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Stuart G. Hibben

Informatics, Incorporated

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13. ABSTRACT

This report includes abstracts and bibliographic lists on contractual subjects that were completed in July, 1973. The major topics are: laser technology, effects of strong explosions, geosciences, particle beams, material sciences, and miscellaneous interest items. A section on atmospheric physics is being published separately.

Laser coverage is generally limited to high power effects; all current laser material is routinely entered in the quarterly laser bibliographies.

An index identifying source abbreviations and a first-author index to the abstracts are appended.

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## 1. Laser Technology

### A. Abstracts

Batanov, V. A., and V. B. Fedorov. Liquid phase flushing - a newly observed mechanism of crater formation during vaporization rise in a laser irradiated metal target. ZhETF P, v. 17, no. 7, 1973, 348-351.

Beam-target conditions are considered under which the main ejection mechanism from the melt zone is by flushing out of the liquid material by vapor pressure, as distinguished from direct vaporization ejection. The conditions for the flushing phase require a relatively shallow crater with a moderate incident beam intensity; quantitatively the conditions are given by

$$t(4\pi^2 v_z^2 \lambda^2 d^4)^{1/3} > 1. \quad (1)$$

where  $t$  = laser pulse duration,  $d$  = crater diameter and  $v_z$  = vapor velocity component normal to the target surface.

Experiments with an aluminum target exposed to millisecond laser pulses generally confirm the theory; Fig. 1 shows the results. Here the flushing mechanism occurred up to about  $9 \text{ Mw/cm}^2$  density, after which direct vaporization ejection begins and crater depth increases more rapidly. Photos of crater formation confirmed that the two discrete phases did occur.

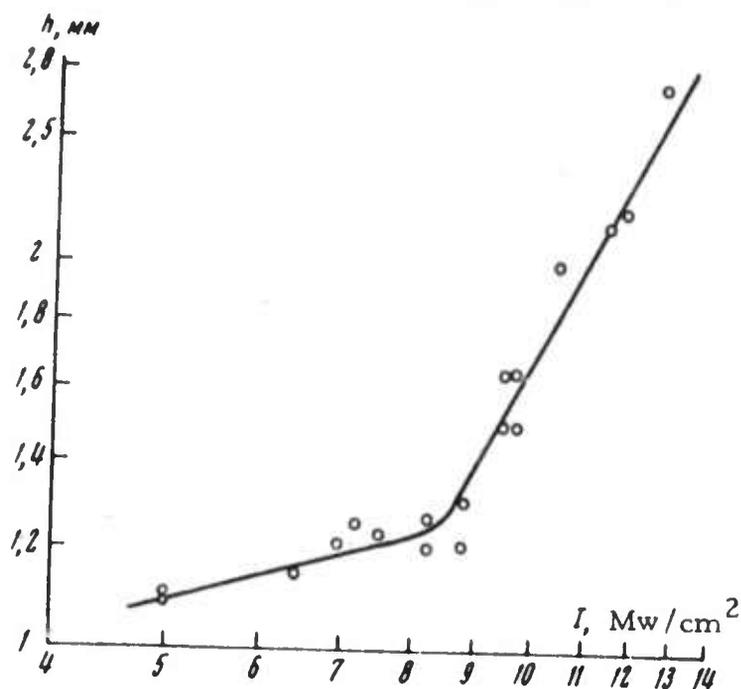


Fig. 1. Mean crater depth in Al vs. laser power density.

Bonch-Bruyevich, A. M., Ye. I. Balashov,  
 A. I. Gagarin, A. S. Zakharov, V. N.  
 Kotylev, and O. I. Kalabushkin. Experimental  
 study of shielding by aluminum vapor. ZhETF  
 P, v. 17, no. 7, 1973, 341-344.

Tests are described in observing the extent and nature of the vapor cloud generated by laser impact with an aluminum target. The laser used was free-running at  $1.06\mu$  and 1 millisecond pulses of up to  $25 \times 10^6$  w/cm<sup>2</sup>, focused to  $0.8$  cm<sup>2</sup> or less on the target surface. To record transmissibility of the vapor cloud, a 1 mm aperture was left in the target to allow comparison of incident and transmitted pulses; a second laser probed the cloud laterally at

varying distances from the surface. Finally, a third laser was used, also parallel to the target face but with a beam diameter  $> 2$  cm, to furnish shadow photos of the entire cloud region.

Results show a rapid drop in transmission within 50-80  $\mu$ sec after pulse incidence. Fig. 1 is a shadow photo of a 4 mm wide target after pulse start, showing the approximately 1 mm deep vapor cloud region. Graphical data show an apparently linear drop in transmissibility with increased pulse power, for both the axial and transverse directions.

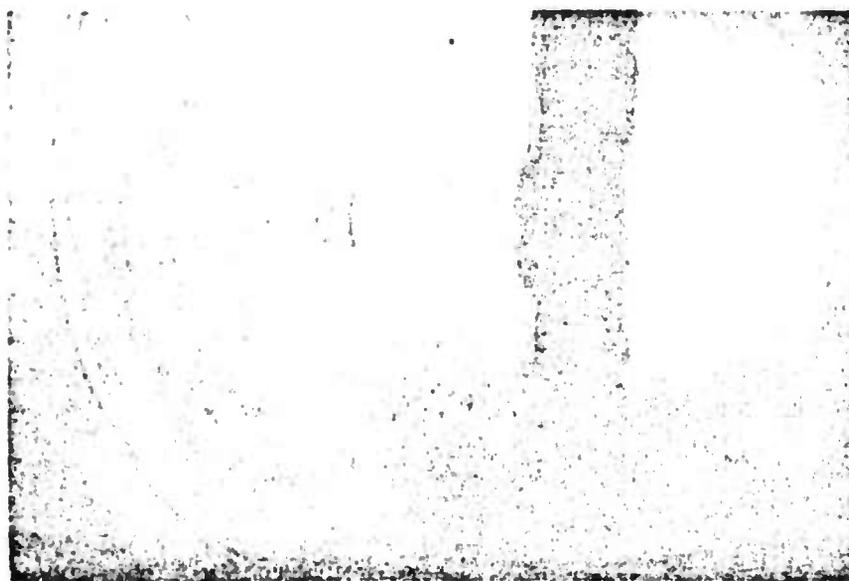


Fig. 1. Vapor cloud, Al target.

25  $\mu$ s after pulse start; target width is 4 mm,  
laser beam from left. Shock wave velocity =  
700 m/sec.

Belyayev, L. M., V. V. Nabatov, V. N.  
Rozhanskiy, N. L. Sizova, and A. A.  
Urusovskaya. Damage mechanism to the  
surface of a CsI crystal by a focused laser  
beam. Kristal, no. 2, 1973, 334-338.

Qualitative effects of a laser beam focused on CsI crystals are discussed for intensities both above and below damage threshold. The crystals were cut to 2 mm thick platelets and chemically polished, then exposed to a free-running ruby laser with a focused spot diameter of 330 microns, applied through variable-density filters. Threshold was about  $130 \text{ j/cm}^2$ ; levels up to  $250 \text{ j/cm}^2$  were used, which was in some cases sufficient to pierce the specimen.

The article mainly discusses the observed effects on crystal structure as a function of orientation and of laser parameters. Fig. 1 shows extrusion effects in two planes for intensity just over threshold. Studies were also done on sub-threshold effects by etching the surface layer away; these showed dislocation effects around inclusions caused by laser exposure.

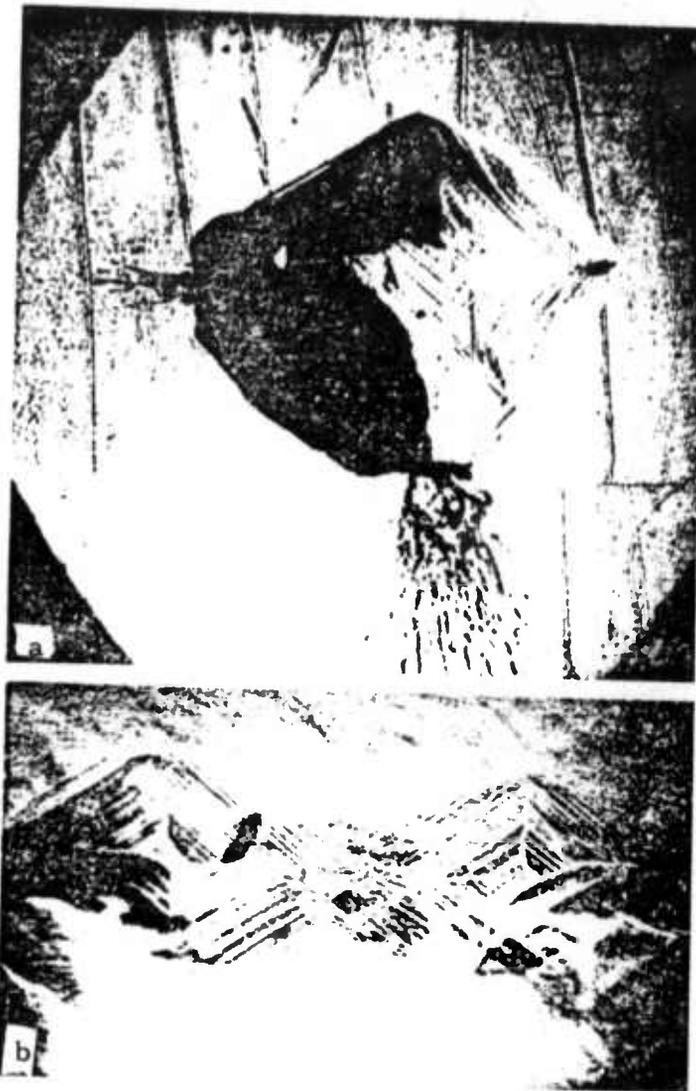


Fig. 1. Extrusion configurations in laser-irradiated CsI, x 200.

a - [100] plane; b - [110] plane.

Hasse, R., A. Knecht, and N. Neuroth.  
Damage to optical glass by giant laser pulses. Part II. Internal glass damage by a converging beam. Schott. -Inform, no. 2, 1972, 8-14 (RZhF, 1/73, no. 1Ye292) (Translation)

Damage thresholds for 103 types of optical, quartz and IR glass were determined, using 40  $\mu$ sec laser pulses at 1.06  $\mu$ . The laser beam was focused on the test specimen by a lens with  $f = 100$  mm. Correlations were obtained between damage threshold and the following glass parameters; thermal conductivity index, density, refractive index, scratch resistance, and conductivity behavior in the neighborhood of the softening point.

Marin, O. Ye., N. F. Pilipetskiy, and V. A. Upadyshev. Formation of laser-initiated cracks. MP, no. 1, 1973, 82-89.

Initiation of cracks in PMMA from laser irradiation was studied experimentally, to clarify inconsistencies in the mechanism of crack formation, postulated on the basis of earlier studies. Irradiation was done with  $10^{-3}$  sec. pulses from a free-running  $\text{CO}_2$  laser. Crack edges were exposed to the incident beam to exclude the possibility of crack propagation from direct absorption by the entire crack area. In this way, gas-filled cavities with nucleating microcracks were detected as the single energy sources for fracture. The cavities are generated by decomposed material in random points of the continuum, owing to laser radiation absorption in discrete microheterogeneities.

