7. A. Engel and M. Steenbeck, Physics and Technology of Electrical Discharge in Gases [Russian translation], Vol. 1, ONTI–NKTP (1935).
8. Yu. A. Medvedev, B. M. Stepanov, and G. V. Fedorovich, "Statistical characteristics of secondary electrons," Tr. VNIIOFI (1975).
9. I. S. Gradshtein and I. M. Ryzhik, Tables of Integrals, Sums, Series, and Products, Academic Press (1966).

ANOMALOUS BEHAVIOR OF AN INTENSE LIGHT FLUX IN A MEDIUM WITH TWO TYPES OF ABSORPTION

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A study was made in [1] of the behavior of the spatial distribution of an intense light flux in an amorphous medium with two types of absorption – absorption by impurities with a subsequent rapid transfer of energy to the medium through radiationless processes and absorption by the medium itself. The latter type does not occur initially but as a result of heating of the zone around the impurity centers there is a temperature shift in the absorption edge and the corresponding parts of the medium start to absorb. This form of absorption eventually predominates for sufficiently large intensities. The details of the radiationless processes and of the temperature distribution around the impurities have been considered in [2, 3]. The situation studied in [1] corresponds to times by which all the populations have reached a stationary distribution and spatial zones far from the front of the light flux.

It is impossible, without making simplifications, to get an analytical solution to this problem for the initial moments of time when the nonstationary nature of the intensity distribution and of the populations are extremely important. We have therefore derived numerical solutions. The calculations showed that the behavior of the light intensity in the transient region is very peculiar. As in [1], we consider the propagation of a plane parallel monochromatic light flux which at the instant t = 0 is incident from the left on the surface of a medium which occupies the first half-space. The equations which describe the process are

$$\begin{gathered}\partial U/\partial t+c\partial U/\partial x=-N_1c\sigma U-N_3c\sigma_0U+\alpha N_4c\sigma_0U;\\ dN_4/\partial t=c\sigma_0U(N_3-N_4);\ N_3+N_4=N_0;\\ \partial N_1/\partial t=-N_1c\sigma U+N_2/\tau;\ N_1+N_2=N;\\ U(x,\ 0)=0;\ U(0,t)=U_0;\ N_1(x,\ 0)=N;\ N_3(x,\ 0)=N_0(x,\ 0)=0,\end{gathered}\tag{1}$$

where U is the density of quanta in the light; N is the concentration of impurities with photoabsorption cross section σ; N_1 and N_2 are the concentrations of impurities in the ground and excited states, respectively; N_0 is the concentration of absorbing molecules in the medium with photoabsorption cross section σ_0; N_3 and N_4 are the concentrations of these molecules in the ground and excited states; τ is the radiationless relaxation time of an impurity; and c is the velocity of light in the medium. The quantum density U is related to the light intensity I by $I = c\varepsilon U$, where $\varepsilon = \hbar\omega$ is the energy of one quantum. The factor α in (1) is introduced to allow for the fraction of quanta reradiated by the medium in the direction of the original flux. The diffusively scattered quanta are assumed to pass outside the zone under consideration and to play no part in (1). The equation for N_4 takes into account the absorption processes and the rapid radiationless deactivation. In order to determine N_0 we utilize the exact equation (2.3) of [1]. We get

$$N_0=(4\pi/3)(3\varepsilon c\sigma U/8\pi v\rho_0)^{3/2}(1+3\varepsilon c\sigma U/8\pi v^3\rho_0(t-x/c)^2)^{-3/2}NN_c,$$

where N_c is the density of molecules in the medium, ρ_0 is the threshold oscillation-energy density at which

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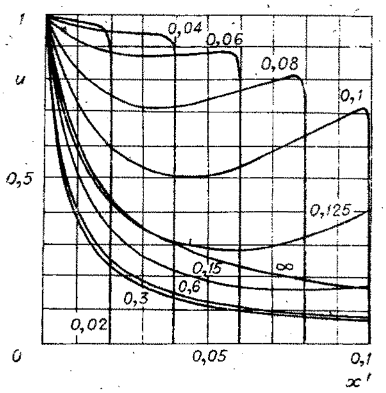

Fig. 1

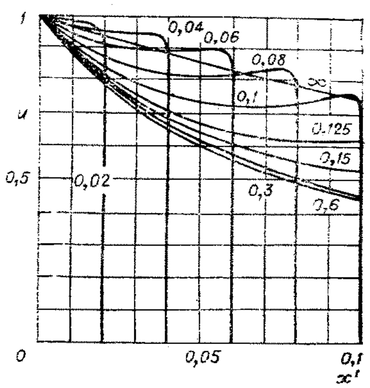

Fig. 2

absorption by the medium begins, and v is a quantity which characterizes the velocity of heat propagation in the medium. In the calculations we introduced the dimensionless quantities

$$u = U/U_0; \quad n_k = N_k/N; \quad t' = N\sigma ct; \quad x' = N\sigma x;$$
$$b = (4\pi/3)(3\varepsilon c\sigma U_0/8\pi v\rho_0)^{3/2} N_c; \quad b_1 = vN_c^{1/3}/c\sigma N.$$

The numerical solution of (1) was found on a BÉSM-4M computer by means of an algorithm which had been checked for stability and convergence. The following parameter values were chosen: $N = 10^{17}$ cm^{-3}, $c = 2 \cdot 10^{10}$ cm/sec, $\sigma = 10^{-18}$ cm^2, $\sigma_0 = 10^{-17}$ cm^2, $\tau = 1.25 \cdot 10^{-10}$ sec, $\varepsilon = 1.78$ eV, $\alpha = 0.5$, and $b_1 = 10$.

