# Development of perturbations when a shell target s compressed by laser radiation

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A numerical investigation is made of the irradiation asymmetry and of the uneven shell thickness on the degree of compression and shape of the target as functions of the amplitude and wavelength of the perturbations.

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Much attention is being paid of late to numerical [1,2] and experimental[3,4] investigations of the compression of microtargets by powerful laser pulses. The question of the development of the nitial perturbations when homogeneous spherical targets are compressed by a specially shaped aser pulse was investigated in[1]. We present here below results of numerical experiments on the compression of the simplest type of shell target, using a two-dimensional procedure[5] in single- and wo-temperature approximations.1)

The target is a glass shell with outside radius $R = 150\ \mu$m, thickness $\Delta = 3\ \mu$m, filled with DT gas to a density $10^{-3}$ g/cm$^3$. The laser pulse waveform is Gaussian with energy 1 kJ and width 1 usec at half height. The laser radiation produces partial evaporation of the shell ($\sim 77\%$ of the glass mass), and the unevaporated part of the shell is accelerated to a velocity $\sim 300$ km/sec and ompressed as the gas. The heating of the gap by compression leads to a noticeable evaporation of he shell on the side of the gas (to 6.5% of the total mass of the glass) and in turn increases the nal compression of the gas.

ABLE I.

| № | $K$ | $A_g$ | $A_\rho$ | $\rho_{max}$, g/cm$^3$ | $T_{max}$, keV | $\Delta_{max} = r_{max} - r_{min}$ | $\delta = \frac{2\Delta}{r_{max} + r_{min}}$ |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 84,0 | $T_e = 4.1$; $T_i = 7.7$ | 0 | 0 |
| 2 | 4 | 0 | 0,015 | 77.5 | $T_e = 3.8$; $T_i = 7.8$ | $0.32 \times 10^{-3}$ | 1,04 |
| 3 | 0 | 0 | 0 | 97,1 | 5.4 | 0 | 0 |
| 4 | 4 | 0 | 0,015 | 85,1 | 4.83 | $0,28 \cdot 10^{-3}$ | 0,9 |
| 5 | 4 | 0 | 0.045 | – | – | $0,25 \cdot 10^{-3}$ | 0,2 |
| 6 | 12 | 0 | 0,015 | – | – | $0,22 \cdot 10^{-3}$ | 0,06 |
| 7 | 4 | 0.05 | 0 | 95,4 | 5,34 | $0,3 \cdot 10^{-4}$ | 0,092 |
| 8 | 4 | 0,3 | 0 | 64.2 | 4.33 | $0,19 \cdot 10^{-3}$ | 0,44 |
| 9 | 12 | 0,05 | 0 | 88,0 | 5,12 | $0.3 \cdot 10^{-4}$ | 0,09 |
| 10 | 0 | 0 | 0 | 20,6 | 22,2 | 0 | 0 |
| 11 | 4 | – | 0 | 20,0 | 22,0 | $0,15 \cdot 10^{-3}$ | 0.25 |

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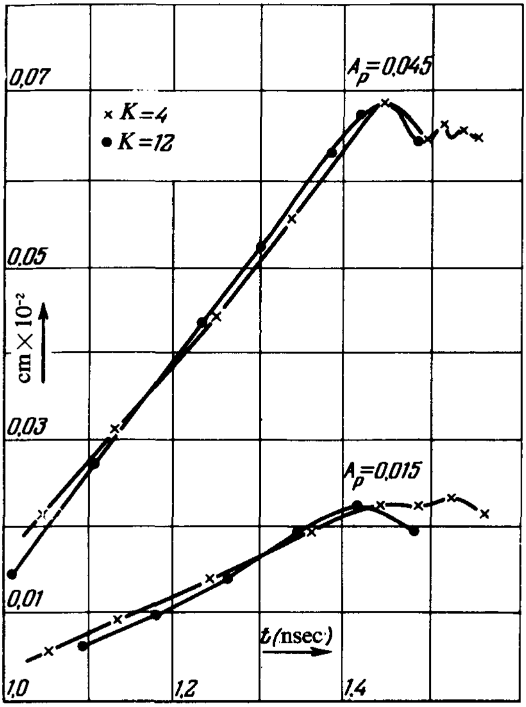


FIG. 1.

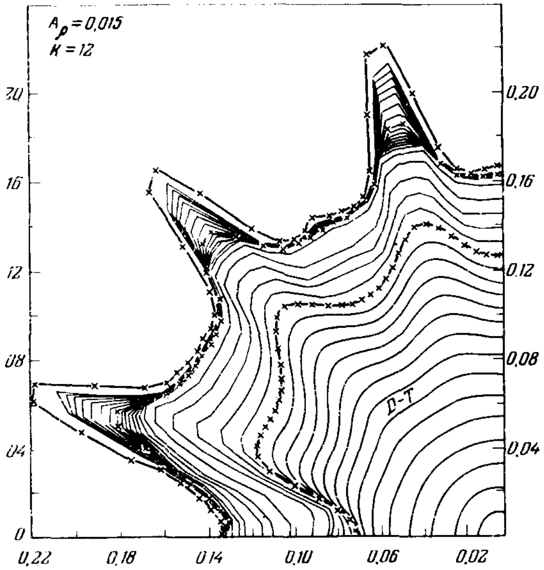
We investigated, for the given shell, the influence of the asymmetry of the irradiation and o the uneven shell thickness on the compression and shape of the gas. The absorption of lase radiation was imitated by energy release in a region, amounting to 0.1% of the mass shell. Th perturbations in the flux were specified in the form $g(t,\theta)=g(t)(1+A_g\cos K\theta)$, where $A_g$ i the amplitude of the perturbation and $K$ is the number of the harmonic.