Diameters of 36 cavities and cracks were measured and gas pressures in the cavity-crack system were calculated for a gas with  $\gamma = C_p/C_v = 1.1$ . The tabulated data (Table 1) and photographs of the cavities and cracks in

Table 1. Experimental parameters of laser-initiated cavities and cracks in PMMA

| Cavity diam., $D_0 \cdot 10^3 \mu$ | Cavity volume $V_0 \cdot 10^{10} \mu^3$ | Crack diam., $D_T \cdot 10^3 \mu$ | Crack area, $S_T \cdot 10^3 \mu^2$ | Crack volume, $V_T \cdot 10^{10} \mu^3$ | $A = \frac{D_T}{D_0}$ | $B = \frac{V_T}{V_0}$ | Gas pressure in: |                  |
|------------------------------------|---|-----------------------------------|------------------------------------|---|-----------------------|-----------------------|------------------|------------------|
|                                    |   |                                   |                                    |   |                       |                       | crack, $P_T$ bar | cavity $P_0$ bar |
| 4.2                                | 380                                     | 22.6                              | 40.0                               | 1780                                    | 5.4                   | 4.7                   | 630              | 3 800            |
| 3.3                                | 180                                     | 19.8                              | 30.8                               | 1290                                    | 6.1                   | 7.1                   | 680              | 5 900            |
| 2.7                                | 99                                      | 16.5                              | 21.1                               | 810                                     | 6.2                   | 8.2                   | 740              | 7 400            |
| 2.5                                | 82                                      | 14.8                              | 17.2                               | 620                                     | 5.9                   | 7.6                   | 790              | 7 400            |
| 2.2                                | 56                                      | 13.2                              | 13.7                               | 460                                     | 6.0                   | 8.2                   | 830              | 8 300            |
| 2.1                                | 47                                      | 11.7                              | 10.7                               | 310                                     | 5.6                   | 7.3                   | 880              | 7 900            |
| 1.8                                | 29                                      | 11.9                              | 11.1                               | 360                                     | 6.7                   | 12.2                  | 880              | 12 700           |
| 1.6                                | 20                                      | 9.8                               | 7.5                                | 290                                     | 6.3                   | 11.2                  | 970              | 12 900           |
| 1.2                                | 9.2                                     | 9.3                               | 6.8                                | 190                                     | 7.7                   | 20.7                  | 990              | 23 600           |
| 1.1                                | 6.2                                     | 9.0                               | 6.3                                | 180                                     | 8.5                   | 29.0                  | 1000             | 32 800           |

the process of formation are shown (Fig. 2); the tabulated data are the



Fig. 2. Crack propagation from cavities

a- typical planar formation; b- rarer case of two necks propagating from one spherical center.

averages of 2-5 measurements. Diameter distribution of cavities shows that most have  $D_0 = 10-30 \mu$ .

The cited data suggest the following fracture initiation mechanism for plexiglass: nucleation centers (cavities), at  $(2-3) \times 10^3$  °K and  $10^3 - 10^4$  atm are surrounded by a liquefied layer of compressed, hot material in which quasibrittle fracture becomes impossible. After attaining a critical dimension ( $\sim 20-30 \mu$ ), a cavity develops necks in the direction of colder material. Subsequently, a neck develops a plane nucleating crack on account of pressure relief; the crack propagates further by direct absorption of radiation. Formation of one large crack from several nucleation centers was in fact observed in subsurface PMMA layers irradiated with CO<sub>2</sub> laser at a moderate power density.

Rubinshteyn, A. I., and V. M. Fayn. Theory of avalanche ionization in transparent dielectrics from the effects of a powerful electromagnetic field. FTT, no. 2, 1973, 470-478.

Probability of avalanche ionization by cumulation of optical pulse energy in a conduction-band electron to a level above the ionization energy  $I$  was analyzed theoretically, without imposing the limitation of a weak alternating field. Avalanche ionization from the effect of a moderate or high-intensity alternating field was also covered by the study, because of its practical importance. The cited problem is treated in the framework of the elemental and kinetic theories, with allowance for single-photon or multiphoton mechanisms of energy transfer. In the case of single-photon transition, analysis of the energy balance of a "seed" electron in the conduction band (elemental theory) led to the conclusion that in a strong field the electron acquires a maximum but limited energy  $\epsilon_{\max}$ . There is a field energy value at which avalanche ionization begins, if  $\epsilon_{\max} > I$ . At  $\epsilon_{\max} < I$ , avalanche ionization cannot occur, regardless of the field magnitude. A similar conclusion

was drawn from application of kinetic theory to single photon transition. However, at  $\epsilon_{\max} < I$ , the probability of avalanche ionization is found to be exponentially small. In that case, an n-photon transition mechanism may effectively determine avalanche ionization.

Lariokhin, B. Lasers in 1973 [Survey of foreign technology]. Krasnaya zvezda, 15 February 1973, p. 3.

In a second article on lasers, the author reviews American, British, and West German periodical literature on recent advances in laser military applications. Developments are reported of laser use in weapon control systems, aerial reconnaissance, and target observation. The cited laser applications in weapon control systems include laser guidance of artillery shells, bombs, ground-to-ground tactical ballistic missiles. Discussions are also cited on laser use for target selection from tactical aircraft, simultaneously with or separately from their use in weapon guidance systems. Foreign (mainly American) aerial laser reconnaissance systems are described, particularly the three-dimensional systems. R&D is reviewed of complex target observation systems using several lasers emitting at different wavelengths.

Raychenko, A. I. Heat propagation in a solid from the action of a short thermal pulse. FizKOM, no. 2, 1973, 137-141.

The one-dimensional boundary value problem of heat propagation in a semi-finite solid from interaction with a pulsed laser beam is solved, with allowance for a finite speed  $c$  of heat propagation. The problem is formulated by a so-called telegraph equation of hyperbolic type. A solution to the problem is obtained in the form of a temperature function  $T_t(x, t)$ , where  $x$  and  $t$  are the space and time coordinates. The solution for  $T_t(x, t)$  in dimensionless variables  $\vartheta = kt/x^2$  and  $\xi = cx/k$ , where  $k$  is thermal diffusivity, reduces to that of a classic parabolic-type equation for the case of high  $\vartheta$  values and  $c \rightarrow \infty$ . In the opposite case of temperature field behind the thermal excitation front, i. e.  $T_t'(\xi, \vartheta) = 0$  and  $1/\xi > \vartheta$ , there is a zero value region of  $T_t'$  in the  $\xi^{-1} \vartheta$  plane, i. e.  $T_t'(\xi, \vartheta) = 0$  when  $\xi^{-1}$  and  $\vartheta$  vary from  $10(1-8 \times 10^{-4})$  to  $10(1+8 \times 10^{-4})$  and from  $10^{-1}(1-8 \times 10^{-4})$  to  $10^{-1}(1+8 \times 10^{-4})$ , respectively. In contrast, the solution of a parabolic equation for  $T_p'$  without allowance for  $c$  is different from zero for all  $\xi^{-1}$  and  $\vartheta$  values. Examples of evaluating the heating effect by both formulas are given.

Vinogradov, A. V., B. Ya. Zel'dovich, and I. I. Sobel'man. Effect of saturation on stimulated scattering from laser heating of plasma. ZhETF P, v. 17, no. 5, 1973, 271-274.

Several important factors, unaccounted for in earlier studies, e. g., by Galejev et al (cf May 1973 Report, p. 11), on stimulated scattering of powerful laser radiation in a dense plasma, are discussed. Calculation of the pumping energy reflection  $R$  from the plasma shows that nonlinear effects

must be accounted for in correct evaluation of gain (g). The most important is the saturation effect, i. e., deformation due to scattering, of the electron velocity distribution function. Calculation of g for a plasma with density  $N < 10^{19}$  without allowance for saturation indicated that a significant laser radiation conversion into scattered waves (Thomson scattering) requires laser power densities  $P_L > 10^{16}$  w/cm<sup>2</sup>. Saturation at this  $P_L$  is shown to limit R by a plasma layer  $L < 10^{-2}$  cm with  $N_e < 10^{19}$  of stimulated Thomson scattering at the  $2 \times 10^{11}$  w/cm<sup>2</sup> level. In a  $\sim 10^{-2}$  cm plasma layer with  $N_e > 10^{19}$  and  $T_{e2} = T_i$ , saturation similarly limits stimulated scattering by ions to the  $10^{13}$  w/cm<sup>2</sup> level, thus minimizing R. The authors note that the modulation index required for a significant R is inversely proportional to L, and hence is very sensitive to the laser pulse shape.

Volyak, T. B., S. D. Kaytmazov, A. M. Prokhorov, and Ye. I. Shklovskiy. Effect of magnetic field on soft x-radiation in a laser plasma. ZhETF, v. 64, no. 2, 1973, 481-484.

The effect of a strong magnetic field on intensity of soft x-rays in the 3-10 Å and 3-7 Å ranges was studied experimentally. The x-rays were generated by radiation of a plasma created by interaction of a Q-switched laser beam at  $\lambda = 1.06 \mu$  with a copper target, positioned in a vacuum chamber within the cavity of a solenoid coil. Laser pulses of 3-6 j and  $\sim 40$  nsec half-width were applied. The plasma electron temperature  $T_e \approx 200-250$  ev was determined from the recorded intensity ratio of x-rays transmitted through two different Be filters. It was observed that in the presence of a 200 kOe field, the total energy of x-rays transmitted through each filter decreased on the average by a 2.5 factor. Evaluation of the plasma parameters revealed

that the magnetic field-induced additional absorption of laser radiation by the plasma can be the cause of the observed phenomenon. Hence, the focused radiation power density must decrease, since the optically dense plasma shields the target from the laser beam.

The experiment shows that using a field geometry which prevents plasma dispersion toward the laser beam, and positioning the target plane at an angle to the optical axis, are necessary conditions for efficient plasma heating in a magnetic field.

Kurbatov, Yu. A., and V. F. Tarasenko.  
Time characteristics of spark discharges  
initiated by laser bursts. PTE, no. 1, 1973,  
142-144.

Experiments are described on triggering a spark discharge by a pulsed nitrogen gas laser beam at  $3371 \text{ \AA}$  with 10 kw peak pulse power and 4 nsec pulse half-width. The laser was intended to decrease the power requirement for a spark discharge. Two experimental spark gap circuits are described: the first for 1 and 3 mm gaps with 10-40 kv applied voltage pulses at 1-3 atm. pressure in the test chamber, the second for 5 and 10 mm gaps with 50-200 kv applied bell-shaped pulses at a pressure  $p = 1-8 \text{ atm}$ . In both arrangements, a copper cathode was irradiated by a nonfocused laser beam through a wire mesh anode. In all experiments without laser irradiation, either discharge time lag  $t_3$  was much greater than with the intensifier pulse, or breakdown did not occur. The experimental data illustrated by the plots of commutation time  $t_k$  versus field intensity  $E$ , or  $p$  and  $t_3 p$  versus  $E/p$ , show that  $t_3$  relative to the time of cathode irradiation was 1-100 nsec, depending on experimental conditions. Measured fluctuations  $\Delta t_3$  were not over 3 nsec even at a nearly static breakdown voltage.

Rodichkin, V. A., and G. Ya. Rusakova.

Effect of electrode-target polarity and lens focal plane position on laser-ignited discharge characteristics. ZhTF, no. 2, 1973, 345-348.

