had a front propagation layer of Al of thickness varying in the range 7– 25 µm, with a 20 µm thick Cu tracer placed behind the propagation layer. The variation of the x-ray source size on irradiating the target (with different propagation layer thicknesses) at a laser intensity of ~1.3×10^{18} W-cm^{-2} is shown in Fig.L.5.3. The x-ray source size is observed to increase from 137 µm (FWHM) to 216 µm (FWHM) on increasing the Al layer thickness from 7 µm to 25 µm. The observed x-ray source size data when fitted to a straight line gives (from the slope) a half divergence angle of 37° for the fast electron beam. The measured value of the half cone angles is broadly in agreement with the reported value. For more details, please refer to *T. Mandal et al., Appl. Phys. B* 119, 2 (2015).

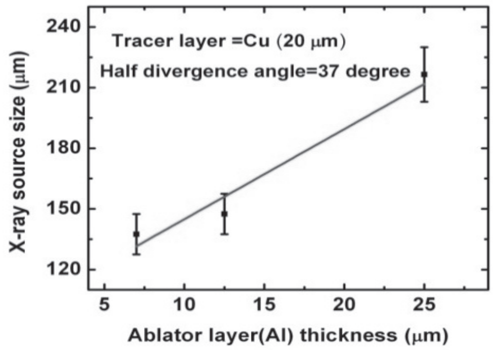

Fig. L.5.3: X-ray source size variation with the Al layer thickness.

Reported by:
T. Mandal (tirtham@rrcat.gov.in) and V. Arora