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Optimization of Direct Drive Fuel Target in Heavy Ion Inertial Fusion
重イオンビーム慣性核融合における燃料ターゲットの最適化

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A sufficient fusion output gain is realized in heavy ion inertial fusion by using light target materials. Fuel target parameters are optimized to obtain the sufficient fusion energy in heavy ion inertial confinement fusion (HIF). In this study, the target structure, the heavy ion beam (HIB) input pulse shape and the HIB input pulse energy are optimized. We performed two-dimensional fluid implosion simulations to obtain a high pellet gain. The optimized target shows a gain 223. The input Pb beam energy is 1.8MJ.

1. Introduction

Research issues in heavy ion beam (HIB) inertial confinement fusion (ICF) include beam bunching, HIB transport in a reactor, non-uniformity of beam irradiation, implosion uniformity, implosion efficiency, energy gain and so on. In fuel target implosion, ICF has two ways of implosion schemes, that is, indirect-driven scheme and direct-driven implosion scheme [1-6].

In this paper, we focus on a direct-drive scheme, and we present an improvement of the pellet gain by the optimization of the target structure and the HIB input pulse shape. As a result, we obtained a pellet gain 223 by optimizing the target structure, the HIB input pulse shape and the HIB input pulse energy.

2. Optimization of target structure and HIB pulse shape

Figure 1 (a) shows the fuel target in our previous work [7-10]. This target consists of Pb and Al as a tamper and a HIB-energy absorber, respectively [7-10]. Figure 1 (b) shows a lightened fuel target. This target consists of Al and C as a tamper and a HIB-energy absorber, respectively [11]. Figure 1 (c) shows the input pulse which we used for each target. We call the low pulse power in the input pulse a foot pulse and the high pulse power in the input pulse a main pulse. The input Pb beam energy is 4MJ. When the fuel target in our previous work is used, we obtain a gain 52.6. A high gain can be achieved by the light-material of tamper (Al) and HIB-energy absorber (C). By the light-material target, we obtained a gain 61.9.
The foot pulse duration is designed so that the main shock by the main pulse overlaps at the inner edge of the DT liquid fuel with the first weak shock to minimize the DT fuel preheating. Therefore, we perform a parameter study for the foot pulse duration for Fig. 1 (b). When the foot pulse duration is changed from 16ns to 22ns, the irradiation for the main pulse starts after 2ns of the foot pulse end. The HIB input energy is fixed to 2MJ, and the main pulse duration is changed to keep the HIB total energy. The maximum gain is at 19ns for the foot pulse duration (see Fig. 2).

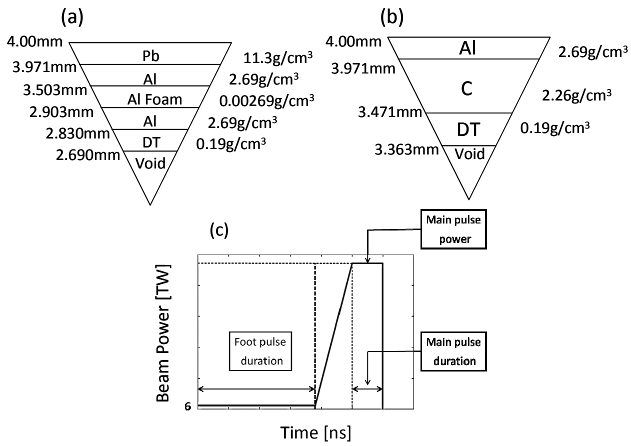

Fig.1. Target structures (a) consists of Pb and Al as a tamper and a HIB-energy absorber, respectively, and (b) consists of Al and C as a tamper and a HIB-energy absorber, respectively. (c) HIB pulse shape used for each target.

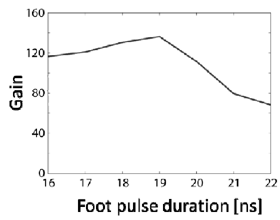

Fig. 2. The pellet gain versus the foot pulse duration.

The energy-absorber thickness is decided by changing the inner radius of energy absorber layer. We change the C thickness from 400μm to 700μm and set the optimal foot pulse duration in the pulse shape for each thickness of energy absorber (C). When the C thickness is thin, the interception of the heat that enter the DT fuel layer becomes difficult. However, when the C thickness is thick, the pellet gain becomes lower. When the thickness of energy absorber is 500μm, we obtain the gain of 137 (see Fig. 3).