Divergence of opinion on selection of the electrode-target polarity which would minimize response delay of a laser-ignited air discharge gap prompted the present experimental study of the breakdown time lag, at power densities near the optical breakdown threshold. A 20 Mw Q-switched ruby laser beam was focused in an 11.7 mm discharge gap, and breakdown time lag was measured by a method analogous to that described earlier by Babalin et al (ZhTF, 1970, 1718). The average power density in the focal plane of the focusing lens was  $\sim 2 \times 10^{10}$  w/cm<sup>2</sup>.

The experimental plots of breakdown time lag (Fig. 1) show that at  $E_0/p \gg 23$  v/cm x torr,  $t_3$  is shorter, when the target electrode is the anode rather than the cathode of the discharge gap. The opposite is true for

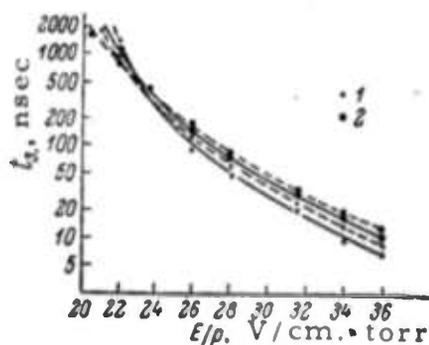


Fig. 1. Breakdown time lag  $t_3$  versus  $E_0/p$ , where  $E_0$  is the electrostatic field potential across the gap, and  $p$  is gas pressure. Lens focal plane - target electrode distance  $x = 5$  mm (solid curves) and 0 (dashed curves); points 1 and 2 correspond to the data with positive (anode) and negative (cathode) electrode target, respectively.

the  $E_0/p \leq 23$  v/cmxtorr region. At  $E_0/p \geq 24$  V/cmxtorr,  $t_3$  decreases with increasing  $x$ . In contrast, at  $E_0/p \leq 24$  V/cmxtorr,  $t_3$  increases with lengthening of  $x$ . At  $E_0/p \approx 24$  V/cmxtorr,  $t_3$  is nearly independent of  $x < 6$  mm.

The cited data are interpreted by means of shadow photographs of the discharge channel, which were taken at  $x = 4$  mm,  $E_0/p = 31$  V/cm x torr, and a 20 nsec delay of intensifier pulse. Once the channel is formed the discharge gap can be treated as the "point-plane" gap. This assumption was confirmed in the experiment with a metallic point substituted for the plasma point. The main conclusion was drawn that at a beam intensity above the laser flare formation threshold, but lower than gas breakdown threshold, radiation must be focused on the positive electrode to minimize breakdown time lag, and on the negative electrode to maximize the working range of potentials across the electrodes of the laser-ignited discharge gap.

Karlov, N. V., N. A. Karpov, Yu. N. Petrov, and O. M. Stel'makh. Self-focusing of CO<sub>2</sub> laser emission in resonance absorptive gases. ZhETF P, v. 17, no. 7, 1973, 337-340.

Self-focusing was observed of pulsed CO<sub>2</sub> laser radiation during its propagation in resonance absorptive gases BCl<sub>3</sub> and SF<sub>6</sub> at 10.6  $\mu$ . Experiment was conducted with a 5-10 kw CO<sub>2</sub> laser and 20  $\mu$ sec pulse duration. The radiation was focused in front of the window of the test vessel, such that diverging rays passed through the specimen gas. When BCl<sub>3</sub> was irradiated at 1 atm, self-focusing occurred at a point a certain distance from the window; an increase of laser power gave rise to a number of self-focus

points. The distance of the focus points increased with pressure drop and at pressures less than 0.1 atm, beam constriction was insignificant.

In the case of  $\text{SF}_6$ , the focusing distance was very small. At 0.25 atm self-focusing in  $\text{SF}_6$  was a thin beam of diameter 0.2 mm and at a distance of 3-4 cm. A relationship is plotted of the nonlinear refractive index  $n_2$  as a function of gas pressure (Fig. 1). The maximum value of  $n_2$  for  $\text{BCl}_3$

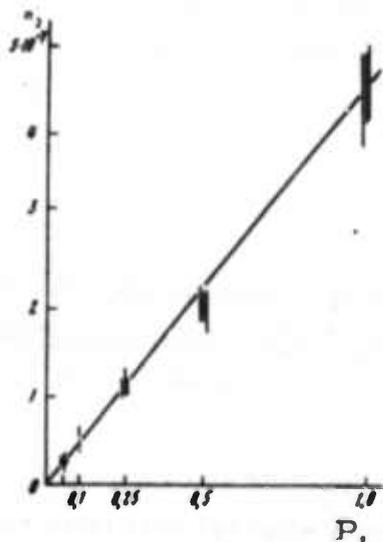


Fig. 1. Relationship of refractive index  $n_2$  in  $\text{BCl}_3$  to gas pressure.

is  $(4.6 \pm 0.7) \times 10^{-7} P$  CGSE and for  $\text{SF}_6$  -  $5 \times 10^{-5} P$  CGSE, where  $P$  = gas pressure

Anisimov, S. I., and A. Kh. Rakhmatulina.

Dynamics of vapor expansion from evaporation  
in vacuo. ZhETF, v. 64, no. 4, 1973, 869-876.

The dynamics of vapor expansion from laser evaporation is theoretically examined using the Boltzmann equations for gas motion. The

authors consider the evaporation of a semi-infinite solid body with a constant temperature  $T_0$  in an initially empty space. Equations are obtained for the motion of the evolved gas; solutions are limited to one-dimensional unstable problems, and the surface temperature and particle distribution function of surface ejecta are assumed to be independent of time. A transition is observed from a free-molecular regime of vapor expansion, occurring at the initial evaporation stage, to motion of a continuous medium. Conditions are discussed under which the motion of the vapor bulk can be expressed by gas dynamics equations. Boundary conditions are obtained for gas dynamics equations at the evaporation surface.

Burakov, V. S. Inertness criteria of a plasma to powerful laser radiation. ZhPS, v. 18, no. 4, 1973, 604-609.

The author attempts to define the level in laser diagnostics of a plasma at which the laser intensity exceeds some threshold, beyond which its effect on the plasma unduly distorts the original state under observation. This is broadly defined as the plasma excitation limit; for purposes of argument it is here given as a degree of change in optical density  $\delta = 2\sigma$  of a specified plasma layer, where  $\sigma$  is unit measurement error. In practical cases,  $\delta$  is in the vicinity of 0.1. With this criterion the author derives approximate expressions for tolerable laser probe density, differentiating between the excitation effects of short and long pulses relative to  $\tau^*$ , the time to establish a Boltzmann distribution of population.

The theoretical results were tested against data of Burakov et al (ZhPS, v. 16, 1972, 240) for pulsed ruby passage through a hydrogen and carbon plasma, and gave a theoretical threshold of  $2.5 \text{ Mw/cm}^2$ ; against the actual value of  $3-5 \text{ Mw/cm}^2$ ; an analogous result was obtained for a xenon plasma (Generalov et al, ZhETF, v. 56, 1969, 789). The discrepancies are considered tolerable in view of the approximate nature of the theoretical formulas used.

B. Recent Selections

i. Beam-Target Effects

Buravl'ov, Yu. M., B. P. Nadezhda, and I. O. Novokhats'kiy. Certain characteristics of the effect of focused laser radiation [on materials]. IN: Fiz. tverdogo tela. Res. mezhved. temat. nauch-tekhn. sb., no. 2, 1972, 87-90. (RZhMetallurgiya, 6/73, no. 61863).

Gulyayeva, A. S., M. A. Gurevich, L. A. Zhukova, N. M. Klimova, B. A. Krasnyuk, and V. N. Maslov. Structural changes in gallium arsenide caused by laser radiation. FiKhOM, no. 3, 1973, 17-21.

Gurevich, G. L. Theory of thin film destruction by laser radiation. FiKhOM, no. 3, 1973, 5-11.

Korolev, N. V., V. V. Ryukhin, and G. B. Lodin. Laser micro-analysis with controlled electrical synchronization of probe excitation. ZhPS, v. 19, no. 1, 1973, 21-26.

Kovarskiy, V. A., N. F. Perel'man, and E. P. Sinyavskiy. Nonradiating recombination in semiconductors at a deep level in a strong electromagnetic wave field. FTT, no. 6, 1973, 1809-1813.

Nemchinov, I. V. Gas dispersion behind deflagration waves, actuated by powerful radiation flux. ZhPMTF, no. 3, 1973, 41-48.

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#### 4. Particle Beams

##### A. Abstracts

Bugayev, S. P., F. Ya. Zagulov, Ye. A. Litvinov, and G. A. Mesyats. Volt-ampere characteristics of multi-edge diodes, operating in an explosive regime of electron emission. ZhTF, no. 3, 1973, 611-614.

An experimental investigation is made of the operation of cathodes consisting of a set of razor-shaped blades, arranged in parallel in an explosive regime of electron emission. The aim of the study was to determine the conditions at which observance of the "3/2" law should be expected for a diode having a cathode with numerous emitting centers. The volt-ampere characteristics were recorded and an investigation was made of the structure of the beam at accelerator voltages up to 300 kv and a pulse duration of 30 nanoseconds. The experimental apparatus is described.

The "3/2" law for a planar diode

$$t = 2.33 \cdot 10^{-6} \sqrt{\frac{S}{d^2}} \quad (1)$$

holds for the conditions

$$a \ll d, vt \ll d, d \ll r_0, t_{\text{ign.}} \ll t_{\text{pulse}} \quad (2)$$

where  $a$  is the distance between the axes of the emitting filaments,  $d$  is the distance between the cathode plane and the anode,  $v = a/t$ ,  $r_0$  is the initial radius of the cathode;  $S = Nla$  is the area of the cathode, where  $N$  is the number of filaments, and  $l$  is the length of one filament.

During the experiment, conditions (2) were observed in a satisfactory manner. Radiograms were obtained which indicate the structure of the electron beam: at low voltage, electrons are emitted not from the entire cathode, but only from discrete parts of it; the value of the emission current

is described by the Childs-Langmuir law. To account for voltages to 500 kv, Eq. (1) is rewritten with account taken of relativistic effects:

$$i = 2.33 \cdot 10^{-6} u^{3/2} \frac{S}{d^2} \left[ 1 - \frac{3}{56} \left( \frac{eu}{mc^2} \right) + \frac{15}{1408} \left( \frac{eu}{mc^2} \right)^2 - \frac{3}{1024} \left( \frac{eu}{mc^2} \right)^3 \right], \quad (3)$$

where  $m$ ,  $e$  are the mass and the charge of an electron,  $c$  is the velocity of light. The volt-ampere characteristic of a pulse diode is presented. Current may increase due to the preliminary formation of plasma at the cathode prior to arrival of the main voltage pulse, as a result of explosion of the edges due to pre-pulses; this effect can cause an almost tenfold increase of the current in the diode.

