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TWO-DIMENSIONAL NUMERICAL SIMULATIONS OF LASER IRRADIATED TARGETS

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Abstract

We present numerical simulations of strongly two-dimensional laser experiments.

First, it is concerned to restitute the direct driven implosion of microballoons irradiated with the two beams of Phebus laser facility at 0,53 µm wavelength and 3.2 TW power.

In the second experiment, we study the impact between two foils. The accelerated foil is irradiated at 0,35 µm wavelength with a power of 20 GW.

The numerical simulations are realized with the two-dimensional lagrangian FCI 2 code. The X-ray diagnostics are simulated with the DXFCI 2 code.

In spite of numerical difficulties, principally close to the laser axis and the target interfaces, calculations have been carried out for a sufficient long time to provide results in accordance with the experiment.

A simulation of the implosion of 600 µm in diameter microballoons made with an absorption rate of 40 % provides a neutron yield as well as X-ray emission peaks in agreement with the experiment.

In the plane target case, it is shown that, for 80 µm in diameter focal spot, the 2D effects occuring in the acceleration of the foils influence in a preponderant way the energy transfer between these two foils.

1. HYDRODYNAMIC FCI2 AND DIAGNOSTIC DXFCI2 CODES

FCI2 is a two-dimensional lagrangian code with cylindrical revolution symmetry. The incident laser beam is either parallel to the symmetry axis, or focused on a point of this axis. The bremsstrahlung absorption is treated by means of a ray-tracing method with 100 laser beamlets. A fraction of the incident energy on the target is absorbed by inverse bremsstrahlung along the laser beams and a fraction of the power reaching the cut-off density is taken to simulate resonant absorption. The resonant absorption can be shared in :

- absorption on thermal electrons

- creation of suprathermal electrons

The X-ray emission and suprathermal electrons transport are computed with a multigroup method. The thermal electron flux limiter is equal to 0.05.

DXFCI2 is the code allowing to simulate the diagnostics of the X-ray emitted during the target implosion. These diagnostics are X-ray pinhole and streak cameras in the range 0.8 - 4 keV. DXFCI2 works as post-processor of the FCI2 code. At a fixed time, the initial radiative intensity Io is calculated for every 2D mesh. The 3D mesh zoning is built up by means of cylindrical symmetry round the laser axis. Then, the radiative transfer equation driving Io evolution up to the diagnostic is resolved. The detection direction (generally 90° from the laser axis), the diagnostic-plasma distance, the pinhole diameter and the attenuators placed between the plasma and the diagnostic are taken into account.

2. SIMULATIONS OF MICROBALLOON IMPLOSION

2.1. CONDITIONS OF THE EXPERIMENTS

The experiments are performed with the Phebus laser facility operating at 0.53 μm wavelength [1], [2].

The laser pulse varies from 200 ps to 1 ns (FWHM). In the 200 ps case, the pulse is fitted to a gaussian shape with a maximal power of 3.2 TW ; this corresponds to 820 J incident energy for the two beams of Phebus system. The laser beams are focused tangentially to the target as indicated on inset of Fig.1. The irradiance repartition within the focal spot is approximately gaussian.

The targets are glass microballoons (SiO_2) full with deuterium-tritium (DT). Their characteristics are as follows :

- microballoon diameter :

  200 µm < D < 630 µm at 200 ps

  600 µm < D < 975 µm at 1 ns

- SiO_2- shell thickness :

  about 1 µm at 200 ps

  about 2 µm at 1 ns

- DT pressure : 5 bars

Some of these microballoons are coated with Au (about 0,1 µm in thickness). The goal of such a coating is to improve the implosion symmetry owing to radiative transfer. In this case, pinhole photographs show that the transverse dimension of the core is reduced.

2.2. NUMERICAL RESULTS

We present the simulation of a glass microballoon implosion irradiated with 200 ps laser pulse. Here, the diameter and the thickness of the target are respectively 631 µm and 1.22 µm.

In this simulation, the absorption of laser energy is treated with an absorbed energy rate of 40% in accordance with the experiment. The ratio of the suprathermal electrons energy to the incident energy is equal to 7.3%.

In spite of numerical difficulties, principally due to mesh crossing on the axis, the calculation has been carried out up to 992 ps. Figure 1 illustrates the hydrodynamic behavior of the target at 900 ps.

The neutron yield is equal to 3.10^6 after the first shock convergence. This value is in agreement with the experiment.

On pinhole and streak-camera pictures a core emission is seen. The time delay between the corona emission and the core emission is about 1 ns. The numerical pictures obtained with the DXFCI2 code reproduce the experimental photographs.

