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Influence of Controlled Asymmetry of X-Ray Field on Neutron Yield Generation in Indirect Drive Experiments on Iskra-5 Laser Facility

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ISKRA-5 facility [1] were used to perform investigations of the effect of controlled X-ray field asymmetry on the compression degree and the neutron yield in indirect (X-ray) drive targets [2]. 12 beams of ISKRA-5 facility were input into the spherical gold hohlraum of 2 mm in diameter [3] through 6 laser entrance holes of 600 micron in diameter. The glass spherical target (microballoon) with DT gas was placed inside the box. The laser radiation input was on the inner surface of the hohlraum. The typical input laser energy was between 6.3-7.8 kJ and the FWHM pulse duration was 0.28-0.39 ns. X-ray generated on the wall of the box irradiates the glass microballoon. The field asymmetry was induced by shift the central glass capsule with respect to the center of hohlraum forward to the special 7th hole 600 micron in diameter. In different experiments relative shift Δ/R_{box} was varied as 0, 1/3, 1/2, 2/3, 1 (here Δ is a shift, R_{box} is a hohlraum radius). The experiments demonstrated neutron yield reduction with increasing of asymmetry degree (see figure 1). In parallel with this fact, shifting of microballoon about central position caused the rise of compression time $\tau_{\gamma n}$, which was determined by indirect method using the compressed region X-ray luminescence [4]. To carry out analysis and comparison with 2D calculations we show on figure 2 the time delay of neutron generation as a function of target shift calculated relative the time delay of experiment with zeros (symmetrical case) shift.

To determine the degree of X-ray field asymmetry on the surface of microballoon we performed calculations of laser and X-ray propagation in the hohlraum for its different position (shifts). The results of these calculation are presented on figure 3.

Then these dependencies were used in 2D simulations using code MIMOSA ND [5]. In these calculations the compression of central capsule under asymmetry X-ray field condition was studied. The boundary condition of spectral X-ray field density $U_\nu(t,\theta)$ was the following:

$$U_\nu(t,\theta) = U_\nu(t)\cdot f(\theta),$$

where $U_v(t)$ was calculated in full scale 1D calculations for symmetrical case using experimental data for laser pulse and target parameters. Asymmetry function $f(\theta)$ was taken from figure 3.

In 2D simulation we used experimental parameters of the target too. The maximum asymmetry was realized to the case with shift $\Delta/R_{box}=1$. For this case calculated neutron yield decreased more then 1000 time relative the case with capsule in center of the hohlraum. Calculated neutron yield versus microballon shift is shown on figure 1 too. On this figure we presented also the calculated dispersion of the X-ray filed on the surface of central target. One can see that theoretically calculated asymmetric X-ray field allows to give satisfactory explanation for the experimentally observed neutron yield reduction in relation to the microballoon shift value. The simulations showed also that there is the time delay of neutron generation relative to the self generated X-ray pulse.

Analysis of simulations showed that shift of the target on value comparable with its diameter weakly influences on compression dynamic and neutron yield. Such behavior caused by the fact that X-ray filed dispersion has gently sloping minimum near the hohlraum center. It is the explanation of high stability of experimental results with symmetrical target observed on ISKRA-5 facility [6].

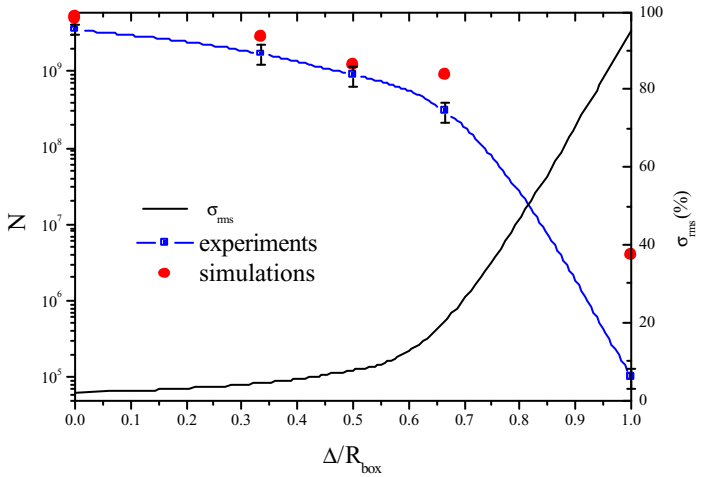


Figure. 1. Experimental and calculated neutron yield as a function of relative shift of the glass target with DT gas. σ_{rms} is calculated dispersion of X-ray field on the surface of the target.