Kazanskiy, L. N., and B. N. Yablokov.  
Powerful nanosecond generator. IN: Tr.  
 2-go vses. soveshch. po uskoritelyam  
 zaryazhen. chastits, 1970, v. 1. Moskva,  
 Nauka, 1972, 98-100. (RZhElektr, 1/73,  
 no. 1A288)

A general description of the cited generator is presented, as well as its design calculations, the selection of its parameters, its design features, and operational results. The generator is designed for supplying the field emission electron gun of the ESU-1 accelerator with single pulses having the following parameters: voltage 2 Mv, current 5 kiloamperes, pulse rise time 12 nanoseconds, and pulse duration of 35 nanoseconds. The output pulse is formed by a dual shaping line which is charged by a Marks bank. A feature of the generator is its reduced dimensions. The generator uses a liquid polarized dielectric -- glycerin with high dielectric constant. The pulse of the double shaping line is transformer-coupled for decreasing the

line charge. The discharger of the double shaping line is connected between a ground electrode and high-voltage electrode, at the point where voltage is supplied to the high-voltage electrode from the voltage-pulse generator. This facilitates control of the discharger, and provides for cutoff of the voltage pulse generator from the electron gun and the double shaping line after commutation of the double shaping line. A schematic diagram of the generator is provided. The double shaping line consists of two lines, coupled together at the input of the transformer which is in the form of a smooth exponential coupling. The charge in the second line is effected via a helical short-circuit line. All components of the generator, including the voltage-pulse generator, are constructed coaxially; this permits the grounded electrode to be used as a shield, and minimizes edge effects.

Smiyan, O. D. Mechanism of processes taking place during treatment by electron beam. FiKhOM, no. 2, 1973, 3-9.

A study is reported on the initial stage of the fusion of metal by an electron beam. A new scheme of this process is proposed, which enables an explanation to be made both of the formation of the entire range of the various forms of the fusion of metal by an electron beam during welding, and of the various types of the treatment of materials by an electron beam (melting, welding, dimensional treatment, and evaporation).

The action of a focused electron beam on metal is as follows: an induced instantaneous internal point heat source is formed followed by isentropic expansion of the melt volume. Next, part of the liquid metal is forced out onto the surrounding colder metal; vapor-gas bubbles are formed, as well as a pulsating highly ionized plasma; part of the liquid metal is drawn

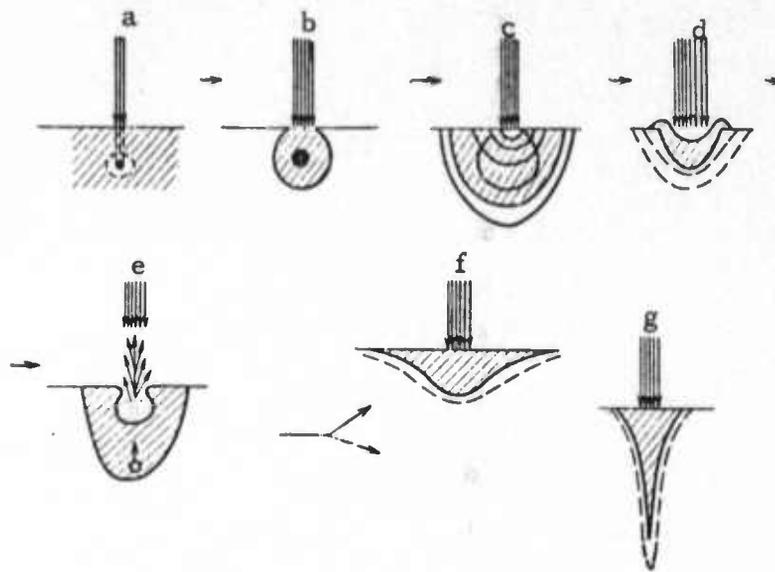


Fig. 1. General sequence of the interaction of a focused electron beam with metal. Shaded portions indicate liquid phase of the metal.

along by a thin plasma column, which originates in the center of the electron beam and bombards the cathode of the electron gun (see Fig. 1).

Depending upon the electron-treatment regime, the density and energy of the electron beam, and the thermophysical property of the target material, the role and significance of each of the enumerated factors change, and so does the relationship among them, as well as the thermal effect resulting from their combined action upon the metal. Fig. 2 shows crater formations in steel and nickel target specimens.

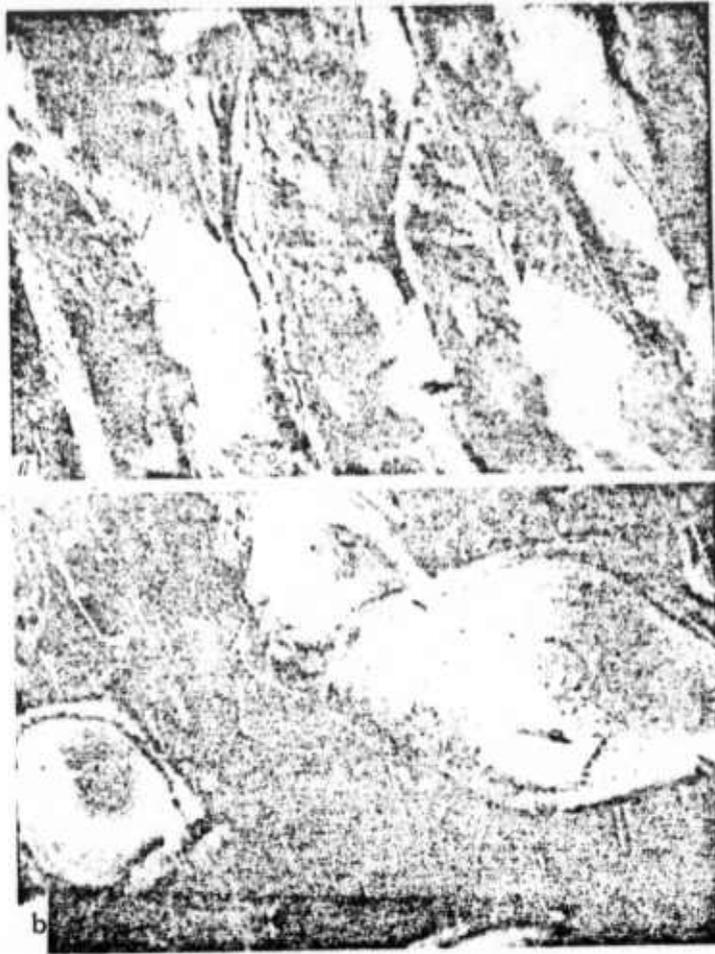


Fig. 2. External view of melt crater, x 40.  
a - type Kh18N9T stell; b - Ni single crystal

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Bredikhin, M. Yu., A. I. Maslov, Ye. I. Skibenko, and V. B. Yuferov. Heating of dense plasma with powerful electron beams. ZhTF, no. 3, 1973, 517-524.

A determination was made of time and functional relationships of the electron temperature, the mean ion energy and the amplitudes of superhigh-frequency oscillations induced in argon plasma to the parameters of a beam-plasma discharge within the magnetic field range of 10-35 koe in the center of the trap. The plasma was formed by interaction of an electron beam with a dense gas target; a description of the experimental equipment is given. The electron temperature of the plasma was determined by an X-ray technique and diamagnetic probes. Calorimetric measurements showed that the total power losses of the electron beam during passage through the plasma reach 50 - 60%. With an electron beam power of about 4 Mw, values of  $T_e \approx 3 - 4$  kev were obtained, with the temperature increase proportional to the input of energy into the plasma. The process of plasma heating is accompanied by intensive microwave radiation, the power of which is several orders greater than the level of thermal radiation. The amplitudes of the shf oscillations induced in the plasma were measured in relation to the current and energy of the electron-beam. It was established that the amplitude of these oscillations depends more upon the energy of the beam than upon its current.

On the basis of relationships of the current of neutral atoms arriving at the detector to the intensity of the magnetic field and the density of the neutral gas, the energy distribution of atoms emitted from the plasma was plotted for several values of the magnetic field. From comparison of experimental results with theory, the conclusion was drawn that the basic mechanisms causing heating of plasma electrons are cyclotron resonance and hybrid resonance. In the region of low density of the neutral gas, with  $H_0 \leq 10$  koe, and small density gradients  $dN/dr$ , and when the electron plasma frequency is approximately equal to the electron cyclotron frequency, the

principal mechanism leading to the heating of plasma electrons is cyclotron resonance; under these conditions the contribution of hybrid resonance is of a limited nature. With a higher gas density and greater intensity of the magnetic field, when the electron plasma frequency is greater than the electron cyclotron frequency, the plasma heats up primarily owing to hybrid resonance. In this case, favorable conditions are realized for absorption of the oscillations induced in the plasma; these oscillations propagate against the magnetic field and attenuate in the plasma layer.

Yegorov, N. V., G. N. Fursey, and A. V. Kocheryzhenkov. Kinetic effects during field emission from high-resistance n-Si. FTT, no. 3, 1973, 892-894.

A study is made to determine whether the appearance of nonlinear volt-ampere characteristics during field emission from n-Si is accompanied by corresponding kinetic effects. Research was done on n-Si specimens with  $\rho = 10, 50, 300, 800,$  and  $2000$  ohm x cm. For specimens with  $\rho = 10$  and  $50$  ohm x cm the v-a characteristics were linear, and no kinetic effects were manifested. For n-emitters with  $\rho = 300, 800,$  and  $2000$  ohm x cm kinetic effects appeared which were superficially analogous to those shown with p-Si. In all the cases where kinetic effects appeared in n-Si, the v-a characteristics had a saturation sector. The saturation current densities considerably exceeded those of the saturation currents observed at room temperatures for p-Si. For the specimen shown in Fig. 1 b,  $j = 1 \times 10^4$  a/cm<sup>2</sup>. The kinetic effects were manifested most clearly for n-Si specimens with  $\rho = 2000$  ohm x cm, and it is for these specimens that the principal results are presented.

The typical form of oscillograms is presented in Fig. 1 a. As with p-Si, in region I of the v-a characteristics a lag in the appearance of the field-emission current is observed, in relation to start of the voltage pulse (Fig. 1 b).

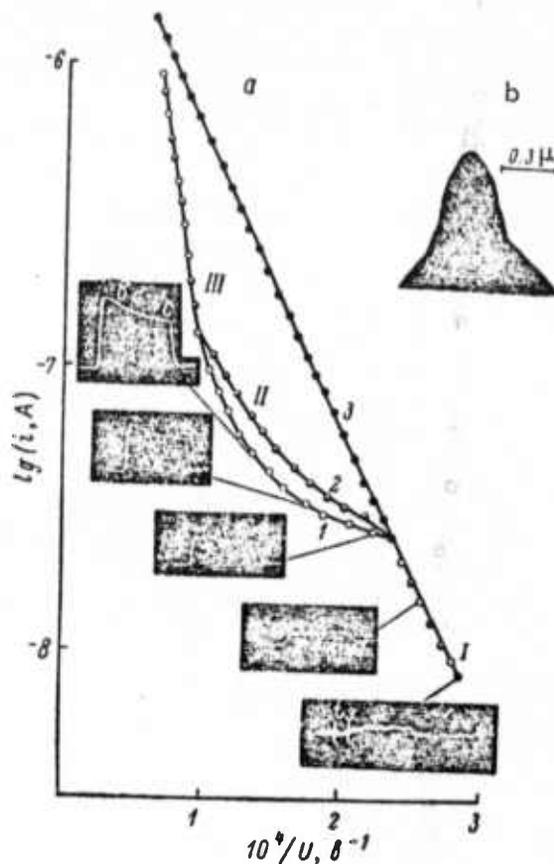


Fig. 1. Volt-ampere characteristics.

1 - steady-state; 2 - constructed from current values in the quasi-steady sector at the end of a pulse lasting  $\tau = 100$  microseconds; 3 - constructed on the basis of current maximum. a - current waveforms; b - photomicrograph of a semiconductor field emitter. Time  $t_3$  is the lag time of a current pulse in relation to cut-in of the voltage pulse.

