Stability of a solid fusion fuel compression using tailored laser pulse

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We propose a solid sphere target, compressed by a temporally tailored laser pulse, as an alternative fusion fuel for fast ignition (FI). The solid fusion fuel for FI has several advantages in the inertial fusion energy development; (i) solid DT fuel is more feasible for mass production compared to layered DT fuel capsule, (ii) solid sphere has larger tolerance to hydrodynamic instabilities due to smaller Rayleigh-Taylor instability growth and smaller in-flight aspect ratio compared to those of the layered capsule. Compresssion of deuterated plastic (CD) solid sphere with Gaussian laser pulse was observed to be hydrodynamically stable even without any beam spatial smoothing techniques by using the Ti-Kα(4.51keV) monochromatic radiography[1].

Maximum density is limitted to about 32 times the initial density for an ideal gas that is compressed by a spherically converging single shock wave. Isentropic compression by tailored shock wave sequence is required to produce higher density fuel, which was first suggested by Kidder in 1974 [2]. The maximum compression ratio is determined by the pressure ratio between the initial value and the final value, and the pressure ratio is correlated with the intensity ratio. The intensity ratio of 10^5 is necessary to compress the ideal gas to 1000 times its initial density. In the early stages of compression, shock waves generated by low intensity lasers, whose ablation pressure is close to or smaller than the Fermi pressure of meterial, are affected by the initial material properties. In the final stage of compression, the laser plasma interaction may affect absorption of the laser light by the plasma and the hot electron generation that preheats the fuel or strengthen the pressure of shock wave. Modeling and experimental results are presented at the conference.

We also have numerically studied dependence of tailored laser pulse shapes and spatial beam non-uniformity on the compression of solid sphere using three-dimensional (3D) hydrodynamic simulation code (IMPACT-3D). Experimental pulse shapes may deviate from designed pulse shapes because of technical limitations and inaccuracies in modeling the equation of states also induce errors in pulse shape design. Resistance to deviation from the designed shape and spatial non-uniformity of applied pressure were investigated using three-dimensional (3D) hydrodynamic simulation code (IMPACT-3D). In this simulation, the spatial pressure distribution on the surface of the solid sphere was calculated by 3D ray tracing code.

References

[1] H. Sawada *et al.*, *Appl. Phy. Lett.*, **108** (2016). [2] R. E. Kidder, *Nucl. Fusion*, **14** (1974).