§37. Development of the Electron Spectrometer for Measuring the Energetic Electron from LFEX Laser in FIREX-I Project

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The high energetic electron measurement is one of the most important issues to research the ignition mechanism in the Fast Ignition Realization Experiment (FIREX) Project[1]. It is also important for the energy spectra with angular distribution because the electron spread is different by the target design. Therefore we have been developed the compact electron spectrometer so as to be installed on different angular potions. We have been preparing the calibration using L-band LINAC in the Institute of Scientific and Industrial Research, Osaka University.

The calibration has been performed using single pulse at two different energy of 11 MeV, 27 MeV. Main energies and charges in the calibration were 11 MeV, 27 MeV and 16 pC, 100 pC, respectively. Electron beam from LINAC passes among air. Own vacuum chamber was prepared because the beam scattering by air should be minimized. The beam size is 5 mm at the exit of the beam line and 10 mm at 13 cm from the exit in air. The energy spreads are 0.2 MeV at 11 MeV and 0.3 MeV at 27 MeV, respectively.

The analyzer was tested to measure energetic electrons from the aluminum plain target with 10 μm thickness irradiated by LFEX laser (maximum energy 10 kJ, the wave length of 1.05 μm, 4 beamlets) with the energy of 120 J and the pulse duration of 4 ps. The analyzer was installed on the Gekko XII Target chamber I at 20.9 degrees against the laser injection direction where was at the rear side of the target. This shot has been done by compression of one beam let LFEX laser. The alignment of the analyzer was performed by viewing the dummy target (illuminated by the He-Ne laser). The maximum electron energy of 3 MeV could be observed when the LFEX laser was collimated up to 75 x 110 μm and the laser intensity of 3.5 x 10^{17} W/cm^2. Figure 1 shows the energy spectrum of the electron beam.

The energy loss can be negligible in this energy target although it is very important in the imploded target. The electron spectrometer only detects the escaped electrons over 0.5 MeV into and the amount of the electrons observed are strongly limited by the high electrostatic potential formation by the electrons.

The spectrum is obtained from the energy calibration and the intensity calibration. Two different plots, which are derived from the energy calibration factor and orbit calculation using measured magnetic field are shown in Fig. 1. Solid lines in Fig. 1 indicates those Maxwellian fittings as follows,

$$\frac{dN}{dE} = \left(\frac{N_0}{T}\right)\left(\frac{E}{T}\right)^2 \exp\left(-\frac{E}{T}\right), \qquad (1)$$

where N, and T are the beam amount and the effective electron temperature, respectively. Here the relativistic effect is considered because the electron velocity is close to the light velocity. The effective electron temperatures are 0.55 MeV and 0.80 MeV, respectively. Observation of energetic electrons means the pulse compression system of LFEX laser was successfully completed.

In different shot, we can also obtain the spectra. In this shot, the LFEX laser with energy of 100 J and duration of 4ps is collimated to two spots of 24.5 μm x 44.1 μm and 24.5 μm x 29.4 μm. The total power is 1.4 x 10^{18} W/cm^2. The relation between the effective electron temperature and the laser beam intensity is known as the scaling driven semi-empirically.[2]

$$T_e(MeV) = 0.4 \times \left[\left(\frac{I_L(W/cm^2)}{10^{18}}\right)\lambda(\mu m)^2\right]^{1/3} \qquad (2)$$

where T_e and I_L are the effective electron temperature and the laser beam intensity, respectively. Figure 2 shows the comparison between the experimental temperature and the empirical temperature.

1)H. Azechi, "Present status of the FIREX program for the demonstration of ignition and burn", Plasma Phys. Control. Fusion Vol. 48, pp. B267—B275 2006.12.
2)private communication.

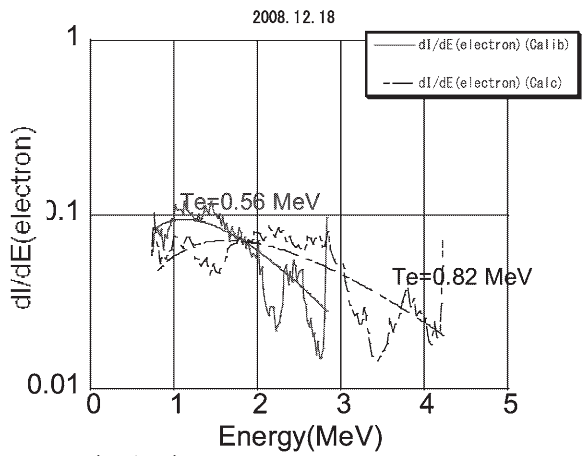

Fig. 1. The spectrum.

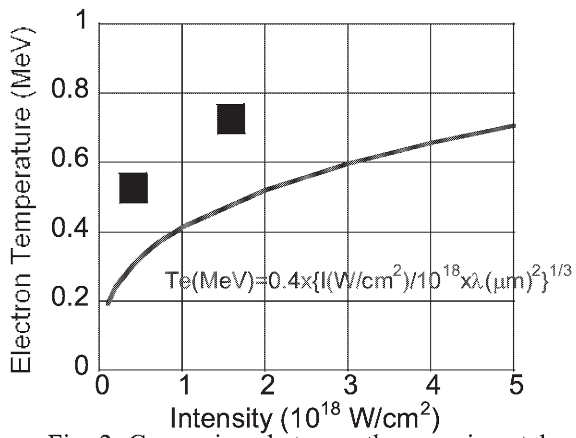

Fig. 2. Comparison between the experimental temperature and the empirical temperature.