In region II of the  $v$ - $a$  characteristics (oscillogram in Fig. 1 a), the field emission current changes with respect to time in a manner very similar to that observed for p-Si specimens. Also typical is the appearance of a current maximum with a subsequent sharp decline (sector b), and slow relaxation (sector c). In distinction from p-Si specimens all the characteristic times, and particularly the time of slow relaxation, are considerably shorter. There is also a considerable difference in the ratios of the maximum current to the current at the end of the pulse (Fig. 2).

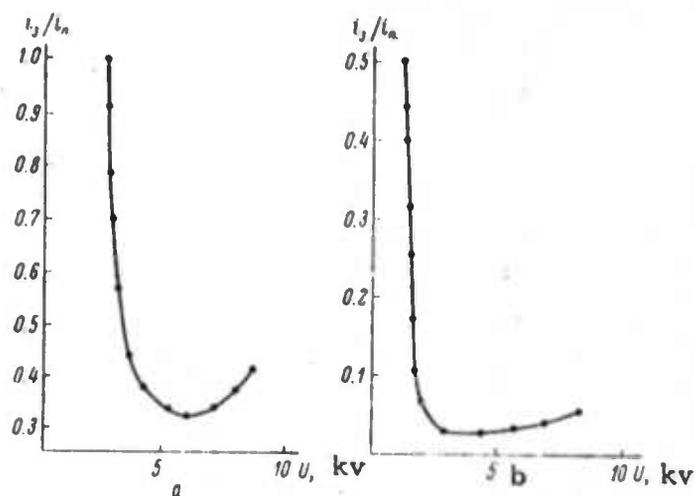


Fig. 2. Functions  $i_3/i_n - b(u)$ , where  $i_n$  is the value of the current in the region of the maximum and  $i_n$  is the value of the current at the quasi-steady sector at the end of a pulse with duration  $\tau = 500 \mu\text{sec}$  for p-Si (a) and n-Si (b).

The quantitative differences of the kinetic characteristics observed for n-Si and p-Si specimens cannot be entirely explained by the effect of the surface states, and are apparently linked to processes within the volume of a semiconductor emitter.

Sinev, V. P. Thermal effect of an electron beam on solids. FiKhOM, no. 2, 1973, 134-137.

A theoretical model is introduced of the thermal effect of a high-density electron beam on a solid. The model assumes the partial transfer of electron energy to the bulk material; in this case, the total thermal effect  $Q$  is the sum of simultaneous effects from the point source  $q_1 = kQ$  near the solid surface and from a linear source  $q_2 = (1-k)Q$  which can act to a depth  $\delta$  below the surface (Fig. 1).

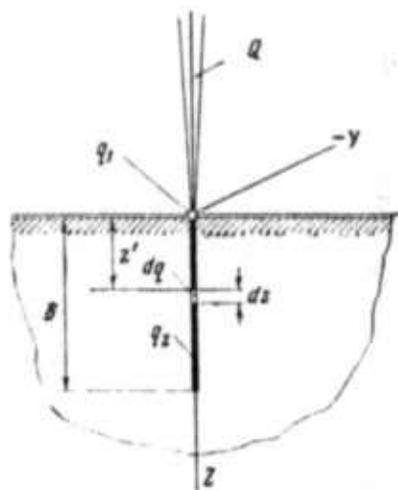


Fig. 1. Diagram of electron beam thermal effect on a solid.

Formulas are derived from the cited model for temperatures  $T_1$  and  $T_2$  from the continuous effects of the point and linear stationary sources, respectively, where the linear source was considered as the sum of instantaneous point sources  $dq_2$ .  $T_1$  and  $T_2$  are expressed as  $f_1(R)$  and  $f_2(r)$ , respectively, where  $R = \sqrt{x^2 + y^2 + z^2}$  and  $r = \sqrt{x^2 + y^2}$ . The expressions of  $T_1$  and  $T_2$  are combined into one equation  $T(x, y, z) = T_1 + T_2$  which gives temperature  $T$  of the stationary point  $M(x, y, z)$ . Isotherms are plotted from

this equation for molybdenum heating with electron beams of different Q. The isotherms assume different shapes, depending on  $\delta$  and the coefficient k of energy distribution. In agreement with experiment, e. g., electron beam welding, theoretical isotherms assume an approximate triangular shape when  $\delta$  and  $\tau_2$  are increased. In the case of electron beam welding, the approximate value of k was evaluated from experimental data to be 0.2-0.7 which is in agreement with the theoretical model.

Buts, V. A. Stability theory of an electron beam in an inhomogeneous dielectric medium.

ZhTF, no. 3, 1973, 456-466.

Instability development of a homogeneous infinite electron beam during propagation through an inhomogeneous medium is studied theoretically. The mechanism of the beam instability development is similar to that described by Kurilko (DAN SSSR, v. 208, no. 5, 1973, 1059) for a homogeneous medium.

Only individual beam particles in an inhomogeneous medium emit transient radiation instead of Cerenkov waves. Calculations by two independent methods show that transient radiation generates a beam instability whose increment  $\gamma$  is proportional to radiation magnitude from an individual particle, and beam density  $\omega_b$ . The practically important problem is solved of beam propagation along a metallic waveguide of radius a which is located in a strong magnetic field ( $\omega_H \geq \omega, \omega_b$ ) and is filled with a periodically inhomogeneous plasma. Propagation of an electron beam in such a system increases the amplitude of both longitudinal and transverse waves; conditions for oscillation rise are formulated for both the nonrelativistic and relativistic cases. These show that the plasma inhomogeneity period at a high beam propagation velocity ( $v_0 \sim C$ ) is significantly longer than at a low  $v_0$ . This

result is explained by the shift of transient radiation peak toward shorter waves, when particle velocity is increased. The width of the instability region increases, together with  $\gamma$ , when beam modulation index is increased.

It is shown that in the system under study transverse waves can also develop under certain conditions. Thus a direct amplification of transverse waves by an electron beam may be feasible in amplifiers and oscillators without conversion of the beam longitudinal oscillations into transverse e-m waves. Buildup of longitudinal oscillations in the nonrelativistic case is described without accounting for the transverse waves effect. In contrast, rise of both longitudinal and transverse waves in the relativistic case is described adequately only with allowance for the interaction between the two kinds of waves.

Gorelik, G. Ye., N. V. Pavlyukevich, T. L. Perel'man, and G. I. Rudin. Melting of a semi-infinite body from an internal point heat source. IFZh, v. 24, no. 3, 1973, 525-532.

Liquid phase formation and melting front propagation in a semi-infinite body from the effect of an electron beam are analyzed, using the approximation of a point internal heat source. Solution of the symmetrical Stefan problem by the method of successive iterations led to the conclusion that nonstationary heat conductivity is the main determinant of melting front propagation during a dimensionless time  $\tau \geq 1$ . A formula is derived for the melting zone radius  $r_1$  in a semi-infinite body, which shows the effect of a flat free surface on melting front propagation.

Solution of the spherically symmetric problem for a real three-dimensional heat source shows that source distributivity  $b$  must be taken into account at  $\bar{r}/b \leq 1$ , where  $\bar{r}$  is the maximum melt radius for a point source. Formulas are also derived for the melt pressure and radius of the plasticity region as functions of stress field components which determine time of melt ejection.

Kovalenko, V. P. Observing feedback in a plasma-electron beam system. UFZh, no. 3, 1973, 514-515.

In a study on electron beam-plasma interaction, a positive feedback from an argon plasma-beam interaction to the beam at its entrance to the plasma was observed, in the absence of an external source of modulation, e. g. a magnetic field. The feedback was evidenced by fairly regular beam oscillation at the entry point, at a frequency equal to that of oscillations recorded in the nonlinear interaction region (meniscus). There is a breakdown in oscillations in the absence of meniscus. It is shown that interposition of a high-frequency tunable resonator at the beam entrance does not significantly affect oscillation excitation, since oscillations at the meniscus are nearly independent of tuning. In these experiments the resonator acted as a measuring instrument only. Thus the existence of feedback, and hence beam modulation from the feedback, is confirmed experimentally. It is noted that regularity of beam oscillations is a prerequisite for bunching.

Yurike, Ya. Ya., V. F. Puchkarev, and  
D. I. Proskurovskiy. Appearance of  
luminescence between electrodes during  
spark current rise time in a vacuum break-  
down at constant voltage. IVUZ Fiz, no. 3,  
1973, 12-16.

New experimental data were obtained in support of an earlier assumption by two of the authors that the breakdown at constant voltage of a narrow vacuum gap is initiated by an explosion-like appearance of cathodic flares (February 1972 Report, p. 112). In experiments similar to those described in the cited study, times were determined of luminescence appearance directly in front of the cathode and anode, as well as in the center of the interelectrode gap, and were compared with the onset of the spark current rise. Luminescence was recorded with a photomultiplier with  $\sim 3$  nsec. time resolution. The experimental data of both constant and pulsed voltage breakdowns revealed that only luminescence at the cathode appears simultaneous with the onset of current rise. Confirmation was thus obtained of the earlier assumption that in all breakdown cases studied, irreversible breakdown of vacuum insulation is caused by the explosion-like onset of cathodic flares.

Rosinskiy, S. Ye., and V. G. Rukhlin. Magnetic  
and charge neutralization of an electron beam  
injected in magnetically-active plasma. ZhETF,  
v. 64, no. 3, 1973, 858-867.

The behavior of a cold magnetically-active plasma following injection of a low-density electron beam parallel to an external magnetic field is examined with ion effects taken into account. The magnetic and charge neutralization effects are emphasized. Asymptotic formulas for the beam-induced electromagnetic fields, counter-current and charge density are derived by a method described earlier (ZhETF, v. 61, 1971, 177). The

cited formulas are analyzed in the cases of a weak ( $\Omega_i \leq \nu_i$ ) and a strong ( $\Omega_i \geq \nu_i$ ) magnetic fields, where  $\Omega_i$  and  $\nu_i$  are ion gyrofrequency and collision frequency, respectively. In the former case, diffusion length  $z'$  is the same as in nonmagnetized plasma, but the width of the ring layer which contains the fields and currents increases under the condition of magnetic neutralization. Radial dependence of the azimuthal magnetic field  $B_\phi(r)$  within the ring layer becomes quasiperiodical when  $B_\phi$  intensity is increased. When  $\Omega_i \geq \nu_i$ , the ion effect becomes significant;  $z'$  then decreases relative to that in a nonmagnetized plasma. Conditions are also formulated for the absence of magnetic and charge neutralization. In that case, any forward beam current through the plasma in excess of the Alfvén current becomes impossible.

Pustovalov, V. V., V. P. Silin, and V. T. Tikhonov. A quasilinear theory of parametric instability of a magnetoactive plasma. ZhETF, v. 64, no. 3, 1973, 848-857.

The article considers the theory of parametric resonance - a quasilinear relaxation theory of a parametrically excited plasma, located in a constant and homogeneous magnetic field. The quasilinear theory of the magnetoactive plasma irradiated by an intensive electron beam is developed by means of equations for pair correlation functions of plasma particles. The equations are solved for the case of low electron oscillation amplitude in the pumping wave field. It is shown that quasilinear parametric saturation of the increasing noise of a magnetically active plasma in a weak pumping field occurs owing to deformation of the electron distribution function in a comparative narrow epithermal velocity interval, when the heating effects may be neglected. Time variations are derived for parametric oscillation growth, spectral energy density of parametrically excited plasma excitations, and electron distribution function. A significant number of fast electrons is observed, i. e., about 0.1 percent of the total number.

