DOI: 10.34854/ICPAF.52.2025.1.1.135

«SHOCK IGNITION» EFFECT FOR INDIRECT-DRIVE ICF TARGET *)

Vergunova G.A., Guskov S.Yu.

P.N. Lebedev Physical Institute of the Russian Academy of Sciences,
vergunovaga@lebedev.ru

The shock-ignition method was proposed for direct-drive inertial confinement fusion (ICF) [1]. A distinctive feature of the method is to provide a stronger separation of the processes of compression and heating of a thermonuclear target compared to the traditional approach to spark ignition by using a laser pulse with a significant increase in the power of its final part. The first part of the pulse has the same smooth character of temporary power profiling as in the case of traditional spark ignition, and is intended for slow low-entropy compression of the target at a power of about 100 TW for a time of about 20 ns. In the final part, in a few hundred picoseconds, the power increases 4-5 times and persists for 200-400 ps. This part of the pulse is designed to generate an incendiary shock wave with a pressure of 200-300 Mbar [1,2,3], which provides a high degree of energy concentration in the central area of the target.

In [4], based on simulation and theoretical studies, the possibility of effective application of the shock wave ignition method for the target of ICF indirect irradiation with a pulse of laser-induced X-ray radiation was justified for the first time, including in experiments at the current NIF facility of the Livermore Laboratory (USA) and installations under construction with an energy of about 2 MJ.

The report is devoted to further investigation of the physics of shock-wave ignition of indirect irradiation ICF targets, including the formation of a laser-induced X-ray pulse with a short final stage of multiple power increase, taking into account the dynamics of the thermodynamic state of the laser-to-X-ray converter and matching the parameters of the thermonuclear target with the parameters of the X-ray-generating laser pulse to maximize the thermonuclear gain coefficient. The research is based on numerical simulations of the radiation hydrodynamics of a full cycle of processes, including the interaction of a laser pulse with a converter and the generation of an X-ray pulse for shock wave ignition, the interaction of an X-ray pulse with a capsule, compression, ignition and stagnation of a target. The great potential for increasing the energy efficiency of the indirect-drive target due to the use of the shock wave ignition method is justified: with the same mass of thermonuclear fuel, the gain can be increased by an order of magnitude or more compared to the current record gain in relation to laser energy of about 2 achieved using the indirect-drive traditional spark ignition scheme in experiments on the NIF installation.

In the final part, in a few hundred picoseconds, the power increases 4-5 times and persists for 200-400 ps.

References

[1]. V.A. Shcherbakov, Sov. J. Plasma Phys. 9, 240 (1983).
[2]. R. Betti, C.D. Zhou, K.S. Anderson et al., Phys. Rev. Lett. **98**, 155001 (2007).
[3]. S.Yu Gus'kov et al Plasma Phys. Control. Fusion 64 (2022) 045011 (13pp)
[4]. S.Yu. Gus'kov and G.A. Vergunova. Physical Review E. – 2024. – Vol. 109. – P. 065209. – DOI 10.1103/PhysRevE.109.065209.

*) abstracts of this report in Russian