§34. Simulation of Fast Ignition by Using 1-D Hydrodynamic Code ILESTA-1D

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Fast ignition method[1] in the laser fusion enables sufficient fusion gain achievement with smaller input energy than conventional central ignition method. This property enables not only the reduction of the energy and cost of the driver laser but also the decrease of the target yield, which leads to the lower pulse heat load on the first wall. Such small target yield and low pulse heat load can realize the design of the reactor with a dry wall chamber. Thus the understating of the physics of fast ignition is quite important.

Fast ignition and succeeding fusion burn include quite complex physics phenomena (i.e., relativistic laser-plasma interaction, mechanism of fast electron beam generation, interaction between fast electron beam and extreme high-density core). In addition, fast ignition is essentially asymmetric heating and two-dimensional simulation is necessary for the analysis. Such detailed simulation, however, is very time-consuming. While the design of high gain target requires wide-range parameter scans of the pellet shaping and laser pulse tailoring. Thus we tried to simulate fast ignition by one-dimensional hydrodynamic code.

Thus we have introduced 1-D hydrodynamic simulation code ILESTA-1D[2] (developed by ILE, Osaka University) and carried out implosion simulations. As mentioned above, the code is one-dimensional and the detailed physics process of fast heating cannot be reproduced. However, propagation speed of burn wave is much faster than the expanding speed of the pellet. Thus the difference in heating region does not affect so much on the burning property. And heating mechanism of pellet core in fast ignition is dominated by electron heating with fast electron generated in laser-plasma interaction. Thus we modified the code to reflect fast heating by adding artificial heating source in the energy equation. It is modeled as a homogeneous heating of electrons in core region (assuming spherical region with optical depth ρR=0.4g/cm^2, which coincides to the ignition condition of 10keV core[3]) at the time just before when the maximum compression is achieved.

Figures 1 and 2 are the one example of streamline plot (radius-time diagram) and the temporal electron temperature evolution, respectively. An abrupt increase of electron temperature from 5keV to 15keV in the core region can be seen immediately after the injection of heating laser (at 18.09ns in this case). At present we obtained the pellet gain G=100, which is sufficient value for the commercial plant, with the laser energy of 400kJ (350kJ for implosion, 50kJ for heating, and assuming 20% coupling of heating laser). Then target yield is 40MJ and the design of 5-6m radius dry wall chamber is considered to be possible. Figure 3 shows the relation between irradiation time of fast heating laser and resulting fusion energy gain. It can be seen that the fusion gain strongly depends on the irradiation time (note that the time interval of each point is only 10ps). It is the great benefit of developing one-dimensional analysis method to be able to perform such wide-range parameter scan.

This work was performed with the support and under the auspices of the NIFS Collaborative Research Program (NIFS04KFDF001).

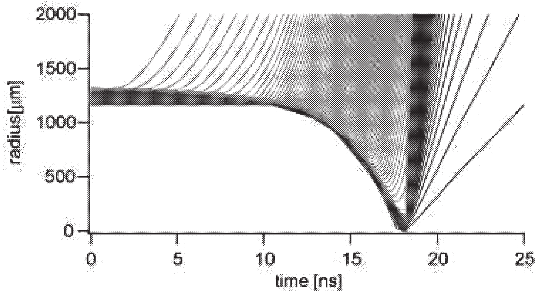

Fig. 1 Radius vs. time diagram of implosion simulation with pellet gain G=100.

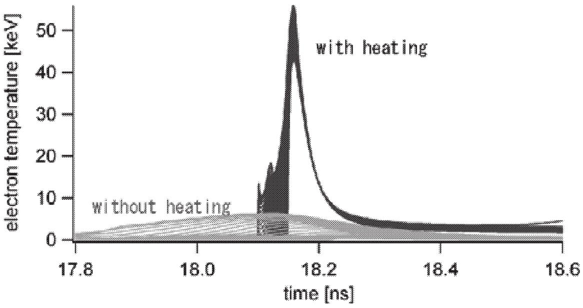

Fig. 2 Electron temperature evolution around the time of heating laser injection.

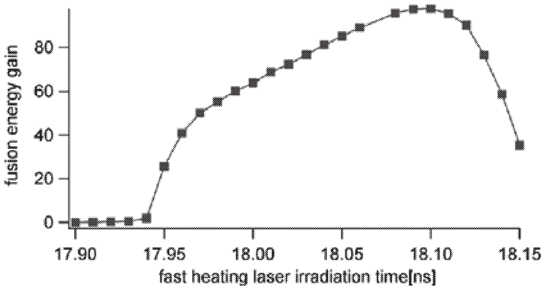

Fig. 3 Relation between fast heating laser irradiation time and resulting fusion energy gain.

REFERENCE
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2)H., Takabe et al., Physics of Fluids, vol.31, 1988, pp.2884-2893.
3)S., Atzeni et al., Japanese Journal of Applied Physics, vol. 34, 1995, pp.1980-1992.