Zakatov, L. P., A. S. Kingsep, and A. G. Plakhov. Experimental observation of nonlinear stabilizing of electron beam instability in plasma. ZhETF P, v. 17, no. 6, 1973, 280-284.

Under the conditions of most plasma-beam experiments, the main nonlinear process is the scattering of Langmuir waves on plasma ions. While stimulated scattering under conditions of weak turbulence has up to now not been observed experimentally, a number of effects exist which can be explained by means of such a process. In the described experiments, the condition was adhered to wherein the main nonlinear effect, namely the scattering of waves on ions, results in the reflection of a wave with an insignificant loss of momentum.

If two electron beams are injected into a plasma opposite one another, and the energy of each of them is subject to the condition for wave reflection with insignificant momentum loss, the more energetic beam generates a noise regime in the plasma which effectively stabilizes the second beam. Since the electron temperature (and particularly the ion temperature) is determined rather imprecisely in plasma-beam experiments, the energy difference which corresponds to optimum stabilization must be selected experimentally.

A description of such an experiment is given, together with a schematic diagram. Electron guns EG-1 and EG-2 were situated at opposite ends of the vacuum vessel. The beam currents and the beam energy could be varied within wide limits, so that optimal operating regimes could be selected. The current pulses of EG-1 were 250 microseconds in duration, and those of EG-2 were 130 microseconds. EG-1 and the plasma injector were turned on simultaneously, and EG-2 went off with a lag of 100 or 300  $\mu$ sec. The 100  $\mu$ sec lag permitted the beam of EG-2 to be injected into the plasma with a high degree of oscillations induced by the beam of EG-1, and the 200-microsecond lag provided for injection of the beam of EG-2 in the presence of thermal noises.

Direct observation of the stabilization effect of a beam in plasma was conducted by means of measurement of the distribution functions of the beam particles vs. longitudinal energies. Two beams were injected into cold hydrogen plasma along the magnetic field, counter to one another, in the above-indicated time sequence. At equal fixed currents of the two beams, the optimal relationship was found between the energies of the stabilizing beam and the test beam. It was determined that the stabilization effect is most clearly expressed when the beam energies are similar and the energy difference does not exceed (1 - 2) kev at a stabilizing-beam energy of 13 kev and currents of 10 a.

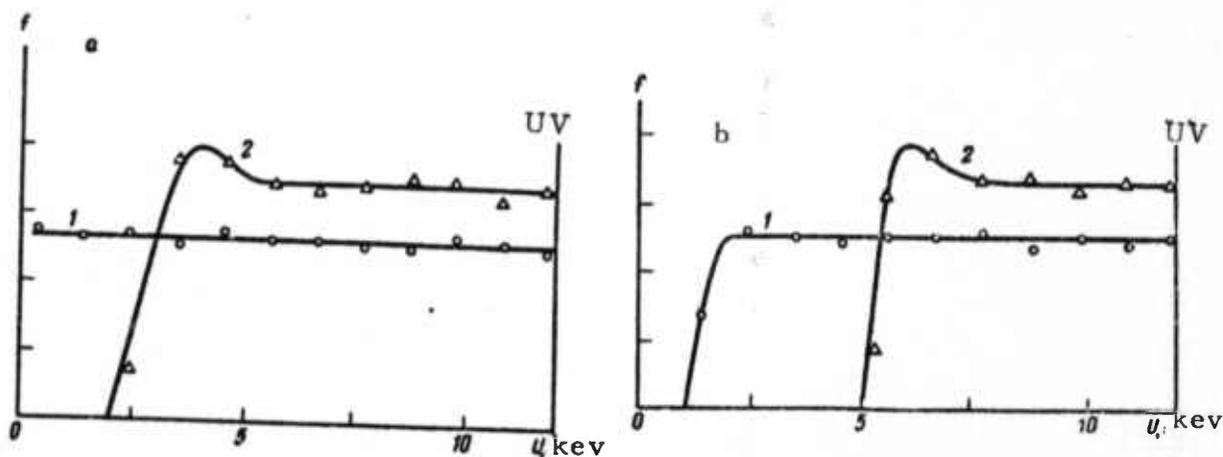


Fig. 1. Distribution functions of electrons vs longitudinal energies in the test beam at plasma outlet. a) curve 1- without a stabilizing beam; curve 2- with a stabilizing beam. The current of the test beam is 8 a, the energy is 12 kev, the current of the stabilizing beam is 8 a, the energy is 13 kev; b) same, for a test-beam current of 5 a.

Shown in Fig. 1 a (curve 1) is the distribution function in the test beam of EG-2 at the plasma outlet in the absence of the EG-1 stabilizing beam. The distribution has the usual form of a plateau all the way to zero

energies. With simultaneous passage of the two beams, the distribution function changes: the beam is less "diffused" with respect to the energies, i. e., it is stabilized (curve 2). Decreasing the current of the test beam gives better stabilization, as seen in Fig. 1 b.

Measurements of plasma diamagnetism have shown a considerable decrease in the effectiveness of heating from the test beam in the presence of the stabilizing beam. The stabilization effect is noted to a large degree on the diamagnetic signal, since in this case average values are measured for the entire volume of the trap, and nonfulfillment of the stabilization conditions in individual local zones, as well as "diffusion" of the beam prior to entry into the trap, are in this case insignificant.

Vyatskin, A. Ya., V. V. Trunev, and  
Kh. -I. Fitting. Penetration of 0.5-4 Kev  
electrons through thin films of various  
metals. RiE, no. 2, 1973, 432-434.

Earlier studies have been made on the integral characteristics of the penetration, reflection, and absorption of electrons with initial energies of  $E_0 = 4-30$  kev in thin films of some metals and semiconductors (Al, Cu, Au, Ge, Si). General empirical relationships have been established which describe the integral coefficients of penetration  $\eta$  and reflection  $r$  as a function of the film thickness and the initial energy:

$$\eta = \exp[-\alpha x^p], \quad (1)$$

$$r = r_0(1 - \exp[-\mu x^p]). \quad (2)$$

where  $\alpha$  and  $\mu$  are coefficients which depend upon the initial energy and the

substance,  $r_0$  is the coefficient of reflection in the case of a massive specimen; parameter  $p$  does not depend upon the initial energy and is determined by the properties of the substance.

The present paper presents the results of a simultaneous study of the characteristics of penetration, reflection, and absorption of electrons with the initial energies of 0.5-4 keV in aluminum and beryllium, by the method of leakage through of thin films measuring in the range of 150-3000 Å. The experimental procedure is briefly described. Measurements were conducted in a working vacuum of  $5 \times 10^{-8}$ - $10^{-7}$  torr. The primary functions  $\eta(E_0)$ ,  $r(E_0)$ , and  $\gamma(E_0)$  were obtained in the films ( $\gamma$  -- absorption). The primary functions were converted to a set of curves  $\eta(x)$ ,  $r(x)$ , and  $\gamma(x)$  on the basis of the law of charge conservation,  $r + \gamma + \eta = 1$ . In Fig. 1 these

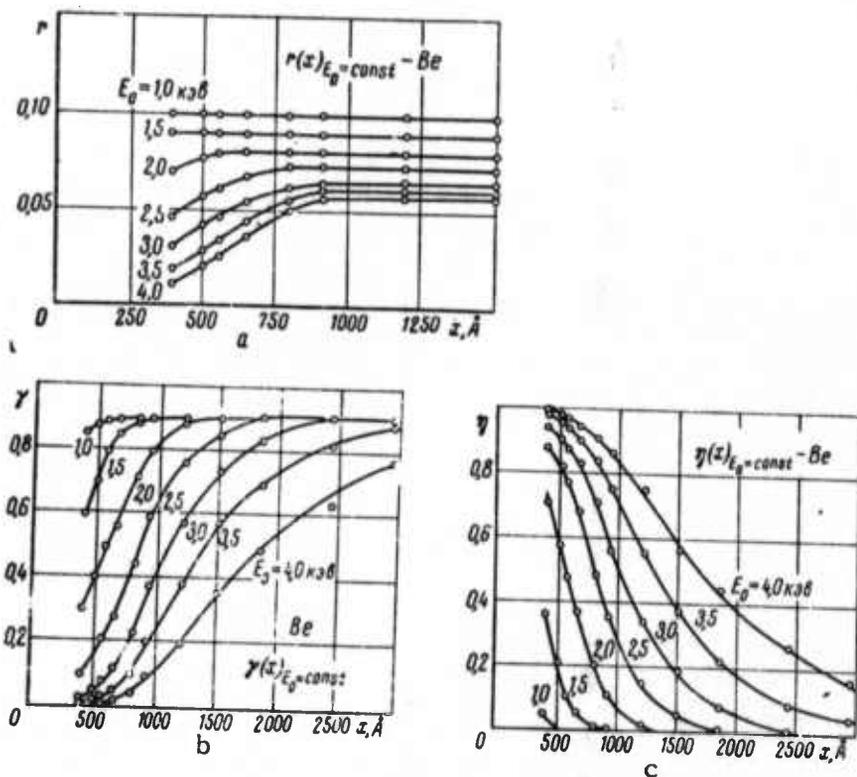


Fig. 1. Relationship of the coefficients of reflection  $r$ , absorption  $\gamma$  and penetration  $\eta$  to film thickness  $x$  for Be: a-  $r$ ; b-  $\gamma$ ; c-  $\eta$ .

curves are presented for Be. Within the range of small thicknesses (up to 400-600 Å) and at initial energies of 3-4 keV, almost a complete absence of electron absorption is noted, and only a redistribution of coefficients  $\eta(x)$  and  $r(x)$  occurs in accordance with the equation  $\eta + r = 1$ . This indicates a considerable degree of electron scattering and reflection, and the relatively small role of deceleration.

An analysis of  $\eta(x)$  and  $r(x)$  for Al and Be showed that they are reasonably closely described by Eqs. (1) and (2), but with changing values of  $p$ . Values of the experimental parameters  $p$ ,  $\alpha$ , and  $\mu$  are given by the authors in tabular form.

Hence the relationships (1) and (2), established previously within the energy range of 4-30 keV, may be used for describing the characteristics of penetration and absorption within the range of 0.5-4 keV, if account is taken of the change of parameter  $p$  and the relationship of the reflection coefficient  $r_0$  to the initial energy.

B. Recent Selections

Abu-Asali, Ye., B. A. Al'terkop, R. D. Dzhamalov, and A. A. Rukhadze. Nonlinear ionic surface oscillations in a semiconfined current-carrying plasma. ZhETF, v. 64, no. 6, 1973, 2051-2056.

Bazhenov, G. P., Ye. A. Litvinov, G. A. Mesyats, D. I. Proskurovskiy, A. F. Shubin, and Ye. B. Yankelevich. Metal influx into the cathode flare during explosive emission of electrons from metallic points. Part 1. Initial explosion of points with typical geometry of the field emitters. ZhTF, no. 6, 1973, 1255-1261.

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Manzyuk, N. A., V. L. Sizonenko, K. N. Stepanov, V. A. Suprunenko, Ye. A. Sukhomlin, and A. M. Ternopol. Electrical conductivity of plasma during collective interactions in a heavy-current gas discharge. IN: Fizika plazmy i problemy upravlyayemogo termoyadernogo sinteza. Resp. mezhved. sb., no. 4, 1973, 15-20.