The possible errors in the production of the shell (uneven thickness) was imitated by specifying a variation in the shell density: $\rho(\theta)=\rho_0(1+A_p\cos K\theta)$.

The results of the calculations are listed in Table I.

A comparison of the calculations carried out in the two-temperature approximation (variant 1 and 2) and in the one-temperature approximation (3 and 4) has shown that a calculation wit two temperatures does not change qualitatively the development of the perturbations. Variant 5–11 were therefore calculated in the single-temperature approximation. To study the role of shel evaporation on the gas side, the gas was assumed to have no thermal conductivity in variants 1 and 11.

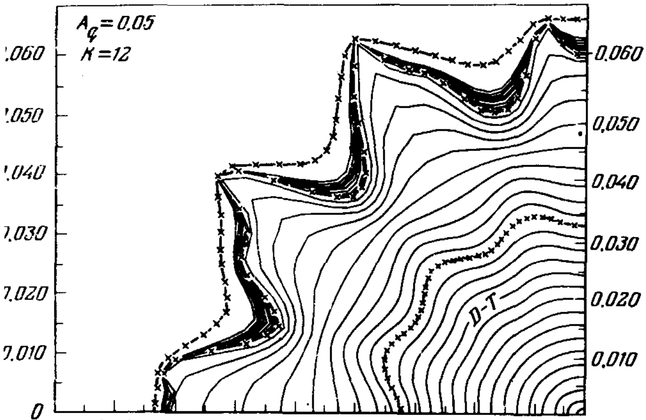
The development of perturbations on the interface between the gas and the glass proceeds i the following manner. The glass shell is accelerated by a series of shock waves traveling from th accelerated front of the thermal wave. The shock waves, which carry the perturbations due t asymmetry of the irradiation or the shell, emerge from the gas-glass boundary at different time and with different intensities. Therefore different sections of the boundary cease to move simultaneously and acquire different velocities. In the course of the flight of the shell, this boundary move



'IG. 2.

n a stable manner, but the resultant perturbations continue to grow linearly (see Fig. 1) up to the nstant of the arrival of the shock wave reflected from the center, and do not depend on the number f the harmonic. The independence of the number of the harmonic is the consequence of the fact hat at the considered wavelengths ($L$) the flight time of the shell ($T$) at the characteristic speed of ound ($C$) of the convex and concave sections formed in the shell do not interact with one another $CT = 10^{-3}$ cm, $L = 5 \times 10^{-3}$ cm).

The linear growth of the perturbations indicates that for the considered wavelengths and for a aussian laser pulse the instability zone connected with the evaporation of the shell on the outside oes not exert a substantial influence on the growth of the perturbations. When the shock wave



'IG. 3.

reflected from the center passes, the amplitude of the perturbations on the gas—glass bounda decreases. By that instant of time the temperature in the gas reaches ~1 keV, and the heating the shell from the inside is initiated. Conditions for instability are created on the front of tl thermal wave—the amplitude of the perturbations again begins to increase. Figure 2 and 3 sho the state of the target at the instant of the maximum compression of the gas for variant 9 and at tl instant of the rupture of the shell for variant 6.

An analysis of the calculations has led to the following conclusions:

1) Shell-type targets are less sensitive to irradiation asymmetry than to the inaccuracies in tl shell manufacture. The considered type of shell target is less sensitive to asymmetry of tl irradiation than homogeneous targets[1] for the given model of laser-emission absorption.

2) At the considered wavelength, the principal growth of the perturbations takes place in tl course of the flight of the shell; this growth is linear in time. The rate of growth of the perturb tions is proportional to the amplitude of the perturbations in the stream or to the differences in tl shell thickness, and does not depend on the number of the harmonic (see Fig. 1).

3) The evaporation of the shell plays a substantial stabilizing role in the development of tl perturbations of the gas—glass boundary at the instant of the stopping of the shell.

The one-dimensional calculations in the single- and two-temperature regimes were carried o by E.V. Kurasanov in accordance with a program devised by him.

[1)] The results of this study were reported at the Third Session of the Counsel on Plasma Physics Zvenigorod in February 1976.

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[1] A.A. Bunatyan, V.E. Neuvazhaev, L.P. Strotseva, and V.D. Frolov, Chislennoe issledovan razvitiya vozmushcheniĭ pri szhatii misheni obostrennym impul'som (Numerical Investigation the Development of Perturbations when a Target is Compressed by a Sharpened Pulse), Prepri IPM Akad. Nauk SSSR, No. 71, Moscow, 1975.
[2] P.P. Volosevich, E.G. Gamaliĭ, A.V. Gulin, V.B. Rozanov, A.A. Samarskiĭ, N.N. Tyurina, ar A.P. Favorskiĭ, Pis'ma Zh. Eksp. Teor. Fiz. **24**, 283 (1976) [JETP Lett. **24**, 252 (1976)].
[3] G.H. McCall and R.L. Morse, Laser Focus, December 1974, p 48.
[4] N.G. Basov, A.A. Kologrivov, O.N. Krokhin, A.A. Rupasov, G.V. Sklizkov, and A.S. Zhikano Pis'ma Zh. Eksp. Teor. Fiz. **23**, 474 (1976) [JETP Lett. **23**, 428 (1976)].
[5] N.N. Yanenko, V.D. Frolov, and V.E. Neuvazhaev, Izv. CO Akad. Nauk SSASR, 1967, No. No. 2; Chislennye metody mekhaniki sploshnoĭ sredy **3**, 90 (1972), Novosibirsk.