§28. Design Study on Foam-Cryogenic Targets by Integrated Simulations

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The purpose of this study is to analyze the recent fast ignition experiments with cone-guiding targets$^{1)}$ and carry forwards a design of form-cryogenic targets. To simulate overall physics phenomena and identify the crucial issues involved in the core plasma heating, an integrated code system, "Fast Ignition Integrated Interconnecting code" (FI^3 code)$^{2)}$, was developed. In this code system, the implosion dynamics is simulated by an ALE-CIP radiation hydro-code "PINOCO"$^{3)}$. A collective PIC code "FISCOF"$^{4)}$ simulates laser-plasma interactions to evaluate the time-dependent energy distribution of relativistic electron beam (REB). The core heating process is simulated using a relativistic Fokker-Planck (RFP) code$^{5)}$ coupled with a hydro-based burn simulation code "FIBMET"$^{6)}$.

Integrated Simulation

Using the FI^3 code system we analyzed the core heating properties of a cone-guiding shell target. First, an implosion simulation was carried out for a polystyrene target (1.06 g/cm^3, 8μm-thickness, 250μm inner radius) which is attached with an Au cone having an opening angle of 30 degree. At the maximum compression, the optical size of the core, $\int \rho(r=0)dz$, reached 0.14 g/cm^2.

The profiles of fast electrons generated by laser –plasma interaction were then evaluated with FISCOF. The Au cone tip was modeled by the 10μm-thickness plasma with n_e = 100 n_c, where n_c is the critical density. The 60μm-thickness imploded plasma was putted behind the cone tip. The simulation was carried out by assuming that the electron density in the rear of the cone tip is $n_{e,rear}$ = 100 n_c, 10 n_c and 2 n_c. A 750 fs Gaussian pulse (λ_L=1.06μm, I_L =10^{20}W/cm^2) was assumed as a heating laser. The forward-directed fast electrons were observed behind the cone tip.

Using the imploded core profile at the maximum compression and the time-dependent momentum profiles of REB obtained for the cases of $n_{e,rear}$ = 100 n_c, 10 n_c and 2 n_c, we simulated the core plasma heating with FIBMET. The REB source was injected behind the cone tip by assuming a super-Gaussian profile with 30μm width. **Figure 1** shows the temporal evolutions of bulk electron and ion temperatures averaged over the core region (ρ> 10g/cm^3).

In the low density plasmas located between cone tip and dense core, a static field is built up owing to a strong micro-instability, which moderates the fast electrons and reserves the energy around the cone tip for a long time. Due to this density gap effect, in the case of $n_{e,rear}$ = 10 n_c, the core heating rate and the resultant temperature rising rate are low in the early stage of core heating (t < 2ps) compared with the case of $n_{e,rear}$ = 100 n_c. The core heating duration, however, is long since the sloshing fast electrons in the cone tip continue to be released from the cone tip after the laser irradiation. Thus, in the case of $n_{e,rear}$ = 10 n_c, the core temperature reaches ～0.5keV; the temperature increment is 0.20 keV, which is a higher increment than that (0.17 keV) in the case neglecting the density gap between the cone tip and the dense core.

The core size is smaller than the range of MeV electrons, so that most of the fast electrons penetrate the core. The energy coupling from the REB to the core was estimated to be 22% in the case of $n_{e,rear}$ = 10 n_c; the coupling from the heating laser to the core was only 6.5%.

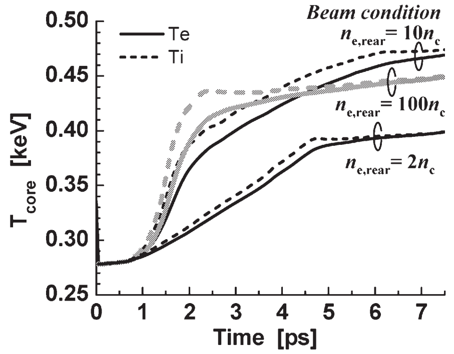

Fig.1 Temporal evolution of core plasma temperatures for three different electron densities in the rear of cone tip.

Discussion

The integrated simulations assuming long duration (750 fs) for the heating laser showed that the density gap effect is more pronounced than in the previous simulations assuming short pulse (150 fs). However, we could not obtain core heating as observed in the experiments. In the simulation the core was heated up to 0.5keV, which is still lower than the temperatures measured in the experiments. In the above simulations, the heating laser-plasma interactions were treated by 1D-PIC, which resulted in underestimating the energy coupling from laser to fast electrons. For further study, in addition to inclusion of collisions in the cone and the geometrical effects in laser-plasma interactions, we should consider additional heating mechanisms such as fast ion heating.

References

1) R. Kodama et al., Nature, **412** (2001) 798; **418** (2002) 933.
2) H. Sakagami, K. Mima, Laser Part. Beams, **22** (2004) 41.
3) H. Nagatomo et al., Proc. of 2nd IFSA (Kyoto, 2001), Elsevier, 140 (2002).
4) H. Sakagami et al., Proc. of 3rd IFSA (Monterey, 2003), ANS, 434 (2004).
5) T. Yokota et al, Phys. Plasmas, **13** (2006) 022702.
6) T. Johzaki et al, J. Plasma Fusion Res. SERIES, **6** (2004) 341.