24D17

Formation of High ρ-R core using slow implosion method for Fast Ignition
高速点火のための低速爆縮による高密度半径積コアの形成

Hideo Nagatomo[1], Atsushi Sunahara[2], Tomoyuki Johzaki[2], Hitoshi Sakagami[3], Kunioki Mima[4]
長友英夫[1]，砂原淳[2]，城﨑知至[2]，坂上仁志[3]，三間圀興[4]

[1]*Institute of Laser Engineering, Osaka University*
2-6 Yamadaoka, Suita, Osaka 565-0871, Japan
[1]大阪大学レーザーエネルギー学研究センター 〒565-0871 大阪府吹田市山田丘2-6
[2]*Institute for Laser Technology*
2-6 Yamadaoka, Suita, Osaka 565-0871, Japan
[2](財) レーザー技術総合研究所 〒565-0871 大阪府吹田市山田丘2-6
[3]*Fundamental Physics Simulation Research Division, National Institute for Fusion Science*
322-6, Oroshi-cho, Toki, Gifu 509-5292, Japan
[3]核融合科学研究所基礎物理シミュレーション研究系 〒509-5292 岐阜県土岐市下石町322-6
[4]*The Graduate School for the Creation of New Photonics Industries*
1955-1 Kurematsu-cho,Nishiku,Hamamatsu,Shizuoka,431-1202, Japan
[4]光産業創成大学院大学 〒413-1202 静岡県浜松市西区呉松町1955-1

In the implosion phase of the Fast Ignition scheme, most critical issues are breakup of the cone tip and the formation of high ρR core plasma to improve its heating efficiency. Also material of the cone tip is essential for high energy electron transport. For the integrated FI experiment at ILE Osaka University, robust and reliable implosion must be redesign. In this paper, feasible target design under the constraint condition of existing GXII and LFEX facilities is studied using two-dimensional radiation hydrodynamic simulations, and an optimum target design based on low velocity implosion is proposed.

1. Introduction

There are some difficulties in formation of core plasma for fast ignition scheme. Most of implosion design has inserted cone in shell target to keep the heating laser pass vacuum. Therefore the tip of the cone which is exposed in high density and high temperature core plasma during the last phase of implosion should be survived until the heating time. In FIREX-I (Fast Ignition Realization Experiment phase I) at ILE Osaka University, implosion design is based on conventional high density implosion experiment [1], where implosion velocity is go up to $3.0\text{x}10^7$cm/s to obtain hot spot in the center of core plasma. This is not necessary condition in fast ignition. One possibility to improve process is the slow implosion [2] where implosion velocity is less than $2.0\text{x}10^7$cm/s to keep low adiabat. In this paper a possibility of the slow velocity implosion scheme at GXII laser in ILE is studied using two-dimensional radiation hydrodynamic simulations, and a preferable design for FIREX-I experiment is proposed.

2. Simulations

The 2-D radiation hydrodynamic code, PINOCO [3] is used for this simulation. The laser conditions are based on current GXII performance. The energy and the wavelength of the direct drive laser are assumed as 3.3 kJ and 0.53 μm respectively. The tailored laser pulse is applied and its duration is limited to 4.5 ns due to the GXII limitation. In the conventional implosion, radius and thickness of the typical shell target are 250 μm and 7 μm respectively. Here, they are set to 145 μm and 25 μm respectively after optimization using 1-D simulations. Robustness of the implosion is necessary against laser non-uniformity and target surface roughness. In this study non-uniformity of laser irradiation are assumed as mode 6, and amplitude of 5%, which are typical numbers in GXII facility.

Figures 1 and 2 show the temporal ρ-R of compressed core plasma in cases of conventional implosion and slow implosion respectively. The solid lines and dashed lines indicate the implosion with uniform laser irradiation and with non-uniform laser irradiation respectively. In this ideal case ρ-R is 0.48 g/cm^2 with uniform laser irradiation whereas 0.25 g/cm^2 with non-uniform laser irradiation. On the contrary, in low velocity implosion cases, they are about 0.30 g/cm^2 for both cases. In realistic conditions, the higher mode of laser non-uniformity and target surface roughness must be seeded furthermore and the hydrodynamic instability will be grown exponentially. Thicker shell target of low velocity implosion will be robust and stable against such perturbations also.

