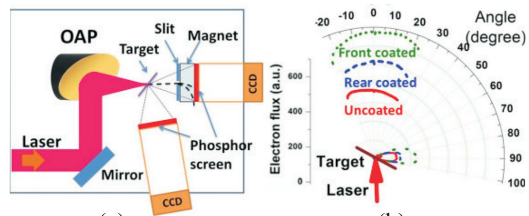
L.4: Intense laser driven fast electron generation in transparent target and effect of pre-plasma formation

Fast electrons generation and transport in high intensity laser plasma interaction has been an interesting subject due to applications towards generation of ultrashort x-ray sources, fast ignition concept and acceleration of high energy protons. For these applications, higher flux density and energy of fast electrons is desirable. Fast electron generation and transport in visibly transparent dielectrics such as mylar is of interest, as in such targets Cherenkov radiation imaging can also be used as a diagnostic. However, in such targets, fast electron generation and its transport is affected due to its dielectric nature, finally leading to lesser flux and energy. Therefore, it is important to explore techniques to enhance electron flux and energy from such targets. One way is having a thin metal coating on the front surface of mylar as it would change the preplasma scale length due to different plasma formation threshold for mylar and metal. In addition, a metal coating on the rear surface would also be interesting to understand the physics issues related to sheath field formation along with the improvement of escaping electron flux.

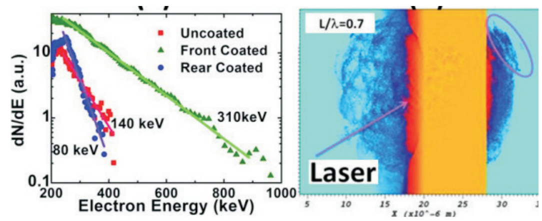
We have studied fast electron generation from a thin transparent mylar foil using 160 mJ, 30 fs Ti:Sapphire laser pulse focused to an intensity of ~ 10^{19} W/cm^2. The laser pulse was *p*-polarized and the incidence angle was kept ~30°. The contrast for the ASE prepulse at 1 ns prior was measured to be better than ~2×10^{-9}. Bare and Al coated (thickness 50 nm) mylar foil of thickness 8 µm were used as target in three configurations: (a) uncoated mylar foil, (b) front Al coated mylar foil with laser irradiating on coating side, and (c) rear Al coated mylar foil with laser irradiating mylar side. The experimental setup is shown in Figure L.4.1(a). Fast electrons emitted from the target foil along forward direction were detected using setups made up of a combination of phosphor screen and a 14 bit CCD camera. Energy spectrum of the electron beam was recorded using a magnetic spectrograph consisting of a magnet (Strength~330 G) and phosphor screen as detector.

Generation of directed fast electrons was observed for all the three target configurations. The forward beam peaked nearly along laser propagation direction having a divergence > 40°. The net charge contained in this beam was calculated to be ~ 45 ± 5 pC. Figure L.4.1(b) shows the polar plot of the fast electron angular distributions observed. It can be seen that on average the electron flux in the case of front Al coated mylar (configuration b) is ~1.8X larger than for the bare mylar (configuration a), whereas, the flux for the rear Al coated mylar (configuration c) is in between.



(a) (b)

Fig. L.4.1: (a) Experimental setup, and, (b) polar plot of fast electron angular distribution for three different target configurations.



(a) (b)

Fig. L.4.2: (a) Electron spectra for three different target configurations and (b) Electron density map as obtained from 2D PIC showing clear signature of fast electrons.

Electron energy spectra is shown in Figure L.4.2 (a). The spectrum for bare mylar foil (configuration a) extends upto ~ 400 keV with a fitted fast electron temperature of ~ 140 keV. Further, the spectrum for front Al coated mylar indicates comparatively higher maximum energy upto ~900 keV with an enhanced electron temperature of ~310 keV. Finally, the maximum energy for rear Al coated mylar remains nearly the same as bare mylar but with little less temperature (~80 keV).

Preplasma generation is expected to be more in the case of Al coated mylar compared to the bare mylar as the intensity ionization threshold is smaller in Al compared to mylar. Presence of longer extent preplasma helps in higher laser energy absorption and thereby generates more fast electrons. Further, as the laser power used is more than the threshold power, relativistic self-focusing can occur in the preformed plasma in turn increasing the effective laser intensity. It would also increase the energy and temperature of the fast electrons. The enhancement in electron flux at the rear coated mylar is due to formation of preplasma on the rear Al surface leading to retardation of the electrostatic sheath field and resulting in escape of more electrons. Figure L.4.2(b) shows the electron density map obtained through 2D PIC simulation performed using EPOCH code. It shows clear signature of energetic fast electrons for longer preplasma case (L/λ~0.7). For further information, please see *T. Mandal, V. Arora, A. Moorti, A. Upadhyay, and J. A. Chakera., Phys. Plasmas 26, 013103 (2019)*).

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