Other simulations have been carried out with an Au coated target irradiated with 1ns laser pulse. Experimental results are compared to calculations using either a LTE treatment or a non-LTE treatment based on the Mixed Model [3]

3. SIMULATIONS OF THE DOUBLE-FOIL EXPERIMENTS

3.1. CONDITIONS OF THE EXPERIMENTS

The experiments are realized with the P 102 laser facility operating at 0.35 µm wavelength [4]. The laser pulse was 850 ps FWHM. It is fitted to a double-gaussian shape with a maximal power of 20 GW ; this corresponds to a maximum irradiance of 2.10^{14} W/cm^2 for 10 J incident energy. The laser beam is parallel to the symmetry axis. The averaged irradiance profile measured in the focal spot (80 µm FWHM) is represented on Fig. 2.

The targets are double-foils of aluminium. The thicknesses of irradiated and impact foils are 3 µm and 1,5 µm respectively. The foil separation is 40 µm.

3.2. NUMERICAL RESULTS

For these simulations, using a short wavelength induces that the suprathermal electrons are not taken into account.

The impact and the shock transfer between both foils are treated by a lagrangian method with rezoning capabilities.

The collision between both foils occurs at 715 ps. At this time, the axial and radial velocities of the accelerated foil dense part are respectively equal to 10^7 cm/s and $2.5.10^6$ cm/s. The induced shock reaches the second foil rear face at 800 ps.

As in the spherical simulations, the calculation is affected by numerical difficulties ; however it has been carried out up to 1.05 ns (Fig.2). At this time, the axial velocity of the accelerated foil dense part is practically unchanged ($1.1.10^7$ cm/s), while the radial velocity has sensibly increased

(~ 6.10^6 cm/s) in the zone between 40 µm and 70 µm. This increasing of the radial velocity shows clearly the lateral expansion of the foil. In the same way, the radial velocity of the zone under collision of the impact foil increases up to 4.10^6cm/s on a 100 µm diameter.

These results confirm previous simulations realized with a 3 µm thick aluminium single foil [5] ; it has been shown that at 1.25 ns the accelerated surface is about six times higher than the focal spot surface.

On Fig.2, due to numerical limitation, the velocity of the impact foil rear face close to the laser axis is overvalued (~ 2.10^7 cm/s) ; this leads to an artificial deformation of the meshes. However, the shape of the dense part iso-densities is not affected by this phenomenon.

4. CONCLUSION

The numerical restitution of strongly two-dimensional experiments has been undertaken by means of the FCI2 and DXFCI2 codes.

In the case of the implosion of 600 µm in diameter microballoons irradiated with the Phebus laser facility at 0.53 µm, the shock neutron yield as well as the time delay between the core emission and the corona emission are in agreement with the experiment. For the double-foil experiments performed with the P 102 laser facility at 0.35 µm, the calculation has been carried out up to 430 ps after the impact between both foils. The motion of the second foil has been investigated on a 100 µm distance and a 160 µm diameter for a 80 µm focal spot and a 40 µm foil separation.

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FIGURE CAPTIONS

FIGURE 1

Hydrodynamic behavior of the spherical target at 900 ps. The laser beams are focused as indicated on inset.

FIGURE 2

Laser irradiance profile and hydrodynamic behavior of the double-target at 1,05 ns.

