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The Uniformity of the Laser Absorption on the Inner Surface of the Cone-shell Target for Fast Ignition with Internal Heating Scheme

内部直接加熱による高速点火核融合において現れるターゲット内面でのレーザー吸収分布の一様性の評価

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A new ignition scheme was suggested for efficiently heating a compressed fuel core. In this new scheme, a hollow spherical CD shell is pierced for irradiating the heating laser into the inner surface. The high temperature is achieved by directly heating the inner surface by the heating laser. The inner surface is thought to be illuminated overall due to the multiply scattering effect in the sphere. In this paper, we show that the temperature on the inner surface is globally raised by this multiple scattering effect.

1. Introduction

The concept of inertial confinement fusion is to compress a few millimeter of a spherical capsule that confines DT fuel to more than 10 times initial radius and burn the compressed fuel core by fusion reactions [1]. The burning of the fuel core requires high density (~600 g/cc) and high temperature (~10 keV), which is done by fusion reaction in a part of the compressed fuel region. This trigger for burn is called “ignition” and such small region is called “hot spot” or “hot spark”.

We have developed a new ignition scheme. Figure 1 shows the schematic illustration of the new scheme. In this scheme, a hollow spherical CD (deuterium doped plastic) shell with a hole is imploded by lasers and heating laser is irradiated into the inner surface through the hole. The inner surface is ablated and begins expanding inward by this heating laser. When this expansion plasma collides at the center, the target center has high temperature and may be hot spot if the timing is right. 1D spherical hydro simulation shows that ion temperature of the center region can be ~20 keV if the 500μm ϕ and 7 μm thickness target has 500 eV of ion temperature at the initial condition.

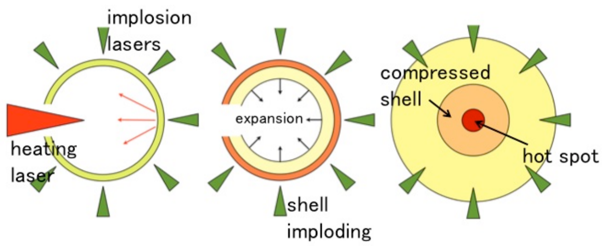

Fig. 1. Schematic illustration of direct heating

The inner surface must be illuminated globally for realizing this 1D result. On the other hand, incident laser can be reflected over and over in the target. It is thought that the inner surface can be illuminated globally by this cavity multiple scattering. In this paper, we discuss cavity multiple scattering of the incident laser by simulation.

2. Simulation

To simulate the trajectory of incident laser, we have used ray trace method [2]. The laser light is divided into multiple beamlets and each beamlet is treated as a ray. The shell is assumued as being plasma. Thus we compute the trajectory of each beamlet propagating in plasma. The laser absorption process is treated by inverse bremss,

$$\kappa = \frac{25Z}{\lambda_L^2 T_e^{3/2}}\left(\frac{\rho}{\rho_{cr}}\right)^2 \Bigg/ \sqrt{1-\frac{\rho}{\rho_{cr}}}, \qquad (1)$$

where κ, Z, λ_L, T_e, ρ and ρ_{cr} are the absorption coefficient as the unit of cm, charge number, laser wave length as the unit of μm, electron temperature as the unit of keV, mass density and critical mass density of plasma [1].

Figure 2 shows the incident laser and target profile. The laser is incident from left side with F = 5 and d/R = 4. The wavelength is 1.06 μm. Figure 3 shows the ray trajectories in this incident condition without absorption. Namely, this result shows the pure geometrical path of the laser. It is found that rays are reflected many times.

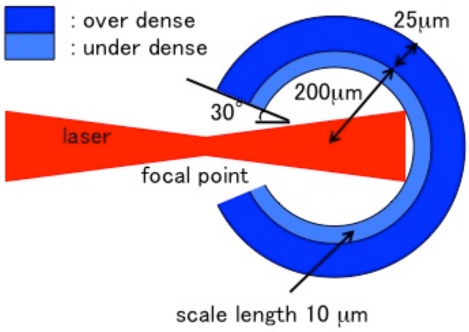

Fig. 2. Incident laser and target structure

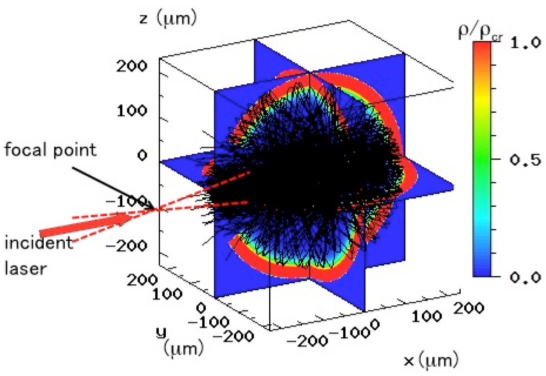

Fig. 3. Ray trajectories

Next we consider the absorption process and the time evolution of the temperature. The deposit energy on the plasma from laser is converted directly internal energy. As for the incident laser energy and the time interval, we set 100 J and 100 ps respectively. The temporal and spartial profile are assumed constant. Figure 4 shows the time evolution of the temperature in x-y plane.

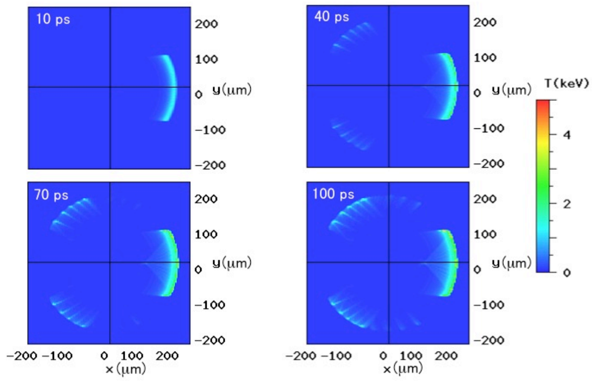

Fig. 4. Time evolution of temperature in x-y plane

From this result, we can find following process. The temperature at directly irradiated region is firstly raised. The more temperature increases, the less absorption rate becomes (see also Eq. (1)). Thus subsequent laser light (10 ps – 40 ps) is absorbed at the second reflected face. The temperature also rises at this face after several tens of ps, and then the absorption rate becomes zero. Finally, the incident laser during 70 ps to 100 ps is absorbed at the third reflected face.

The temperature of the inner surface rises non-locally by these consecutive processes. It depends on the laser intensity and geometrical condition of the target and the laser. Although hydrodynamic motion is neglected in this simulation, the scattering from the distorted interface due to the hydrodynamic motion is also important. We will discuss the detail at the presentation.

Acknowledgments

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