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Implosion dynamics in fuel pellet with adjusted structure for ion-beam stopping range in heavy-ion inertial fusion

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Heavy-ion-beam inertial confinement fusion (HIF) is a reliable energy source for future human society [1]. Normally, the irradiation scheme for HIF is indirect driven by heavy-ion-beams (HIBs). A massive-ion beam driver system proposed by Takayama, et al provided a direct driven method for HIF [2]. However, the HIBs from massive-ion beam driver system are still limited from the irradiation point. In the direct drive HIF, the fuel pellet usually consists of tamper, ablator, and fuel layers. The HIB irradiation heats up the ablator layer to expand and compress the fuel layer to a high temperature state to ignite the fuel. The nonuniformity of compression results in a decrease in the compression of the fuel. The limited irradiation from incident HIBs leads nonuniformity of the energy deposition in ablator layer, which becomes the source of nonuniformity of compression process.

The HIBs deposit the major part of energy in the Bragg peak at the end of the stopping range. The adjustment of fuel pellet structure can be an effective method to reduce the nonuniformity in energy deposition of HIBs [3]. As is shown in Fig.1, at the center of incident HIB the thickness through tamper and ablator is b, however, at the edge of incident HIB, the thicknesses through tamper and ablator are a and c, and b < a = b, thickness of tamper are different in different region of incident HIBs, which leads the nonuniformity of the Bragg peak region in the ablator layer. Meantime, the pressure gradient from irradiated region to non-irradiated region in ablator leads to the movement of ablator material from the irradiated region to non-irradiated region, which creates a low-density region, and the stopping range of HIB shifts to the fuel layer to preheat the fuel.

To reduce these two unfavorable phenomena, we designed a novel fuel pellet structure shown in Fig.2. The shaded red areas are the areas covered by incident HIBs, and a heavier material is filled in ablator layer to reduce the material movement due to pressure gradient from irradiated region to non-irradiated region. Additionally, the tamper layer is modified to a flower pedal shape to reduce the thickness differences in different region of incident HIBs. In Fig.2, the radius of flower pedal of tamper is 2.47 mm (a tamper with a radius of 4.07 mm is a conventional spherical tamper).

We will report the results of examining the effects using numerical simulations.

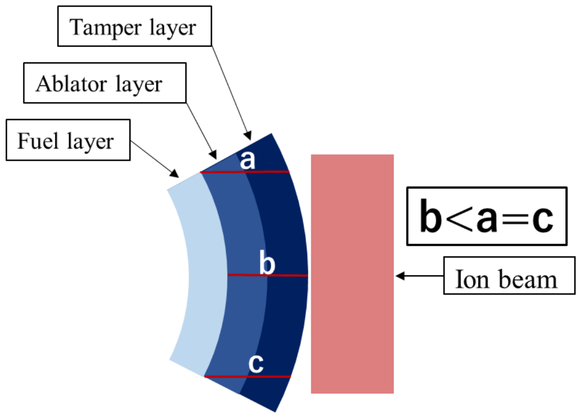

Figure 1. HIB irradiating target with tamper layer. Thicknesses through tamper and ablator are different in different region of incident beam, b < a = c.

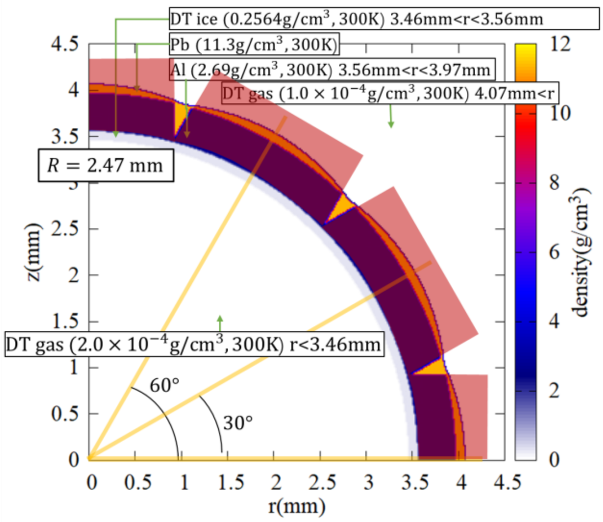

Figure 2. Pellet structure with flower-shaped tamper and non-irradiated region of ablator filled by heavier material. The radius of flower pedal is 2.47 mm, and the shaded red areas are irradiation areas by HIBs.

References

[1] K. Horioka, *Matter Radiat. Extremes* 3, 12 (2018)
[2] K. Takayama, et al., *Phys. Lett.* A 384, 126692 (2020).
[3] Z. Lin, et al, *Plasma Fusion Res.* 17, 2404064 (2022)