X-ray images and collapse time of gas-filled glass microspheres with an aspect ratio of 100–200 at a specific energy deposition 0.2 J/ng[1)]

V. V. Volenko, A. F. Ivanov, L. A. Myalitsin, L. A. Osadchuk, and
A. I. Saukov

(Submitted 21 January 1983; resubmitted 28 February 1983)
Pis'ma Zh. Eksp. Teor. Fiz. **37**, No. 7, 328–331 (5 April 1983)

Experiments on the laser bombardment of gas-filled glass microspheres with an aspect ratio $R/\Delta R = 100$–200 are reported. The SOKOL laser installation was used. The laser power density at the target was $q \simeq (2$–$4) \times 10^{14}$ W/cm^2; the laser pulse length was $\tau_p \simeq 1.0$ ns or $\tau_p \simeq 0.3$ ns; and the specific energy deposition was $\mathscr{E}_0 \simeq 0.2$ J/ng.

PACS numbers: 52.50.Jm, 52.70. – m, 07.85. + n

1. At a moderate laser power density at the target, $q \simeq (2$–$4) \times 10^{14}$ W/cm^2, the only way to raise the specific energy deposition to the values $\mathscr{E}_0 > 0.1$ J/ng required for increasing the neutron yield[1] is to use targets of small mass and high aspect ratio $R/\Delta R$.

On the other hand, using thin shells to increase the aspect ratio in an effort to increase the specific energy deposition $\mathscr{E}_0$ run the risk, according to two-dimensional numerical calculations[2,3] of causing a pronounced growth of short-wave symmetry perturbations:

$$A/A_0 \sim \exp(R/2\Delta R)^{1/2} .$$

In other words, this approach can increase $\mathscr{E}_0$ at the expense of an instability of the compression in the adiabatic regime.

High densities of a *dt* gas, densities $\rho_{dt} \simeq 4$–14 g/cm^3, and volume-compression factors $\delta \simeq 10^3$ have been achieved under quasiadiabatic conditions in experiments with the ZETA and SHIVA[4,5] devices with targets having a low aspect ratio, $R/\Delta R = 2$–5, with $2R_M \simeq 100$–250 μm. It was pointed out in Refs. 4 and 5 that the experimental results agree well with the results of numerical calculations from one-dimensional gasdynamic programs for $R/\Delta R = 2$–4, implying that the pronounced compression is stable at these low aspect ratios.

2. A series of experiments with thin targets, with a large aspect ratio $R/\Delta R = 100$–200 and a small mass $M_0 \simeq 40$–60 ng, has been undertaken with the SOKOL installation[6] in an effort to increase $\mathscr{E}_0$ at the time of the target collapse. The characteristics of the targets and of the laser pulse, the absorbed energy $\check{E}_n$, and the shell collapse time τ_c in these experiments are all listed in Table I. The bombardment geometry is similar to that described in Ref. 7.

The inhomogeneity of the bombardment, determined by the method of Ref. 7, is $\simeq(\pm 10\%)$. The inhomogeneity of the absorption of the laser energy, on the other hand, is about half this value, as shown in Ref. 8.

© 1983 American Institute of Physics

TABLE I.

Experiment	43	50	54	58
E_L (J)	208	140	190	115
τ_p (ns)	1.0	1,0	1.0	0.3
q (W/cm^2)	$2.2 \cdot 10^{14}$	$1.5 \cdot 10^{14}$	$1.4 \cdot 10^{14}$	$3.3 \cdot 10^{14}$
$2R_M$ (μm)	160.2	158.6	116.4	122.6
ΔR (μm)	0.48	0.4	0.36	0.36
$\delta = \frac{\Delta R_{max} - \Delta R_{min}}{\Delta R}$	46%	60%	2%	37%
P_{dt} (atm)		< 1.0	< 1.0	< 1.0
E_n (J)	20.8	16	11.5	9
τ_c (ns)	1.2	1.1	0.9	—
$\mathcal{E}_0$ (J/ng)	0.2	0.17	0.19	0.2

$\Delta\tau \simeq \pm 0.1$ ns; $\Delta E_L/E_L \simeq \pm 20\%$; $\Delta E_n/E_n \simeq \pm 25\%$

