

SELF-SHIELDING OF THE SURFACE OF BODIES FROM POWERFUL RADIATION

PHYSICS

1970

SovietRxiv

View the original and related papers at <https://sovietrxiv.org/items/ru-197001.49138>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Abstract**Full Text**

UDC 533.9.03+535.211

PHYSICS

E. G. POPOV, A. A. PROVALOV, M. A. TSIKULIN

SELF-SHIELDING OF THE SURFACE OF BODIES FROM POWERFUL RADIATION*(Presented by Academician M. A. Sadovskii, 18 III 1970)*

When a solid body is irradiated by an intense light flux, the surface layer of the substance is heated and evaporates. If the vapor weakly absorbs the radiation, it penetrates into ever deeper layers of the substance and evaporates them—the evaporation wave advances into the substance ⁽¹⁾. But even when the radiation is weakly absorbed, for example owing to thermal ionization, the vapor begins to heat up. Calculations have shown ⁽²⁾ that, at high radiation intensity, the heating of the vapor and the associated increase in absorption lead to the formation of a highly heated opaque layer near the surface.

Thus, regardless of the initial transparency of the vapor, one should expect the appearance of a layer that screens the incident radiation. However, screening of the body surface does not yet mean that evaporation must necessarily cease. The heated vapor itself emits radiation. The intensity and spectral composition of this radiation are determined not so much by the power of the primary radiation as by the optical properties of the evaporated substance. Thus, by means of a focused laser beam it is possible to heat the vapor from the outside to a very high temperature, but because of the opacity of the vapor the surface of the body will receive only the radiation of comparatively cold inner layers. Incidentally, in strong shock waves an analogous phenomenon is already known ⁽³⁾. The gas ahead of the wave front is heated by the radiation of the shock-heated gas and loses its transparency. The radiation of the shock-heated gas, as well as of the strongly heated layer in front of the front, is as it were locked in, and only light from moderately hot layers remote from the front penetrates into the cold transparent gas.

The ideas described above concerning shielding of the surface of bodies, despite their similarity to the already known effect of shielding of strong shock waves in gases, require experimental confirmation. A thorough theoretical analysis in this case is hampered by the absence of reliable data on the photoabsorption of heated vapors.

Fig. 1. Experimental arrangement. 1 —target with a hole at the center of diameter 1 mm; 2 —charge with cumulative recesses, weight 500 g, cast from

Fig. 1. Experimental arrangement. 1 –target with a hole at the center of diameter 1 mm; 2 –charge with cumulative recesses, weight 500 g, cast from TG 40/60; 3 –explosive lens; 4 –aluminum tube with mirror walls, diameter 84 mm; 5, 6 –SFR-2 photochronograph or SP-111 spectrophotochronograph

Figure 1: Fig. 1. Experimental arrangement. 1 –target with a hole at the center of diameter 1 mm; 2 –charge with cumulative recesses, weight 500 g, cast from TG 40/60; 3 –explosive lens; 4 –aluminum tube with mirror walls, diameter 84 mm; 5, 6 –SFR-2 photochronograph or SP-111 spectrophotochronograph

Fig. 2

Figure 2: Fig. 2

TG 40/60; 3 –explosive lens; 4 –aluminum tube with mirror walls, diameter 84 mm; 5, 6 –SFR-2 photochronograph or SP-111 spectrophotochronograph.

In our experiments, targets made of various materials were irradiated by an explosive light source. The latter was a charge of explosive with cumulative recesses, placed in a tube containing argon at atmospheric pressure. The radiator was a powerful

Fig. 2. Photochronogram of the expansion of target vapors, the target being pressed from HgCl powder.

1–target surface; 2–boundary of the expanding vapors (boundary velocity 400–600 m/sec, rise height 7 mm); 3–shock-wave front.

Fig. 4. Spectrophotochronogram of the brightness of the shock wave through an opening in a target pressed from KCl powder ($\lambda = 400\text{--}600 \text{ m}\mu$; the reference line $\lambda = 435.8 \text{ m}\mu$ from a mercury lamp is traced).

the shock wave formed in the tube upon explosion of the charge. The shock wave attenuated as it approached the target, and the brightness temperature of the wave front, measured through a blue light filter, fell from 33,000 to 30,000°K. On the basis of these temperature values and assuming blackbody radiation of the front ($\hat{4}$), the radiant-flux density at the target is estimated as $\sim 3 \cdot 10^6 \text{ W/cm}^2$.*

Earlier the authors ($\hat{5}$), using an explosive radiation source, observed the formation above the target of a luminous region, which was interpreted as vapors of the target material. In the present work it proved possible to confirm the correctness of this interpretation. With the aid of a spectrophotochronograph (5 in Fig. 1), emission lines belonging to the target material were recorded. The temperature of the evaporated substance, measured from the intensities of

Fig. 4

Figure 3: Fig. 4

Fig. 3

Figure 4: Fig. 3

the centers of saturated lines, reached 10,000–15,000°K. The outer layer of the expanding vapors is the brightest (Fig. 2) and emits a continuous spectrum; the temperature here is apparently higher. Vapors at such temperatures can appreciably absorb the incident radiation.

Fig. 3. Brightness temperature of the shock wave in blue light ($\lambda_{\text{eff}} = 432 \text{ m}\mu$, $\Delta\lambda = 51 \text{ m}\mu$), measured without a target (1) and through holes in targets of various materials: 2 –S, 3 –Pb, 4 –asbestos cement, 5 –KCl, 6 –graphite for Fe and Al coincides with 1.

But direct evidence of shielding is provided by the results of recording the radiation reaching the target surface. Through a small hole in the target, using a photochronograph (6 in Fig. 1), the brightness temperature of the shock wave in blue light was measured. A rapid decrease in brightness was found (see Fig. 3). The shielding was manifested even more clearly when the tube was filled with xenon. In these experiments the radiation was recorded with the spectrophotochronograph (6 in Fig. 1). The brightness first decreased in individual lines, and then over the entire observed spectrum (see Fig. 4). For example, for KCl targets the brightness temperature decreased from 50,000 to 6,000°K. Note the difference between the apparent value of 6,000°K and the value 30,000°K measured toward the end of operation of the source in the absence of a target. Such a difference corresponds to the fact that the vapors closing over the hole attenuated the incident radiation by ~ 100 times.

The authors express their gratitude to A. D. Kravchenko for assistance in the experiments, and to I. V. Nemchinov for useful discussions.

Institute of Physics of the Earth named after O. Yu. Schmidt
Academy of Sciences of the USSR
Moscow

Received
18 III 1970

CITED LITERATURE

1. Yu. V. Afanas'ev, O. N. Krokhin, ZhETF, **52**, issue 4, 966 (1967).
2. T. G. Vilenskaya, I. V. Nemchinov, DAN, **186**, 1048 (1969).
3. Ya. B. Zel'dovich, Yu. P. Raizer, *Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena*, Moscow, 1966.

4. Yu. A. Zatspein, E. G. Popov, M. A. Tsikulin, *ZhETF*, **54**, issue 1, 112 (1968).

5. I. F. Zharikov, I. V. Nemchinov, M. A. Tsikulin, *Applied Mechanics and Technical Physics*, No. 1, 31 (1967).

* In the estimates the opacity of Ar for quanta $h\nu > 15.7$ eV is taken into account.

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.