SIMULATION OF THE HOHLRAUM FOR A LASER FACILITY OF MEGAJOULE SCALE

M.N. Chizhkov, M.Yu. Kozmanov, S.N. Lebedev, V.A. Lykov, V.V. Rykovanova, V.N. Seleznov, K.I. Seleznova, O.V. Stryakhnina, A.A. Shestakov, A.V. Vronskiy

Russian Federal Nuclear Center – VNIITF
Vasileva str. 13, Snezhinsk, Chelyabinsk reg., Russia, 456770

E-mail: M.N.Chizhkov@VNIITF.ru

Abstract. 2D calculations of the promising laser hohlraums were performed with using of the Sinara computer code. These hohlraums are intended for achievement of indirectly-driven thermonuclear ignition at laser energy above 1 MJ. Two calculation variants of the laser assembly with the form close to a rugby ball were carried out: with laser entrance hole shields and without shields. Time dependent hohlraum radiation temperature and x-ray flux asymmetry on a target were obtained.

Introduction

The 2D Sinara computer code was developed in VNIITF for simulation of accidental conditions in fast neutron reactors [1]. It was used to simulate the destruction of the reactor core casing and consequences from the destruction of structural components of a nuclear power plant, etc. Sinara code was also used for thermal analysis of the experimental facility ATLAS [2]. Latter its capabilities were extended to allow radiation transport simulations in multigroup kinetic approximation by the finite-difference DSn-method [3]. Then the Sinara code has been adapted for calculations of laser hohlraums, specifically, the equation of energy for matter now considers electronic heat conductivity with flux limitation, a 3D model of laser light absorption is implemented.

Results of first calculations of a laser hohlraum by the Sinara code are presented in the report. For laser energy saving and improving of x-ray flux uniformity on the target the configuration of hohlraum in the form of a rugby ball [4] was used. The calculation variant with the laser entrance hole shields [5] was also performed. Time dependent hohlraum radiation temperature and x-ray flux asymmetry on a target were calculated.

1. Calculation setup

The chosen design of the laser hohlraum is presented in Fig 1. Length of the system is 1.1 cm, equatorial radius – 3.5 mm, radius of laser entrance holes (LEH) – 1.8 mm, LEH are covered by a CH film with thickness of 1 µm. The internal cavity of the hohlraum is filled by the equimolar mixture of hydrogen and helium with the density of 0.8 mg/cc. In the system centre there is a spherical pellet with the external radius of 1.2 mm.

The variant of calculation with the additional shields covering LEH is also performed. LEH shields are golden disks 0.5 mm in radius and 20 µm in thickness. Their hole-facing surfaces are covered with a CH layer 10 µm thick. The shields are 1.2 mm distant from the outer surface of the target. The position and size of shields were optimized using the view factor code [6] in fixed geometry.
Laser radiation transfer and absorption were simulated with the 3D model. Refraction and reflection of laser rays was not modeled (fixed rays trajectories). Irradiation scheme is shown in Fig.2. Laser radiation of a wavelength $\lambda = 0.35 \, \mu m$ was directed into the hohlraum in six cones, three through each LEH. Total laser power versus time was defined in accord with French work [7] (Fig.3). The distribution of laser power between the cones changes with time, the powers of the middle and outer cones are identical. The time dependent energy fraction in the inner cone shown in Fig.4 was defined so that to reduce the second harmonic of x-ray flux on the target to less than 3%.

The spatial grid is essentially not orthogonal and consists from about 60000 cells (Fig.2). Quantity of photons energy groups is 10, number of photons flight directions – 144. Calculations were done with interpolated equations of state in the form proposed in [8] and opacities calculated with the average atom model [9].

2. Calculations Results

X-ray radiation temperature in the hohlraum is one of the most important characteristics for the indirect drive ignition. Fig.5 shows results of the Sinara code calculations for the hohlraum with and without LEH shields. Using of shields has allowed increasing the peak x-radiation temperature on 2% from 310 eV to 317 eV.

For the quantitative analysis of irradiation asymmetry the radiation flux on the target was expanded in terms of Legendre polynomials. Figures 6 and 7 show the amplitudes of radiation flux non-uniformity for Legendre modes $l = 2$ and 4.
The maximum value of amplitude of the second and fourth harmonics most the time does not exceed 5%. Time averaged value of the second harmonic has made 0.29 % ($\sigma = 2.1$ %) in hohlraum without shields, and in hohlraum with shields $-0.59$ % ($\sigma = 2$ %). Average value of the fourth harmonic has made $-1.5$ % ($\sigma = 2.3$ %) and $-1.2$ % ($\sigma = 2.4$ %) for assemblies with and without shields, accordingly. For the symmetry improvement the further optimization is required.

Figures 8-11 show state of the system at the time of the maximum laser power.
Conclusion
Performed two-dimensional calculation has confirmed the possibility of laser hohlraums modeling with the Sinara code. The calculated symmetry of the target irradiation could be improved in both considered system. However it would be excess of calculation accuracy because physical models included in the Sinara code require the further development. Firstly, the implemented laser absorption model does not consider the refraction and reflection of laser rays. Its consideration may lead to some redistribution of laser radiation absorption in a hohlraum. Secondly, Sinara calculations did not allow for the influence of the nonequilibrium ionic structure on absorption coefficients and radiation emission in golden walls. Development of the Sinara code will be continued. It could be used for design of indirectly driven experiments on the Iskra-6 facility which is planned to be constructed in Russia [10].

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