The duration of high ρ-R period (ρ-R > 0.2 g/cm^2) is 80 ps in conventional implosion case and 140 ps in slow implosion case respectively. This is another advantage of low velocity implosion for fast ignition where long heating window is required.

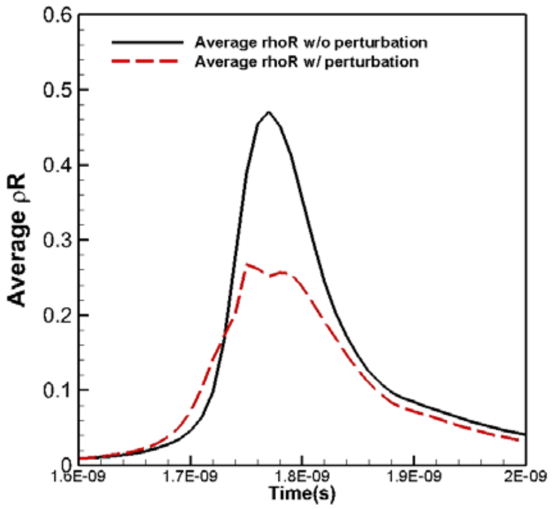

Fig.1. Temporal averaged ρ-R of core plasma in conventional cone-guided implosion case, with non-uniformity laser irradiation case (dash line) and uniform irradiation case (solid line).

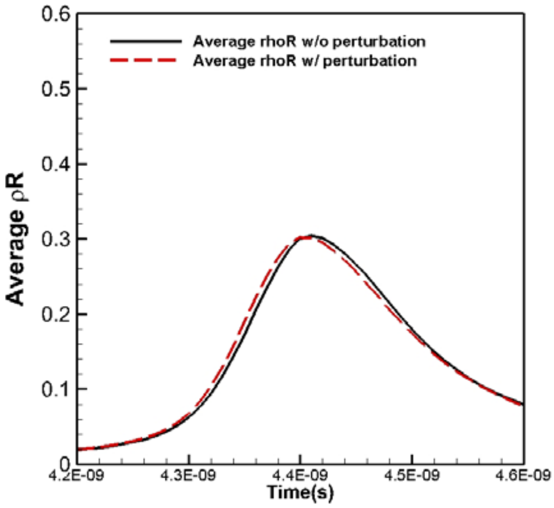

Fig.2. Temporal averaged ρ-R of core plasma in slow velocity implosion case, with non-uniform laser irradiation case (dash line) and uniform irradiation case (solid line).

The breakup time of the tip is 4.36 ns which is slightly earlier than maximum compression time if it is made of Au (thickness: 6 μm). In this study, tip material, shape, and thickness are not optimized yet. It will be able to optimize using pointed cone concept using Diamond-like-Carbon [5].

3. Conclusion

The slow implosion for fast ignition is studied and an optimized design for FIREX-I experiment is proposed using 2-D radiation hydrodynamic simulations. The advantage of the scheme is not only low adiabat implosion but also robust against hydrodynamic instability due to the non-uniform laser irradiation and target surface roughness. Also, relatively longer confinement time may extend the heating window time.

Acknowledgments

These simulations were executed at Cyber Media Center, Osaka University, and ILE Osaka University. The authors would like to appreciate the technical staffs at CMC and ILE Osaka University.

References

[1] H. Azechi *et al.*, Laser Part. Beams, **9**, No.2, (1991) 193.

[2] R. Betti and C. Zhou: Phys. Plasmas **12** (2005) 110702.

[3] H. Nagatomo *et al.*, Phys. Plasmas **14** (2007) 056303.

[4] D.S. Clark and M. Tabak: Nucl. Fusion **47** (2007) 1147–1156.

[5] A. Sunahara *et al.*, Laser Part. Beams, *to be published*.