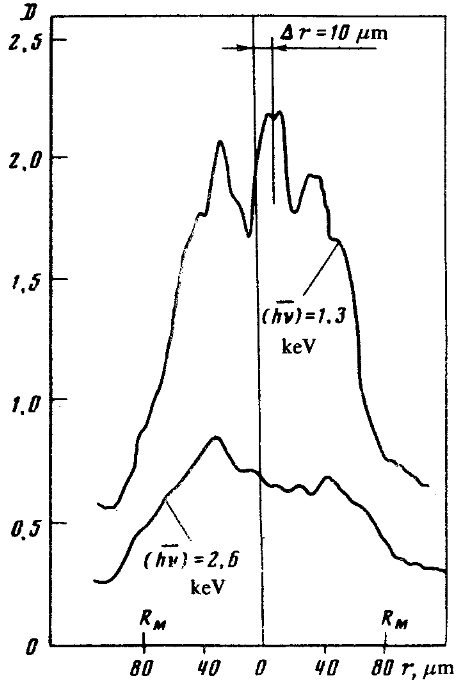

FIG. 1.

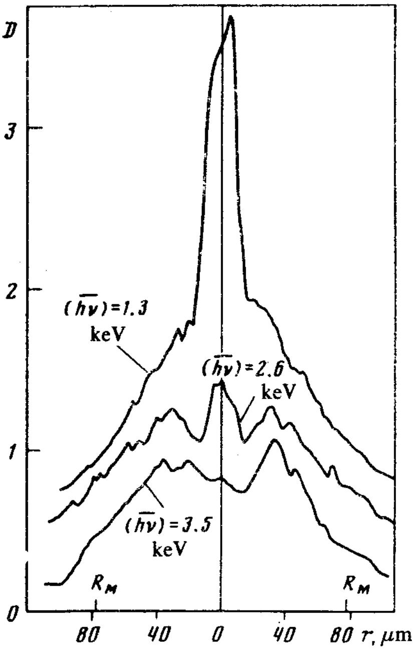

FIG. 2.

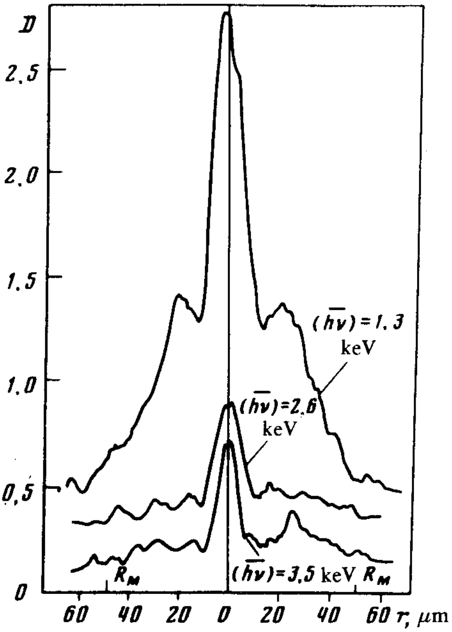

FIG. 3.

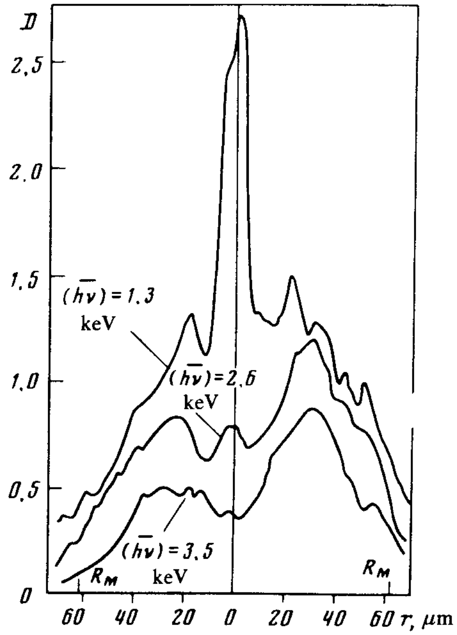

FIG. 4.

From Table I we see that a specific energy deposition $\mathscr{E}_0 \simeq 0.2$ J/ng was achieved. The target collapse time was $\tau_c \simeq 0.9$–1.2 ns, and the average velocity at which the shell moved toward the center of the target was $V \simeq (0.8$–$0.9) \times 10^7$ cm/s.