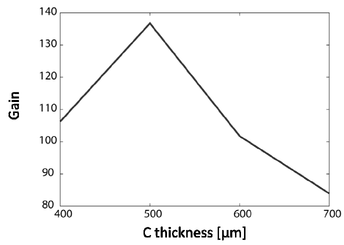

Fig. 3. The pellet gain versus the thickness of energy absorber (C).

We change the main pulse power from 186TW to 436TW for Fig. 1 (b). When the main pulse power is high, the pre-heat on the DT fuel layer becomes large. When the main pulse power is weak, implosion velocity in the DT fuel layer do not become a sufficient speed. When the main pulse power is 336TW, we obtain the maximum gain in this case (see Fig. 4).

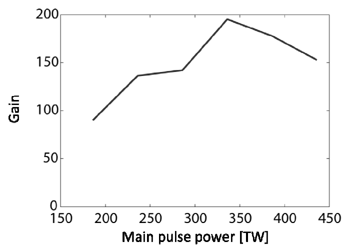

Fig. 4. The pellet gain versus the main pulse power.

We change the HIB input energy from 1.4MJ to 2.0MJ for Fig. 1 (b). When the HIB input energy become large, the pre-heat in the DT fuel layer becomes significant. When the HIB input energy is small, the efficient implosion is not possible, because the implosion velocity in the DT fuel layer does not become a sufficient speed. When the HIB input energy is 1.8MJ, we obtain the gain of 223 (see Fig. 5).

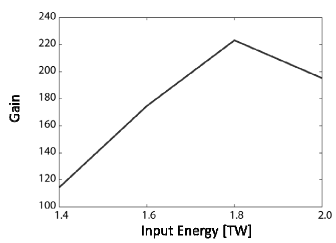

Fig. 5. The pellet gain versus the input energy.

3. Conclusions

In this paper, we discussed the improvement of the pellet gain by the light-material target structure, the optimizations of the HIB input pulse shape and the HIB input pulse energy. The optimized target structure consists of the Al thickness 30μm and the C thickness 500μm as a tamper and a HIB-energy absorber, respectively. We obtain the higher gain in this study, compared with that for the heavy-material target (see Fig.1 (a)). In the near future, a robustness of the target implosion against the implosion nonuniformity should be studied.

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References

[1] C. K. Li, F. H. Seguin, J. A. Frenje, R. D. Petrasso, Phys. Rev. Lett. 92, 205001 (2004)

[2] M. Tabak, D. Callahan-Miller, Phys. Plasmas 5, 1895 (1998)

[3] D. A. Callahan, Appl. Phys. Rev. Lett. 67, L3254 (1995)

[4] M. Tabak, D. Callahan-Miller, D. D. M. Ho, G. B. Zimmerman, Nucl. Fusion 38, 509 (1998)

[5] S. H. Glenzer, L. J. Suter, R. E. Turner, B. J. MacGowan, K. G. Estabrook, M. A. Blain, S. N. Dixit, B. A. Hammel, R. L. Kauffman, R. K. Kirkwood, O. L. Landen, M. C. Monteil, J. D. Moody, T. J. Orzechowski, D. M. Pemmimgton, G. F. Stone, T. L. Weiland, Phys. Rev. Lett. 80, 2845 (1998)

[6] M. D. Cable, S. P. Hatchett, J. A. Caird, J. D. Kilkenny, H. N. Kornblum, S. M. Lane, C. Laumann, R. A. Larche, T. J. Murphy, J. Murray, M. B. Nelson, D. W. Phillion, H. Powell, D. B. Ress, Phys. Rev. Lett. 73, 2316 (1994)

[7] S. Kawata, K. Miyazawa, T. Kikuchi, T. Someya, Nuclear Instrument and Methods in Physics Research A 577, 332 (2007)

[8] K. Miyazawa, A. I. Ogoyski, S. Kawata, T. Someya, T. Kikuchi, Phys. of Plasmas, Vol. 12, 122702 (2005)

[9] S. Kawata, K. Miyazawa, A. I. Ogoyskii, T. Kikuchi, Y. Akasaka, Y. Iizuka, Journal of Physics : Conference Series 112, 032028 (2008)

[10] T. Someya, K. Miyazawa, T. Kikuch, S. Kawata, Laser and Particle Beams, 24, 359-369 (2006)

[11] B. G. Logan, L. J. Perkins, J. J. Barnard, Phys. Plasmas 15, 072701 (2008)