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Simulations of X-ray Fields Generated by Laser in LABIRINTH Target on ISKRA-5 Laser Facility

S.A.Bel'kov, I.M.Belyakov, I.S.Nuzhdina, O.A.Vinokurov

Russian Federal Nuclear Center – Institute of Experimental Physics (RFNC-VNIIEF), 607190, Prospect Mira 37, Sarov, Nizhny Novgorod region, Russia

For some application, for example, for EOS studies on powerful laser facility [1, 2], it is necessary to have a very uniform irradiation of the surface of plane target. For this purpose it is convenient to use special laser X-ray sources, where laser beams are converted to soft X-rays. On ISKRA-5 laser facility [3] two types of laser targets were investigated that can be used as such X-ray sources. Theoretical consideration shown that it is possible to achieve non uniformity less then 3% for experimental condition of ISKRA-5. One of them called ILLUMINATOR [4] widely use in experimental studies of X-ray propagation through the cylinder channel. Another type of X-ray source is a LABIRINTH target.

The LABIRINT target is similar to the target used in the experiments of Refs. [5, 6]. It is a spherical golden box with two holes. Laser radiation enters the box through one of the holes and illuminates the golden cone located in the box center (Fig. 1). The cone in the box is fastened by means of a thin polymer film (chemical composition is equivalent to CH) with a thickness of 1 micron. This film is transparent to X rays and opaque to scattered laser radiation. Thus, the right half of the box is filled only with X rays produced as a result of laser beam absorption in the left half of the box.

Due to its cylindrical symmetry, this target is attractive for 2D modeling. Such modeling might be of interest for revealing characteristic features of its operation and estimating the limit parameters of X rays at the exit hole.

In the computations discussed, the outer diameter of the box D_{box} made 710 microns, and the wall thickness, 40 microns. The diameter of the laser beam entry and X ray exit holes d_1 made 300 microns. Cone wall thickness made about 20 microns. The cone base diameter d_2 also made 300 microns, and the cone height $d_3=d_2/2$.

To model the laser to X-ray conversion and propagation of X-ray in this target we perform 2D calculation using MIMOZA-ND [7] and SATURN [8] codes. This codes differ to each other by approximations used to calculate X-ray transfer. Non equilibrium multigroup diffusion approximation is used for X-ray transfer calculation in MIMOZA-ND code and spectral kinetic equation is used in SATURN code. These computations took into account the following physical processes: two-temperature gas dynamics with electron and ion heat conductivity and electron-ion relaxation; non-equilibrium and non stationary spectral X-ray transport in the diffusion or kinetic equation approximations; energy absorption of laser radiation in the laser corona; non-equilibrium and non stationary plasma ionization kinetics in the average-ion approximation. The transport coefficients, spectral X-ray opacities, spectral luminance of plasma and EOS of matter were calculated in the average ion approximation [9, 10].

The typical value of laser energy was 200 J and laser pulse duration was 0.4 ns. It corresponds to the typical condition of ISKRA-5 experiments. The maximum of laser pulse is reached at time moment 1.0 ns. To simulate laser absorption we used 2 approaches. In the first one special Monte-Carlo computations of laser beam propagation in the left half of the box were performed to specify the laser energy release [11]. With a prescribed density profile in the stationary plasma approximation, there were performed computations of absorption of laser beams coming from the focusing optics of ISKRA-5 taking into account their refraction in the laser corona and re-reflection on the critical surface. Then tabulated results of these computations used in MIMOZA and SATURN codes. This approximation has the restricted application because hot plasma generated inside the box fills rather quickly the left half of the target and laser radiation will be reflected.

In the second one the ray-tracing method used to calculate laser energy deposition inside the box. With the help of it the distribution of absorption energy of laser intensity is calculated at every time step at every plasma point. The last method used in MIMOZA-ND code only.

The major goal of the computations was to determine the basic parameters of X rays, such as the spectrum, spatial distribution and time dependence in the exit hole section. As our calculations shown the boxes gap is closed approximately at the time moment close to maximum laser pulse. So only one half of laser energy can be input to the target. Fig. 2 shows the effective X-ray temperatures as a function of time at the center of exit hole of LABIRINTH obtained in MIMOZA-ND simulations with full (curve 1) and truncated (curve 2) laser pulse. So due to effect of gap closing the maximum X-ray temperature decreases and is less then 85 eV. The result of SATURN calculation is shown et Figure 2 (curve 3) also. One can see that both codes give close behavior.

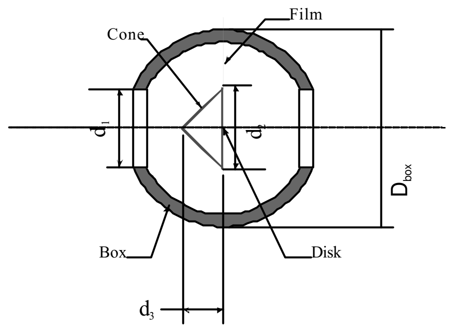

Figure 1. Typical design of LABIRINTH target used in ISKRA-5 facility experiment.

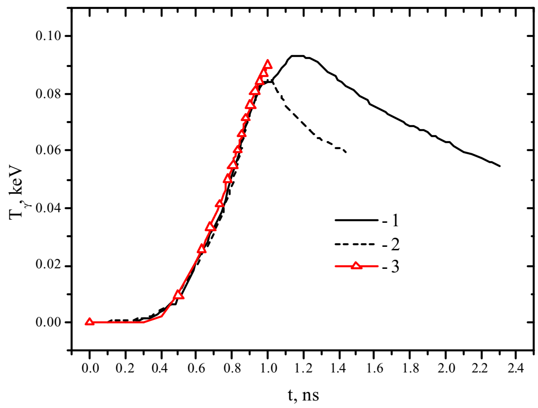

Figure 2. Comparison of effective X-ray temperature dependencies versus time in outgoing hole for different simulations which used MIMOZA-ND code standard (1) and truncated (2) laser pulse and SATURN code (3).

At Figure 3 time integrated X-ray spectra obtained at different time moment in MIMOZA-ND and SATURN computations are shown. As one can see that outcome spectrum is non equilibrium. The maximum of X-ray spectral density is close to quantum energy 600 eV. For blackbody spectrum it corresponds to X-ray temperature 200 eV. But as we see at Fig. 2 the X-ray flux is significantly less then the X-ray flux with this temperature. The both codes give rather good agreement to each other. The nonuniformity of X-ray temperature obtained at section of exit hole in our calculations is less then 2%.

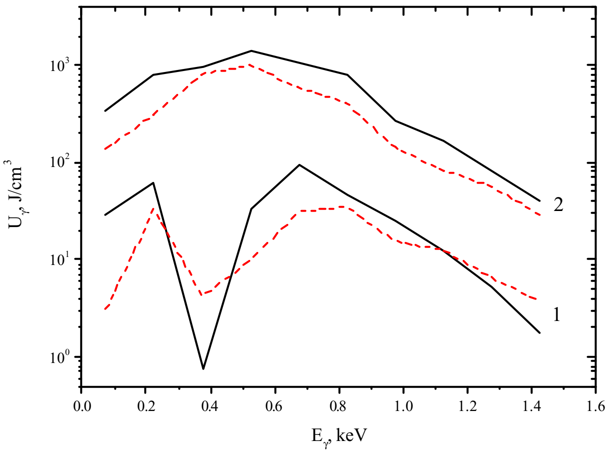

Figure 3. X-ray spectrum in outgoing hole obtained in SATURN (solid curve) and MIMOZA-ND (dashed curve) calculations at different time moment t=0.74 ns (1) and t=1.0 ns (2).

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