Physics design for an indirect-drive decompression-and-recompression inertial-confinement fusion capsule

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Compared to the previous low-foot implosions during the National Ignition Campaign (NIC) on the National Ignition Facility (NIF), the high-foot implosion experiments have achieved an encouraging progress towards indirect-drive (ID) inertial-confinement fusion (ICF) ignition with a yield about 26 kJ. However, the hot-spot stagnation pressure is still low about 220 Gbar and the neutron number hits a $10^{16}$ ceiling although some improved high-foot implosions, such as “adiabat-shaping” for higher compression, T-1 and T-1.5 for larger implosion velocity, etc., have been explored. The NIF experiments indicate that the three-dimensional distortions of the hot-spot and the thin-spots in the areal density of the shell impedes the performance improvement. In this report, the physics design of ID decompression-and-recompression (DR) ICF ignition target is proposed to reduce the hot-spot stagnation-phase perturbation growth. Our purpose of ICF ignition implosion is to best trade off the fuel compression and hydrodynamic instability growth for low-, moderate- and high-mode perturbation during the whole implosion. First, the high-foot pulse accelerates the shell with high-adiabat to reduce the ablation-front growth and the low-mode perturbation feed-through. Second, the shell thickness is increased by reducing the temperature of the middle of main drive portion to further reduce the perturbation feed-through. Third, a shock wave is generated by increasing the temperature of the end of main drive, which can compress the fuel again. In particular, when the convergent DR shock is tuned to encounter the divergent shock from the capsule centre at a suitable position, not only the neutron yield but also the stability of stagnating hot-spot can be noticeably improved, compared to the conventional high-foot implosions. The two-dimensional (2-D) radiation hydrodynamic simulations from the LARED-S code confirm the improved deceleration-phase hot spot stability properties without sacrificing the fuel compression. The 2-D cylindrical hohlraum simulation results from the LARED-JC code indicate that the DR high-foot pulse shape can be generated by a laser facility with energy $E_{\text{laser}} \sim 1.8$-MJ (including 15\% energy loss of the incident energy) and maximum power $P_{\text{laser}} \sim 520$-TW.

Reference