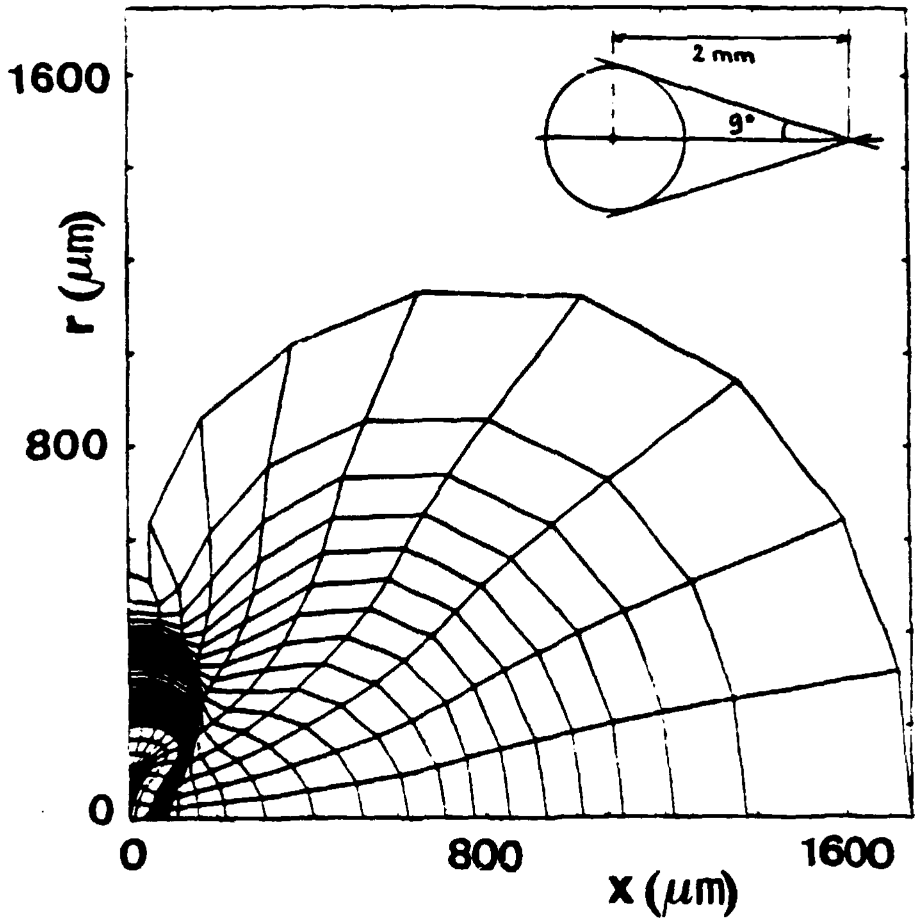

Fig.1

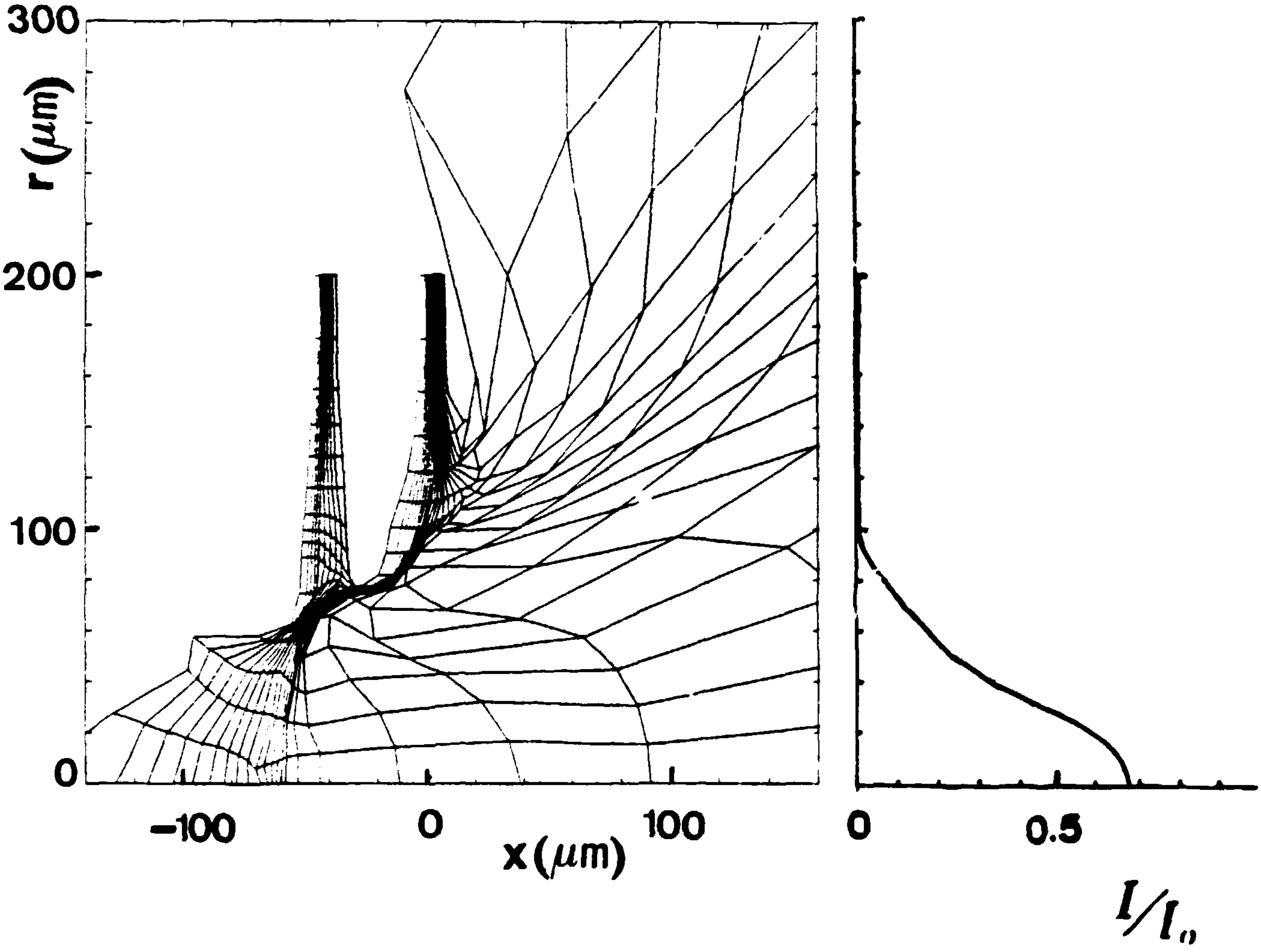

Fig.2