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Zablotskaya, G. R., B. A. Ivanov, S. A. Kolyubakin, A. S. Perlin, V. A. Rodichkin, and V. B. Shapiro. The REP-5 pulsed heavy-current accelerator of relativistic electrons with a 50 ka beam current. Atomnaya energiya, v. 34, no. 6, 1973, 471-474.

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## 5. Material Sciences

### A. Abstracts

Sokolova, T. V., Ye. Ya. Litovskiy, T. B. Buzovkina, and S. S. Bartenev. Analysis of microstructural parameters effect on thermal conductivity of porous ceramic materials. NM, no. 2, 1973, 296-300.

Effects of different microfissility parameters on the effective thermal conductivity  $\lambda_{\text{eff}}$  of porous ceramics are calculated from the formula

$$\lambda_{\text{eff}} = M\lambda_0 \quad (1),$$

where  $\lambda_0$  is the calculated thermal conductivity of a porous material without allowance for microcrack effects, and M is the corrective factor. In calculation of M, the dimensionless parameters defining microcrack dimension,  $\lambda_m$  and  $\lambda_s$  of intergranular material and gas gap, respectively, and intergranular contact area, are taken into account. The calculated plots show M dependence on the cited parameters. The theoretical data were used to evaluate the effect of microstructural parameters on  $\lambda_{\text{eff}}$  of the plasma sputtered coatings of analytical and spectral grade alumina. Comparison of the theoretical and experimental high-temperature dependences of  $\lambda_{\text{eff}}$  for alumina shows that introduction of M narrows the discrepancy between these two sets of data to 100% in contrast to a 500% discrepancy without this correction.

Popolitov, V. I., and A. N. Lobachev. High temperature and pressure interactions of Sb-Te-I-R-H<sub>2</sub>O systems (R = solvent). NM, no. 2, 1973, 210-212.

Hydrothermal synthesis was studied of photoconductive and piezoelectric single crystals in the cited system at 290-450° C with a 15-40° C vertical temperature gradient, and under pressure in the 200-2000 atm. range. The ratios of the Sb, Te, and I reactants and R = HI, HCl, or C<sub>2</sub>H<sub>5</sub>OH concentrations were varied in the experiments. Crystallization regions were determined for Sb-Te-HI-H<sub>2</sub>O; Sb-Te-HI-I-H<sub>2</sub>O; Sb-Te-HI-HCl-H<sub>2</sub>O; and Sb-Te-I-C<sub>2</sub>H<sub>5</sub>OH-H<sub>2</sub>O systems. Single crystals of SbTeI, Sb<sub>2</sub>Te<sub>3</sub>, Sb, Te, and SbI<sub>3</sub> were obtained in variable yields, depending on the ratio of reactants and R concentration. Crystallization rate in the Sb-Te-I-H<sub>2</sub>O system is increased by addition of ethyl alcohol as solvent. It was established that temperature, temperature gradient, and pressure variations within the cited ranges do not affect phase formation. The first two factors, however, increase the crystallization rate.

Uglov, A. A. Seminar on the physics and chemistry of materials processing using concentrated energy fluxes, April 25, 1972. FiKhOM, no. 1, 1973, 158-159.

A brief summary is given of some ten papers presented at the 35th Seminar on the title subject, held at the Baykov Institute of Metallurgy under the chairmanship of Academician N. N. Rykalin. Over 80 Soviet researchers from different institutions participated in the proceedings. The principal topic of the papers and the subsequent discussions was development of solutions to nonlinear and linear heat and mass transfer problems.

A paper by V. V. Salomatov and A. D. Gorbunov (Tomsk) dealt with analysis of high-temperature heating and surface destruction of materials. The authors applied their own method of quasistationary approximation to solve the problem of material ablation from a variable heat flux. They derived sufficiently accurate formulas for engineering calculations of ablation.

I. V. Zuyev and A. A. Uglov (Moscow) reported on fluctuations of the melt depth during electron-beam welding with a dagger-shaped melting zone. Evaluation of the electron beam-metal vapor interaction indicated a pulsed type interaction, even with a continuous beam.

Electron-beam melting was also the subject of an experimental study by E. V. Farber et al, who obtained data relating the temperature field of a molten bath mirror to melting parameters.

B. Recent Selections

i. Crack Propagation

Borisova, Ye. A., I. I. Shashenkova, and R. D. Glebova. Sensitivity of some titanium alloys to cracks. IN: Sbornik. Struktura i svoystva titanovykh splavov, 1972, 154-160. (RZh Metallurgiya, 6/73, no. 61393)

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Edmondson, B., K. Formbi, and M. Stegg. Investigating fracture resilience. IN: Sbornik. Novyye metody otsenki soprotivleniya met. khrupkomu razrusheniyu, Moskva, Mir, 1972, 245-255. (RZh Mekh, 5/73, 5V547).

Finkel', V. M., L. N. Muratova, and V. P. Ivanov. Effect of slip band on crack propagation. FTT, no. 6, 1973, 1917-1919.

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Finkel', V. M., Yu. A. Brusentsov, V. Ye. Sereda, G. B. Muravin, Yu. I. Tyalin, and V. A. Dobkevich. Interaction of stress waves with cracks. IN: Tr. Mosk. in-ta. khim. mashinostr, no. 44, 1972, 65-75. (RZh Mekh, 5/73, no. 5V545)

Kanazava, T., S. Machida, S. Momota, and I. Nagivara. Studying initiation of brittle fracture on the basis of crack opening concept. IN: Sbornik. Novyye metody otsenki soprotivleniya met. khrupkomu razrusheniyu. Moskva, Mir, 1972, 90-106. (RZh Mekh, 5/73, no. 5V555)

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Zhunisbekov, S. Effect of artificial crack-type macroscopic defects on tensile strength of a polyvinylchloride sheet. IN: Sbornik. Tekhn. nauki, no. 2. Alma-Ata, 1972, 89-94. (RZh Mekh, 5/73. no. 5V1350)

ii. High Pressure Research

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vii. Magnetic Bubble Materials

Petrova, L. O., E. I. Ilyashenko, and M. A. Rozenblat. Analysis of interaction between a magnetic saturated overlay and a magnetic bubble. PSS(a), v. 17, 1973, K19-K23.

## 6. Miscellaneous Interest

### A. Abstracts

Gavrilov, F. V., A. S. Myasnikov, G. G. Zhadan, G. S. Orlova, and M. V. Strokin.  
Results of flight tests of an ion engine model with cesium-on-tungsten surface ionization.  
Kosmicheskiye issledovaniya, no. 1, 1973, 140-144.

The November 1969 and August 1970 flight tests of a cesium ion engine model are described and the flight test data of the model are given. The main purpose of the tests was to investigate the efficiency of different neutralizers of the accelerated ion beam under conditions in space. The principal components of the ion engine were the cesium ion source with porous tungsten, ion optical system, and the cesium vapor supply system. The ion engine and the neutralizers were tested on board the "Ion" unmanned space lab (FSL) (Fig. 1).

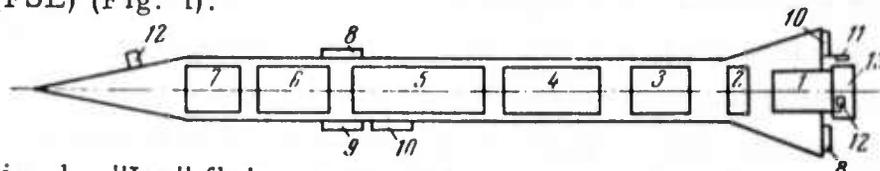


Fig. 1. "Ion" flying space lab: 1- ion engine, 2- magnetic amplifiers, 3- switch gear, 4- voltage converter, 5- power sources, 6- telemetry station, 7- programmer, 8- ion trap, 9- electrostatic fluxmeter, 10- multi-electrode probe, 11- thermionic neutralizers, 12- plasma neutralizer, 13- lid with sorption pump.

The FSL was launched from a geophysical rocket into a ballistic orbit to a maximum altitude of 300 km. The maximum speed attained was 2 km/sec and its rotation angular velocity was  $\sim 3$  rps. The lid with the pump was jettisoned after 98 sec. ( $\sim 140$  km) from the engine start, simultaneously

with the opening of the supply system valve, and switching on of the plasma neutralizer heater. The maximum ion beam velocity was  $\sim 60$  km/sec. As expected, the plasma neutralizer was the most efficient (Fig. 2). The most

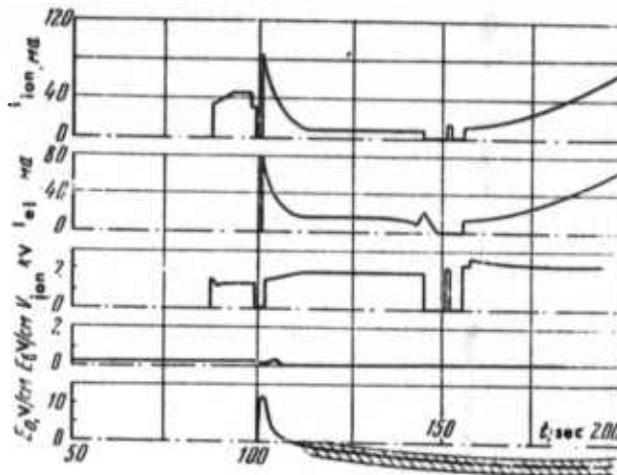


Fig. 2. Variations of ion current  $I_{ion}$ , electron current  $I_{el}$ , ion source potential  $V_{ion}$ , FSL electric field intensity  $E_b$ , and the total FSL field intensity  $E_0$  during ion engine tests.

characteristic feature of the oscilloscope traces in Fig. 2 is the  $E_0$  variations after 98 sec. from the start. Heating of the plasma neutralizer results in formation of a plasma bridge from Cs ions and electrons emitted by a tungsten coil. The "cold" electrons penetrate the ion beam by crossing the bridge and thus cause a sharp drop in the beam space charge. The effect of shifting the thermionic neutralizer position in relation to the ion beam could not be ascertained.

Bondarenko, I. M., A. A. Zagorodnikov,  
V. S. Loshchilov, and K. B. Chelyshev.  
Relationship of sea state parameters to  
spatial spectrum of aerial photographs and  
radar images of the sea surface. Okeanologiya,  
no. 6, 1972, 1099-1106.

Algorithms are derived which relate sea state parameters to two-dimensional energy spectra of aerial photographs and radar images of the sea surface. The algorithms, together with formulas for correction of image scale distortions, can be used to determine various parameters of sea states from the sea surface optical and radar images, obtained with minimum distortion. Analysis of two-dimensional spectra of sea surface images shows the feasibility of determining the number, principal directions, frequency of maximum energy wave, dynamics of initiation and decay of wave systems, in addition to the direction and wave frequency of detached low-frequency wave components (swell). Simple formulas are also derived for computing complex one-dimensional (frequency) and two-dimensional sea state spectra. Special importance is attached to computation of the integral and narrow-band frequency angular spectra of the sea state from radar or photo-images of a large (15x15 km) sea area.

Azimi, Sh. A., A. V. Kalinin, and V. V. Kalinin.  
Effect of electrical circuit parasitic inductance on  
parameters of pressure pulses generated from an  
electric discharge in water. VMU, Geologiya,  
no. 6, 1972, 97-101.