Central emission was detected on an integrated x-ray image of the targets in all the experiments. We turn now to the results.

a. Aspect ratios $100 \lesssim R/\Delta R \lesssim 170$. In all the experiments with values of $R/\Delta R$ in this range the densitometer traces of the x-ray images are similar to those shown for experiment No. 43 in Fig. 1. Central emission was detected only at x-ray energies $(\overline{h\nu}) = 1.3$ keV. The displacement of the central maximum from a central position with respect to the external ring on the x-ray image is proportional to the variation in the target thickness.

b. Aspect ratios $170 \lesssim R/\Delta R$. The densitometer traces of the x-ray images in all these experiments are similar to those shown for experiments No. 50 and No. 54 in Figs. 2 and 3. Central emission was detected on the images with $(\overline{h\nu}) = 1.3$ keV and $(\overline{h\nu}) = 2.6$ keV. In experiment No. 54, with a symmetric target, central emission was also observed on an image with $(\overline{h\nu}) = 3.5$ keV. It is difficult to determine the displacement from a central position in this case because the outer ring is blurred.

c. Short laser pulses. The x-ray images from experiments with short pulses are similar (Fig. 4).

d. Resolution. The resolution of the Obskura method, calculated in accordance with Ref. 9, is $2\delta r \simeq 5$ μm for $(\overline{h\nu}) = 1.3$ keV, $2\delta r \simeq 3.5$ μm for $(\overline{h\nu}) = 2.6$ keV, and $2\delta r \simeq 3$ μm for $(\overline{h\nu}) = 3.5$ keV.

If we assume that the central maximum on the x-ray image with $(\overline{h\nu}) = 1.3$ keV is formed by emission from a region bounded by the evaporation boundary, while the central maximum in the cases $(\overline{h\nu}) = 2.6$ keV and $(\overline{h\nu}) = 3.5$ keV comes from the *dt*-gas–glass region, then we can estimate the volume compression factor in these experiments to be δ (No. 43) $\gtrsim 400$, δ (No. 50 and No. 58) $\gtrsim 10^3$, and δ (No. 54) $\gtrsim 10^4$. At the sensitivity of the method used to detect neutrons, $\simeq 10^3$ 14-MeV neutrons, we observed no neutron emission in any of the experiments. The reason lies in the short lifetime of the *dt* gas in these targets. The targets were filled to a pressure $\simeq 3$ atm, and this pressure had fallen to < 1 atm by the time the experiment was actually carried out, according to radiophysical measurements.

Rigorous proof that a very high volume compression factor ($\geqslant 10^4$) can be achieved in a hydrodynamically stable process would be the detection of products of fusion reactions–neutrons and α particles–and an identification of the region in which they are produced. Nevertheless, the SOKOL experiments with targets with $R/\Delta R = 100$–200 imply that it is possible to achieve these compression factors in experiments with targets with an aspect ratio $R/\Delta R = 100$–200. We can thus search for optimum targets for laser fusion over a broad range of aspect ratios, $R/\Delta R = 30$–200.

[1)] The results of this study were reported at a conference on controlled fusion and the annual session of the Scientific Council on the General Problem of Plasma Physics, held in Zvenigorod in April 1981.

---

[1] E. K. Storm *et al.*, Phys. Rev. Lett. **40**, 1570 (1978).

[2] J. Nuckolls *et al.*, Plasma Phys. Contr. Nuc. Fusion Res. Vol. II, 535 (1974).

[3] G. Fraley *et al.*, Plasma Phys. Contr. Nucl. Fusion Res. Vol. II, 543 (1974).

[4] B. Yaakobi *et al.*, Phys. Rev. Lett. **44**, 1072 (1980).

[5] J. M. Auerbach *et al.*, Phys. Rev. Lett. **44**, 1672 (1980).

[6] V. V. Volenko, A. I. Zuev, A. F. Ivanov, *et al.*, Trudy III-Vsesoyuznoĭ konferentsii "Optika lazerov" (Proceedings of the Third All-Union Conference on Laser Optics, Leningrad, 4–8 January 1982); I. A. Abramov, V. V. Volenko, N. P. Voloshin, *et al.*, Zh. Eksp.Teor. Fiz. **83**, 988 (1982) [Sov. Phys. JETP **56**, 557 (1982)].

[7] V. V. Volenko and V. B. Kryuenkov, Kvant. Elektron. (Moscow) **6**, 1343 (1979) [Sov. J. Quantum Electron. **9**, 789 (1979)].

[8] Yu. A. Zysin, I. A. Abramov, V. V. Volenko, *et al.*, Zh. Eksp. Teor. Fiz. **83**, 1346 (1982) [Sov. Phys. JETP **56**, 773 (1982)].

[9] A. A. Galichiĭ, Yu. A. Mikhaĭlov, G. V. Sklizkov, *et al.*, Pis'ma Zh. Tekh. Fiz. **7**, 1410 (1981) [Sov. Tech. Phys. Lett. **7**, 602 (1981)].

Translated by Dave Parsons
Edited by S. J. Amoretty