§8. Heating for Super Dense Plasma by Fast Electron Based on Electron Magneto-hydrodynamics Model

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In this research, we carried 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 0ps injection 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)].

This year we developed a Monte-Carlo simulation code based on Electron Gamma Shower (EGS) 5 frameworks for estimation of heating temperature via binary scattering processes. Calculation parameters such as number of injected electrons, electron energy distribution, density profile of imploded plasma, and so on are taken from the previous experiment[2)]. Figure 2 shows the fast electron tracks in fuel core plasma when the incident electrons have (a) relativistic Maxwell distribution with 2.2MeV slope temperature and (b) mono-energetic energy with 0.5 MeV. In the case of (a), more electrons pass through the core plasma than the electrons in (b) because higher energy electrons are included in the energy distribution of (a). In this calculation, the electrons whose energy exceeds 2 MeV don't stop at the dense core without depositing its energy, which are inconsistent with the experimental results. In addition, we calculated deposited energy and temperature in spatially divided cells giving an experimental electron flux (assumed that conversion efficiency from laser to electron total energy as 40%). In the results, only half of experimental temperature can be obtained even in a highest temperature cell. Under these results, we conclude it is insufficient to consider only binary collision processes of each particle as the heating mechanism in the experiment.

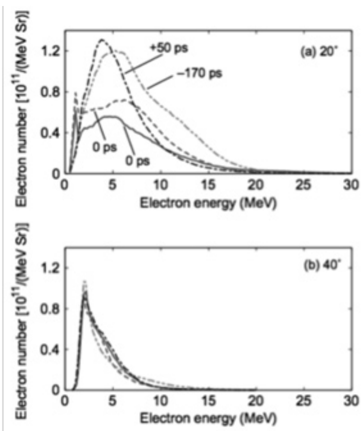

Fig. 1. Electron spectra taken at different viewing angles in fast ignitor integrated experiment at Osaka University[2)]. (a)20° and (b)40°.

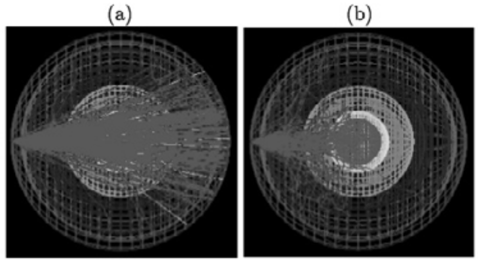

Fig. 2. Fast electron tracks in fuel core plasma when the incident electrons have (a) relativistic Maxwell distribution and (b) 0.5 MeV mono-energetic energy distribution.

From this consideration, we extensively discussed the feasibility of electron magneto-hydrodynamics model as the heating mechanism in fast ignitor. This model treats the ions as a background particle, and then describe temporal evolution of magnetic field from electron equation of motion in plasmas. As the results, electromagnetic shock is excited in the relativistic electron current when the current rushed in the steep density gradient plasma such as implosion plasma, resulting that the energy of electron current is dispersed and deposited in the dense plasma. From the detailed analysis, this model can be adapted to the filamented electron current due to Weibel instability grown at the relatively lower dense plasma.

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.