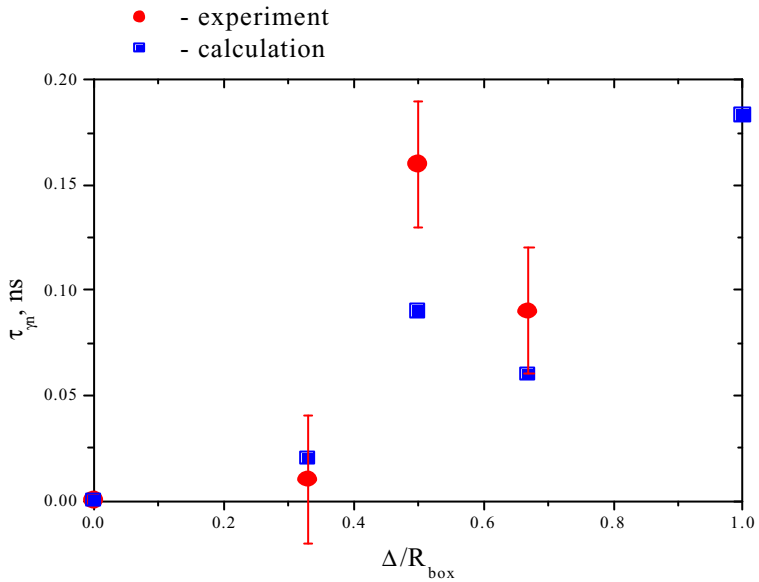
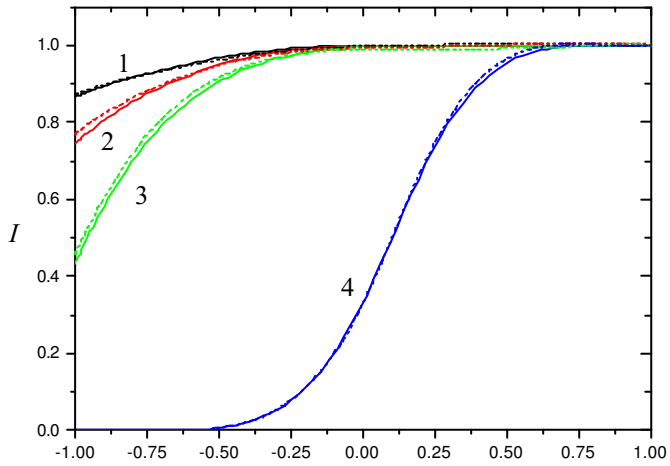


Figure. 2. Experimental and calculated time delay of the neutron yield generation versus glass target position.



Figuer 3. Calculated asymmetry of X-ray field on the surface of the glass microballoon for its different positions Δ/R_{box} = 1/3 (1); 1/2 (2); 2/3 (3); 1 (4). Solid curves are an asymmetry induced by 1 hole, dashed curves are an averaged over azimuth angle asymmetry induced by 7 holes.

Now discuss the results of measurements of neutron yield generation time. Experimental results showed that for zeros or small values of shifts of the central microballoon the average value of $\tau_{\gamma n}$ is smaller in comparison with the experiments with large shifts. Analogous dependency was obtained in behavior of neutron generation time in simulations of these experiments using 2D hydrodynamic code MIMOZA-ND. Calculated results are shown on figure 2 too.

One can see that simulation results qualitatively are rather close to the experimental dependency of time delay upon the shift normalized to the radius of the box-converter. From our point of view some quantitative discrepancy is unessential. For very large asymmetry corresponded to the shift $\Delta/R_{box}\sim1$ we obtained in simulation very sharp increase of time delay. Unfortunately in experiment the whole neutron yield less then the threshold of sensitivity of neutron detector and we could not see this effect directly. Besides experimental data shows more strong dependence of time delay upon the shift for shifts value in diapasons $\Delta/R_{box}=0.5\div0.7$. Nevertheless in spite of these different we can conclude that there are good qualitative and quantitative agreements between our MIMOZA-ND simulations and experimental data. We believe that this difference can be understood if more detailed information about experimental conditions will be included in simulation. So we can conclude that performed experiments are the very convenience instrument to study of accuracy of 2D codes.

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