§38. 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-guided targets and carry forwards a design of form-cryogenic targets, on the basis of the integrated code system, FI^3. In the FY2006, the following simulations were conducted.

1. Simulations of cone-guided shell implosion

2D simulations were performed using PINOCO for a cone-guided CH-D_2 cryogenic target model (16μm thickness 250μm inner radius). It was assumed that the target is irradiated by uniform laser of which wavelength, energy and pulse width are 0.53μm, 3.5kJ and 1.5ns (Gaussin, FWHM), respectively.

It was found that using a shell with a gold reentrant cone coated by CH drastically improves the implosion performance, although the result does not satisfy the condition of core plasma for FIREX-I yet. The maximum areal density and density obtained are 0.193 g/cm^2 and 176 g/cm^3, respectively.

2. Optimization of cone shape

Propagation of the heating laser inside the cone target depends on the cone angle. To find the optimal cone angle for fast heating of core plasma, 2D PIC simulations were performed. The simulation conditions were as follows. The target density is 100 times the critical density for laser field with 1μm wavelength; the diameter of cone tip is 3μm and that of cone entrance is 16μm; cone angle is varied as 20, 30, 45 and 60 degree; laser pulse is focused as Gaussian distribution with spot diameter of about 8.5μm and peak intensity of 2.0×10^{19}W/cm^2; pulse duration is 150ns.

Figure 1 shows the energy spectrum of hot electrons observed at the rear side of cone target for different cone angle. As cone angle becomes smaller, more energetic electrons are generated owing to laser intensification at tip.

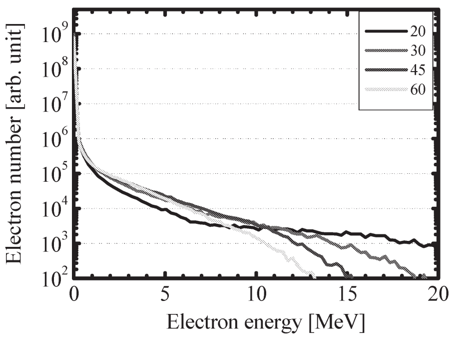

Fig.1 Electron spectra for different cone angle

The energy flux carried by electrons with energy $0.5<E<2$MeV (such electrons contribute most to the core heating) is largest for the 30 degree case. Together with high absorption rate, the 30 degree cone is considered to be optimal for fast ignition.

3. Dependence of core heating on pre-plasma scale length

Low density plasma formed on the cone inner surface before main pulse irradiation may affect the core heating. We evaluated the pre-plasma scale length dependence of core heating efficiency using the FI^3 code system. The cone tip was modeled by 100 n_C and 10μm thickness plasma. The pre-plasma having exponential profile $n_e \propto \exp(x/L_f)$ (L_f = scale length) is attached to the front surface. On the rear surface of the cone tip, we located 24μm thickness imploded plasma with exponential profile of scale length L_f = 10μm. The density is varied from $n_e = 10n_c$ at the contact surface to $100n_c$ at 24μm behind the rear surface. Following the imploded plasma, a $100n_c$, 26 μm plasma is located as the dense core. The heating laser is the Gaussian pulse with λ_L = 1.06μm, τ_{FWHM} = 750fs and $I_L = 10^{20}$W/cm^2. The irradiated laser energy is 0.79J/μm^2, which corresponds to 560J when the laser spot size is 15μm. The simulation time is 6ps.

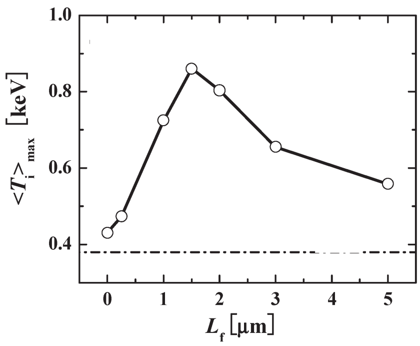

Fig.2 Maximum value of $<T_i>$ as a function of L_f

Figure 3 illustrates the maximum value of the averaged core ion temperature $<T_i>$. With increasing L_f up to 1.5μm, the energy coupling from heating laser to fast electrons becomes high, so that the deposited energy and hence the core temperature also increase. If L_f becomes too long (>2μm), the population of sub-MeV electrons decreases, leading to reduction in the core heating efficiency. Thus, there exist an optimal scale length $L_{f\,opt}$, and in the present simulation $L_{f\,opt}$ = 1.5μm. In this case, the energy coupling from the heating laser to the core is 14.9% and ion in the core is heated up to 0.86keV, which is comparable to the temperature obtained in the experiments.

Examples of major publications

H. Nagatomo, et al., J. Phys. Ⅳ France, **133**, 397 (2006).
T. Nakamura, et al., ibid., **133**, 401 (2006).
T. Johzaki, et al., ibid., **133**, 385 (2006).