§7. Investigation for Heating Mechanism to Super Dense Plasma by Fast Electrons Based on Electron Magneto-hydrodynamics Model

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This research is purposed to carry out an analysis of energy distribution of fast electrons passing through a high-density core plasma by using electron magneto-hydrodynamics model for investigation of core heating in Fast Ignition (FI)[1]. In the previous experiment, we observed significant modulation on electron energy spectrum depending on the plasma core heating by fast electrons created via ultra-intense laser (UIL) plasma interactions. Figure 1 shows electron spectra taken at previous FI experiment in Osaka University taken at (a) 20 and (b) 40 degs. from the UIL injection incidence[2]. Each line indicates the spectra at different timing between UIL injection and maximum compression timing of imploded core plasma from -170 to +50 ps as labeled in the figure, respectively. The 0ps electron spectra shows reduction of number from 1 to 10 MeV electrons compared with the spectra for other timing. In the experiment, neutron yield were enhanced more than 1000 times only at 0 ps injection (optimum timing) than no UIL injection, whereas no neutron increase was observed for other timing. From these results, one can conclude that the electron spectral modification is strongly related to core heating by fast electrons. In order to explore the heating mechanism, we performed preliminary researches to develop a particle simulation code based on the electron magneto-hydrodynamics model, which is expected to explain the heating physics[3].

Last year we conducted a Monte-Carlo simulation based on Electron Gamma Shower (EGS) 5 frameworks for estimation of heating temperature via binary scattering processes. In the results, deposited energy and temperature in spatially divided cells in the core is only half of the

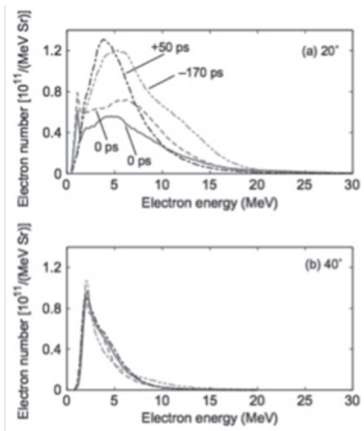

Fig. 1. Electron spectra taken at different viewing angles in fast ignitor integrated experiment at Osaka University[2]. (a)20° and (b)40°.

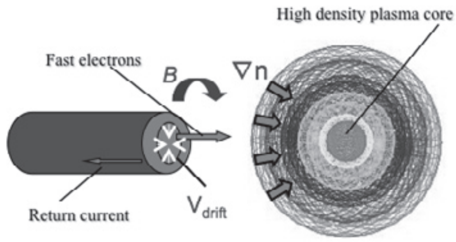

Fig. 2. Possible mechanism of energy dissipation predicted in EMHD model when the electron beam encounter the step-like gradient dense core.

experimental temperature even in a highest temperature cell. In addition, calculated electron spectra indicate only slight reduction of number of electrons compared with low density plasma with broad energy range up to 20 MeV. These results infer that it is insufficient to consider only binary collision processes of each particle as the heating mechanism in the experiment. Instead of binary collision, we introduced the electron magneto-hydrodynamics model to explain the anomalous reduction of electrons[4]. As shown in Fig. 2, when the high density electron current, propagating into large coronal plasma in the imploded plasma, encounters the core with steep density gradient, self-created magnetic field by electrons pinches the current itself, resulting in dissipation of current and deposition of its energy around the dense plasma. From the preliminary analysis using a hydro-code, the energy range to be affected by this mechanism agrees with the experimental observation. So that there is a possibility that EMHD model explains the energy deposition in the integrated experiments.

From this consideration, we extensively discussed how to introduce the effect in the simulation. Because the electron energies are in relativistic range such as several tens MeV, the laser plasma interaction should be treated by particle-in-cell modeling. On the other hand, the plasma density ranges from low dense plasma to 100 times of solid or more denser plasma. In addition, collective behavior is significantly important to reproduce an electromagnetic shock structure as the energy dissipation mechanism. We conclude to develop a new code based on the relativistic PIC code coupled with hydro-magnetic dynamical treatment of background plasma. The details of the code and the calculation results will be presented in the future.

1) Tabak, M. et al.,: Phys. Plasmas **1** (1994) 1626.
2) Yabuuchi, T. et al.,: New J. Physics **11** (2009) 093031.
3) Sundar, S and Das, A.,: Phys. Plasmas **17** (2010) 022101.
4) Yadav, S.K., Das, A., and Kaw, P., Phys. Plasmas 15 (2008) 062308.