THE MODELING OF THERMONUCLEAR TARGET COMPRESSION AT LASER ENERGY 1 MJ

Galina V. Dolgoleva[1], Alexandra I. Lebo, Ivan G. Lebo[2]

[1] Institute of Applied Mathematics, Moscow, Russia,

dolgg@list.ru

[2] Moscow Technologic University MIREA, Moscow, Russia,

lebo@mirea.ru

ECLIM-2016

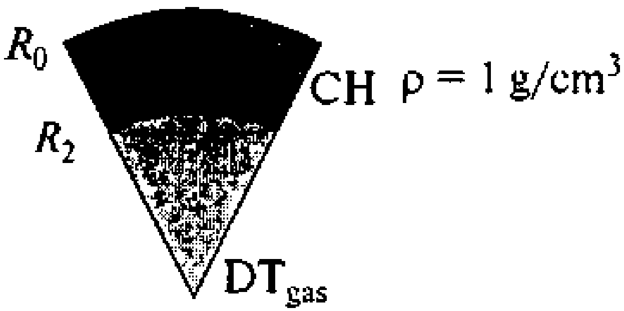
Using the methods of mathematical modeling, we study the possibility of achieving gain in a thermonuclear target compression direct (k_f) of about 1 at an energy laser at 1 MJ. In the calculations we simulated the heating and compression of shell targets of the polymer filled with deuterium-tritium (D-T) mixture. The target was irradiated by a laser with a wavelength of 0.351 μm and energy 1MJ. The laser pulse had a growing front the front to a point of time t_1 , then constant fast decaying pulse and the falling edge. Considered two types of targets: gas-filled and cryogenic. Calculations are made for two programs, and a comparison of the results obtained.

- In the Atlant_Sp program, in Lagrange spherical coordinates, the compression of the capsule target and the generation of spontaneous magnetic fields is simulated in two-dimensional geometry. In the given calculations, the equations of gas dynamics, heat transference for electronic and ionic plasma components, and the propagation of laser beams in the plasma are simulated in spherical coordinates. In the calculations it was assumed that the laser beams are being propagated exactly along the radius and are absorbed due to the reverse bremsstrahlung mechanism. The energy that has achieved the critical surface is absorbed in the nearest Lagrange cell. The plasma in the calculations was ideal and totally ionized but at the end stage there was a possibility to include the degeneration of the Fermi-Dirac electronic component.

- The one- dimensional Lagrange procedures (CND-code) were created for calculating the thermo-nuclear synthesis targets (laser and heavy-ion). They are based on a system of equations of nonequilibrium radiation gas dynamics. It includes equations of gas dynamics (taking into account electronic and ionic temperatures), the transfer of heat by ions and electrons with the limitation of the diffusion flow, the transfer of radiation in the spectral quasi-diffusion approximation and its interaction with matter, the absorption and transfer of laser energy, the kinetics of the thermonuclear reactions, and the kinetics for the calculation of a medium's non-equilibrium. A medium's non-equilibrium is calculated by approximation of the middle ion.

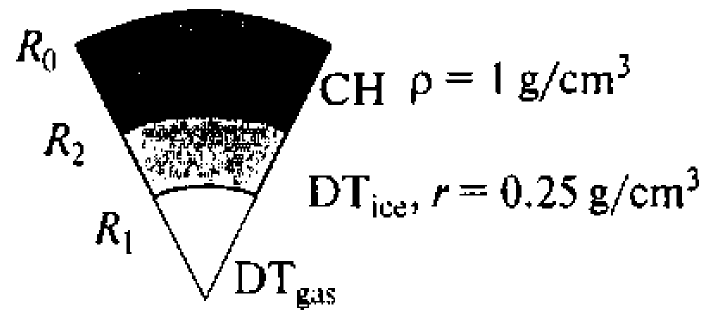
(a)

Gas filled target



(b)

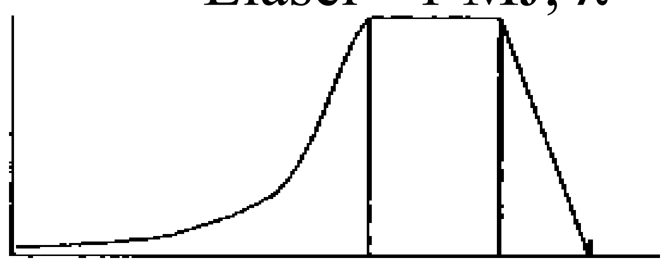
Cryogenic target



(c)

Time form of laser impulse

Elaser= 1 MJ, $\lambda = 0.351$ µm



0 t_1 t_2 t_3 t ns

Fig. 1. Scheme of capsule gas-filled (a) and cryogenic (b) targets; time form of the laser impulse (c).

- For comparison calculations were the following parameters of targets that are not optimal results one-dimensional calculations. This was done intentionally, since the development of hydrodynamic instability introduces a strong uncertainty in the validity of the results that actually shown by the data of experiments at the NIF facility. The authors picked these parameters to ensure the reliability in the predictions, that is, shell had moderate values of aspect ratio (As=60) and the degree of compression of fuel on C_R 10 for gas-filled target, and at 30 for cryogenic. As the target material was taken as the polymer without the incorporation of functional layers from heavy metals. At the same time, from comparison we can conclude the following. The switch to direct compression allows to predict the achievement gains of the target at 1.

The achievement of this level of fusion energy (k_f ~ 1 at E_{las}~ 1MJ) is an important step towards the research on creating an energy reactor based on thermonuclear fusion.

The experimental studies of the hot (*Ti*~ 10 keV) dense plasma in the vicinity of the physical threshold of the fusion reactions ($k_f \geq 1$) can also be of considerable interest in astrophysics and a number of practical applications.

Notice: In details, it would be able to find these results in journal: Mathematical Models and Computer Simulations, 2016, Vol.8, No.4, pp.438-445

BASIC RESULTS

1. The comparative calculations of the radiation and compression of capsule laser targets were carried out by two independent techniques and the satisfactory agreement of the calculation results is shown.

2. By the methods if mathematical simulations, it has been shown that with an energy of the laser impulse at a level 1 MJ and direct radiation of capsule targets , it is possible the achieve the coefficient of fusion amplification in the target of more than 1.

3. Creation of a stable and reliable source of fusion neutrons based on comparatively simple target structures, providing a yield at level of 10^{16}-10^{17} neutrons for laser implosion will allow one to start experimental works on the development of a hybrid nuclear-thermonuclear reactor.

4. It is shown that in direct compression it is possible to obtain the neutron yield by an order of magnitude greater than that obtained in experiments at the NIF facility (LLNL,USA) for indirect compression (indirect drive target).