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Instructions for Preparing Manuscripts for the Proceedings of PLASMA2014
対向テーラードパルス爆縮のシミュレーション

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In order to investigate the high dense core compression in the implosion required for achieving small-size and high-repetition thermonuclear fusion reactor CANDY, we have conducted the implosion experiments with the tailored laser pules. Also, we have conducted the fast-ignition in which the compressed core plasma is irradiated by the ultra-high intense laser. In this talk, we show the results of radiation hydrodynamic simulations of our implosion, and show the current plasma conditions. In our experiments, the amount of laser energy is only several-Joule. However, the conventional shell with diameter of 500 microns can be imploded to central part of the target.

1. Introduction

We have conducted the fusion research and technology development for achieving the small size high-repetition thermonuclear fusion reactor CANDY. In our design, a Deuterium-Tritium fuel pellet is imploded by compression lasers, and then the compressed core plasma is heated by the ultra-intense additional heating. This scheme is the fast-ignition. For this purpose, we have investigated the many elementary physical processes in our laboratory. One of the most important problem to achieve the small size fusion reactor is to achieve the high-dense imploded plasma core. In order to investigate the high dense core compression in the implosion, shaped laser pulse, namely, Tailored pulse is required. We have conducted the implosion experiments with two beams of compression laser with tailored pulse shape. The amount of compression laser energy is several-Joules. In our laboratory, a CD plastic shell of 500 micron diameter is imploded by two beams and we observed the generation of the relatively hot plasma at the center of the target. In this talk, we show results of the radiation hydrodynamic simulations for our implosion experiments to clarify current condition of our plasma.

2. Radiation Hydro simulation

Our hydrodynamic model is two-temperature one-fluid model shown as;

$$\frac{D\rho}{Dt} = -\rho\nabla\cdot\vec{v} \quad (1)$$

$$\rho\frac{Dv}{Dt} = -\nabla(p+q) \quad (2)$$

$$\rho c_{vi}\frac{DT_i}{Dt} = -(p_{THi}+q)\nabla\cdot\vec{v} + \nabla\cdot(\kappa_i\nabla T_i) + \alpha(T_e - T_i) \quad (3)$$

$$\rho c_{ve}\frac{DT_e}{Dt} = -p_{THe}\nabla\cdot\vec{v} + \nabla\cdot(\kappa_e\nabla T_e) - \alpha(T_e - T_i) + Q_L + Q_r \quad (4)$$

Here $\vec{v}$, ρ, p_i, p_e, (e = electron and i=ion) and q are, respectively, velocity, mass density, ion pressure, electron pressure and the artificial viscosity. The total pressure p is defined by $p = p_i + p_e$. In Eqs. (3) and (4), p_{THi} and p_{THe} are defined as $p_{THi} = T_i(\partial p_i/\partial T_i)$ and $p_{THe} = T_i(\partial p_e/\partial T_e)$, respectively. c_{vi} and T_i represent the specific ion heat and ion temperature, and c_{ve} and T_e represent the specific electron heat and electron temperature, respectively. κ_i and κ_e are ion conductivity [3] and electron conductivity [4], respectively. The term $\alpha(T_e - T_i)$ in Eqs. (3) and (4) is electron-ion temperature relaxation term. Here α is determined by the Spizer relaxation time [5]. In Eqs.(3) and (4), ion and electron heat conductions are simultaneously calculated, and we applied the flux-limited Spitzer-Harm model [6] with the flux-limiter of 0.1. The source term Q_L in Eq.(4) is the heating term due to the laser heating term for electrons. For the laser absorption process, we assumed the inverse-bremsstrahlung [7]. The laser energy deposited between the vacuum/plasma boundary and the critical surface is calculated by the ray-tracing method with 100 rays. Figure 1 shows the example of temporal profile of the compression laser pulse.

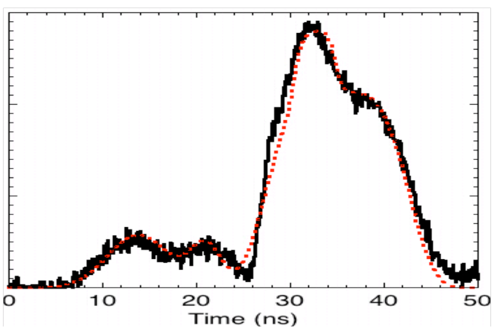

Fig.1 temporal profile of laser pulse

In Fig. 2, we show the calculated radius-time diagram for the typical implosion in our experiments. Here a 500 micron diameter CD is irradiated by the tailored pulse as shown in Fig.1 and imploded successfully. The laser wavelength is 1micron. The amount of compression early in the pulse is several-Joule. Just before the maximum compression, we inject relatively large pulse for generating the shock. Finally the shell is compressed into the center of the target.

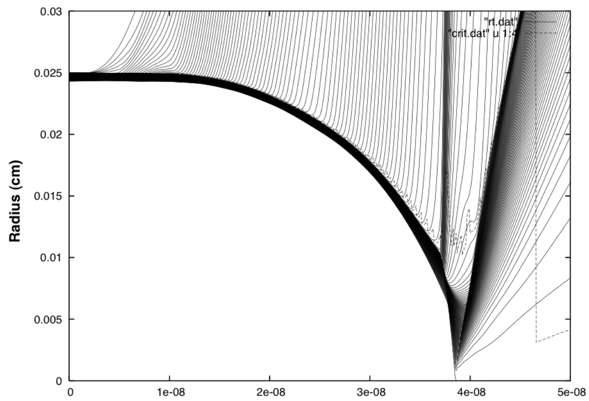

Fig. 2 Calculated radius-time diagram of the implosion

In the talk we will show 1D and 2D analysis of our tailored pulse implosions by 1D and 2D radiation hydroyanmic simulations.

References

[1]Kitagawa Y. et al., "Petawatt-laser direct heating of uniformly imploded deuterated- polystyrene shell target", Phys. Rev. E 71, (2005) 016403

[2]Kitagawa Y. et al., "Fusion Using Fast Heating of a Compactly Imploded CD Core", Phys. Rev. Lett108 (2012) 155001.　108 (2012) 155001.

[3] S. I. Braginskii, "Reviews of Plasma Physics", **1**, Consultants Bureau 205(1965). **1**, 265 (1958).

[4] Lyman Spitzer Jr. and Richard Harm "Transport Phenomena in a Completely Ionized Gas", Phys. Rev. **89**, 977 (1953).

[5] Lyman Spitzer Jr. "Physics of Fully Ionized Gases", John Wiley & Sons Inc. p.115(1962).

[6] R. C. Malone, R. L. McCrory, and R. L. Morse, Phys. Rev. Lett. **34**, 721 (1975).

[7] W. L. Kruer, "The physics of Laser Plasma Interactions", Addison-Wesley Pub. , p. 48 (1988).