An investigation is made of the effect of the parasitic inductance generated in a coaxial cable, up to 300 m long, which carries the electrical

energy between the source and the ship or between the receiver and the source, in the formation of an electric discharge for purposes of seismoacoustic surveying. The theoretical basis for the experimental procedure is explained, and experimental facilities are described. The electric-spark discharge source was situated at a depth of 40 m, and the receiver was situated at a depth of 26.7 m directly underneath the source; in this manner, imposition of the pulse reflected from the water surface upon the direct-wave pulse was avoided. The discharge voltage was 10 kv from a 150  $\mu$ f capacitor bank.

It was established that with a change of the inductance from 15 to 100 microhenries, which corresponds to increasing the length of the coaxial cable from 50 to 320 m, the intensity of the pressure pulse decreases by not more than 20%. Thus, for practical values of the length of the connecting coaxial cable (up to 300 m), the effect of the coaxial cable upon the pressure pulses may be disregarded. Pulse waveforms are shown for cables of different inductances.

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## 7. SOURCE ABBREVIATIONS

|            |   |  |
|------------|---|--|
| AiT        | - | Avtomatika i telemekhanika   |
| APP        | - | Acta physica polonica  |
| DAN ArmSSR | - | Akademiya nauk Armyanskoy SSR. Doklady   |
| DAN AzSSR  | - | Akademiya nauk Azerbaydzhanskoy SSR. Doklady   |
| DAN BSSR   | - | Akademiya nauk Belorusskoy SSR. Doklady  |
| DAN SSSR   | - | Akademiya nauk SSSR. Doklady   |
| DAN TadSSR | - | Akademiya nauk Tadzhikskoy SSR. Doklady  |
| DAN UkrSSR | - | Akademiya nauk Ukrainskoy SSR. Dopovidi  |
| DAN UzbSSR | - | Akademiya nauk Uzbekskoy SSR. Doklady  |
| DBAN       | - | Bulgarska akademiya na naukite. Doklady  |
| EOM        | - | Elektronnaya obrabotka materialov  |
| FAiO       | - | Akademiya nauk SSSR. Izvestiya. Fizika atmosfery i okeana  |
| FGIV       | - | Fizika goreniya i vzryva   |
| FiKhOM     | - | Fizika i khimiya obrabotka materialov  |
| F-KhMM     | - | Fiziko-khimicheskaya mekhanika materialov  |
| FMiM       | - | Fizika metallov i metallovedeniye  |
| FTP        | - | Fizika i tekhnika poluprovodnikov  |
| FTT        | - | Fizika tverdogo tela   |
| FZh        | - | Fiziologicheskiy zhurnal   |
| GiA        | - | Geomagnetizm i aeronomiya  |
| GiK        | - | Geodeziya i kartografiya   |
| IAN Arm    | - | Akademiya nauk Armyanskoy SSR. Izvestiya. Fizika   |
| IAN Az     | - | Akademiya nauk Azerbaydzhanskoy SSR. Izvestiya. Seriya fiziko-tekhnicheskikh i matematicheskikh nauk |

|                  |   |   |
|------------------|---|---|
| IAN B            | - | Akademiya nauk Belorusskoy SSR. Izvestiya. Seriya fiziko-matematicheskikh nauk                                |
| IAN Biol         | - | Akademiya nauk SSSR. Izvestiya. Seriya biologicheskaya  |
| IAN Energ        | - | Akademiya nauk SSSR. Izvestiya. Energetika i transport  |
| IAN Est          | - | Akademiya nauk Estonskoy SSR. Izvestiya. Fizika matematika  |
| IAN Fiz          | - | Akademiya nauk SSSR. Izvestiya. Seriya fizicheskaya   |
| IAN Fizika zemli | - | Akademiya nauk SSSR. Izvestiya. Fizika zemli  |
| IAN Kh           | - | Akademiya nauk SSSR. Izvestiya. Seriya khimicheskaya  |
| IAN Lat          | - | Akademiya nauk Latviyskoy SSR. Izvestiya  |
| IAN Met          | - | Akademiya nauk SSSR. Izvestiya. Metally   |
| IAN Mold         | - | Akademiya nauk Moldavskoy SSR. Izvestiya. Seriya fiziko-tehnicheskikh i matematicheskikh nauk                 |
| IAN SO SSSR      | - | Akademiya nauk SSSR. Sibirskoye otdeleniye. Izvestiya   |
| IAN Tadzh        | - | Akademiya nauk Tadzhiksoy SSR. Izvestiya. Otdeleniye fiziko-matematicheskikh i geologo-khimicheskikh nauk     |
| IAN TK           | - | Akademiya nauk SSSR. Izvestiya. Tekhnicheskaya kibernetika  |
| IAN Tur.         | - | Akademiya nauk Turkmenskoy SSR. Izvestiya. Seriya fiziko-tehnicheskikh, khimicheskikh, i geologicheskikh nauk |
| IAN Uzb          | - | Akademiya nauk Uzbekskoy SSR. Izvestiya. Seriya fiziko-matematicheskikh nauk                                  |
| IBAN             | - | Bulgarska akademiya na naukite. Fizicheski institut. Izvestiya na fizicheskaya instituts ANEB                 |
| I-FZh            | - | Inzhenerno-fizicheskiy zhurnal  |

|                  |   |   |
|------------------|---|---|
| IiR              | - | Izobretatel' i ratsionalizator  |
| ILEI             | - | Leningradskiy elektrotekhnicheskiy institut.<br>Izvestiya               |
| IT               | - | Izmeritel'naya tekhnika   |
| IVUZ Avia        | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Aviatsionnaya tekhnika       |
| IVUZ Cher        | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Chernaya metallurgiya        |
| IVUZ Energ       | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Energetika                   |
| IVUZ Fiz         | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Fizika                       |
| IVUZ Geod        | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Geodeziya i aerofotos'yemka  |
| IVUZ Geol        | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Geologiya i razvedka         |
| IVUZ Gorn        | - | izvestiya vysshikh uchebnykh zavedeniy.<br>Gornyy zhurnal               |
| IVUZ Mash        | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Mashinostroyeniye            |
| IVUZ Priboro     | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Priborostroyeniye            |
| IVUZ Radioelektr | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Radioelektronika             |
| IVUZ Radiofiz    | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Radiofizika                  |
| IVUZ Stroi       | - | Izvestiya vysshikh uchebnykh zavedeniy.<br>Stroitel'stvo i arkhitektura |
| KhVE             | - | Khimiya vysokikh energiy  |
| KiK              | - | Kinetika i kataliz  |
| KL               | - | Knizhnaya letopis'  |
| Kristall         | - | Kristallografiya  |
| KSpF             | - | Kratkiye soobshcheniya po fizike  |

|            |   |   |
|------------|---|---|
| LZhS       | - | Letopis' zhurnal'nykh statey  |
| MiTOM      | - | Metallovedeniye i termicheskaya obrabotka materialov                        |
| MP         | - | Mekhanika polimerov   |
| MTT        | - | Akademiya nauk SSSR. Izvestiya. Mekhanika tverdogo tela                     |
| MZhiG      | - | Akademiya nauk SSSR. Izvestiya. Mekhanika zhidkosti i gaza                  |
| NK         | - | Novyye knigi  |
| NM         | - | Akademiya nauk SSSR. Izvestiya. Neorganicheskiye materialy                  |
| NTO SSSR   | - | Nauchno-tekhnicheskiye obshchestva SSSR                                     |
| OiS        | - | Optika i spektroskopiya   |
| OMP        | - | Optiko-mekhanicheskaya promyshlennost'                                      |
| Otkr izobr | - | Otkrytiya, izobreniya, promyshlennyye obraztsy, tovarnyye znaki             |
| PF         | - | Postepy fizyki  |
| Phys abs   | - | Physics abstracts   |
| PM         | - | Prikladnaya mekhanika   |
| PMM        | - | Prikladnaya matematika i mekhanika  |
| PSS        | - | Physica status solidi   |
| PSU        | - | Pribory i sistemy upravleniya   |
| PTE        | - | Pribory i tekhnika eksperimenta   |
| Radiotekh  | - | Radiotekhnika   |
| RiE        | - | Radiotekhnika i elektronika   |
| RZhAvtom   | - | Referativnyy zhurnal. Avtomatika, telemekhanika i vychislitel'naya tekhnika |
| RZhElektr  | - | Referativnyy zhurnal. Elektronika i yeye primeneniye                        |

|             |   |   |
|-------------|---|---|
| RZhF        | - | Referativnyy zhurnal. Fizika                                |
| RZhFoto     | - | Referativnyy zhurnal. Fotokinotekhnika                      |
| RZhGeod     | - | Referativnyy zhurnal. Geodeziya i aeros''-yemka .           |
| RZhGeofiz   | - | Referativnyy zhurnal. Geofizika                             |
| RZhInf      | - | Referativnyy zhurnal. Informatics                           |
| RZhKh       | - | Referativnyy zhurnal. Khimiya                               |
| RZhMekh     | - | Referativnyy zhurnal. Mekhanika                             |
| RZhMetrolog | - | Referativnyy zhurnal. Metrologiya i izmeritel'naya tekhnika |
| RZhRadiot   | - | Referativnyy zhurnal. Radiotekhnika                         |
| SovSciRev   | - | Soviet science review                                       |
| TiEKh       | - | Teoreticheskaya i eksperimental'naya khimiya                |
| TKiT        | - | Tekhnika kino i televideniya                                |
| TMF         | - | Teoreticheskaya i matematicheskaya fizika                   |
| TVT         | - | Teplofizika vysokikh temperatur                             |
| UFN         | - | Uspekhi fizicheskikh nauk                                   |
| UFZh        | - | Ukrainskiy fizicheskii zhurnal                              |
| UMS         | - | Ustalost' metallov i splavov                                |
| UNF         | - | Uspekhi nauchnoy fotografii                                 |
| VAN         | - | Akademiya nauk SSSR. Vestnik                                |
| VAN BSSR    | - | Akademiya nauk Belorusskoy SSR. Vestnik                     |
| VAN KazSSR  | - | Akademiya nauk Kazakhskoy SSR. Vestnik                      |
| VBU         | - | Belorusskiy universitet. Vestnik                            |
| VNDKh SSSR  | - | VNDKh SSSR. Informatsionnyy byulleten'                      |
| VLU         | - | Leningradskiy universitet. Vestnik. Fizika, khimiya         |
| VMU         | - | Moskovskiy universitet. Vestnik. Seriya fizika, astronomiya |

|          |   |   |
|----------|---|---|
| ZhETF    | - | Zhurnal eksperimental'noy i teoreticheskoy fiziki           |
| ZhETF P  | - | Pis'ma v Zhurnal eksperimental'noy i teoreticheskoy fiziki  |
| ZhFKh    | - | Zhurnal fizicheskoy khimii                                  |
| ZhNiPFiK | - | Zhurnal nauchnoy i prikladnoy fotografii i kinematografii   |
| ZhNKh    | - | Zhurnal neorganicheskoy khimii                              |
| ZhPK     | - | Zhurnal prikladnoy khimii                                   |
| ZhPMTF   | - | Zhurnal prikladnoy mekhaniki i tekhnicheskoy fiziki         |
| ZhPS     | - | Zhurnal prikladnoy spektroskopii                            |
| ZhTF     | - | Zhurnal tekhnicheskoy fiziki                                |
| ZhVMMF   | - | Zhurnal vychislitel'noy matematiki i matematicheskoy fiziki |
| ZL       | - | Zavodskaya laboratoriya                                     |

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