Figures 1 and 2 show the results for $U_0 = 4 \cdot 10^{16}$ ($b = 31.6$) and $U_0 = 4 \cdot 10^{15}$ cm^{-3} ($b = 1$), respectively. The numbers against the curves denote the values of the dimensionless time t'. The asymptotic ($t' = \infty$) value of u was derived from (1) under the assumption of stationary conditions by a numerical calculation based on the Runge–Kutta method. It can be seen from Fig. 1 (where $U_0 = 4 \cdot 10^{16}$ cm^{-3}) that there is a clearly defined intensity peak on the front of the light flux. The intensity then decreases somewhat and finally increases near the surface to its boundary value. As the front moves away from the surface into the interior of the material, the strength of the peak is monotonically reduced. When the front has moved sufficiently far, the spatial distribution of u reaches a minimum value; it then increases again slowly, tending to its limiting $t' = \infty$ value.

The slow increase in the solution after the time $t' \approx 0.3$ is determined by the delaying relaxation of n_0 and n_4 to their limiting stationary values (when $t' = \infty$ we must have $n_4 = n_0/2$, and for $t' \approx 0.3$ we have $n_4 \ll n_0$ over almost the entire range of x'). Figure 2 shows the results for $U_0 = 4 \cdot 10^{15}$ cm^{-3}. Whereas in the first case the absorption by the medium predominated over the given region of x', here for $U_0 = 4 \cdot 10^{15}$ cm^{-3} both types of absorption are equally important. It can be seen from Fig. 2 that the peak near the front is smaller and the general level of the curves is higher than in Fig. 1. The fact that the general level is higher can be explained by the ability of the model [1] to regulate the absorption in the surface layer against variations in incident intensity in such a way that the value of U at large distances from the surface remains almost constant in the stationary state. Thus the value of $u = U/U_0$ for sufficiently large t' must increase as U_0 is reduced. We might note that calculations on the stationary system (1) by the Runge–Kutta technique give the value 1 : 3 for the ratio of the values of U at $x' = 1$ corresponding to U_0 equal to $4 \cdot 10^{16}$ and $4 \cdot 10^{15}$ cm^{-3}: this confirms the property we have described.

The existence of the peak near the front and the behavior of this peak can easily be explained from physical considerations. The absorption due to heating of the medium up to some threshold temperature cannot act immediately after the flux arrives at some particular point but is subject to some delay caused by the finite rate of heating. Thus the absorption at a given point is initially due mainly to the impurities and is weaker and linear. After some characteristic time, determined by the parameters in the expression for N_0, the regions around the impurities heat up to the threshold temperatures and the stronger, nonlinear absorption of the medium comes into play and causes a reduction in intensity behind the front of the flux. The magnitude of the reduction depends on how far the absorption of the medium predominates over that of the impurities and thus the intensity peak at the front is much more pronounced for $U_0 = 4 \cdot 10^{16}$ cm^{-3} than for the case $U = 4 \cdot 10^{-15}$ cm^{-3}.

This nonmonotonic decrease in flux intensity that we have calculated for the transient state is very interesting from the point of view of practical applications both in the sense that the flux intensity at a given point can be maintained between certain levels as the incident intensity varies and in the sense that it should be possible to derive specially shaped light pulses.

In conclusion, the authors wish to express their gratitude to S. I. Anisimov for his interest in this work and to O. A. Ponomarev and T. M. Martem'yanova for a useful discussion.

LITERATURE CITED

1. Yu. I. Lysikov and O. A. Ponomarev, "A model of a nonlinear absorbing medium," Zh. Prikl. Mekh. Tekh. Fiz., No. 1, 19-22 (1974).
2. S. I. Anisimov and B. I. Makshantsev, "The role of absorbing inhomogeneities in the optical breakdown of transparent media," Fiz. Tverd. Tela, 15, No. 4, 1090-1095 (1973).
3. B. I. Makshantsev, A. A. Kovalev, R. K. Leonov, and I. A. Yampol'skii, "Radiationless electron transitions and thermal effects in transparent dielectrics under the action of a laser pulse," Zh. Tekh. Fiz., 44, No. 1, 164-172 (1974).

NEAR FIELD DIFFRACTED AT A DIELECTRIC WEDGE

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The integral equations of macroscopic dynamics [2] are used in [1] as the basis of a solution to the problem of the diffraction of a plane electromagnetic wave with a known polarization at a rectangular dielectric wedge. Expressions are given in this paper for the total electromagnetic field both inside a dielectric wedge of arbitrary flare angle and outside the wedge. The method used is the same as in [1].

1. Field Structure inside the Dielectric Wedge

Suppose that a plane electromagnetic wave is incident on a dielectric wedge of arbitrary flare angle α. The dielectric permittivity ε and the magnetic permeability μ of the wedge are in general complex and of arbitrary value. Without loss of generality, we can choose the polarization of the incident wave so that the field has the nonzero components

$$\mathbf{E}_0 = (E_{x0},\ 0,\ 0),\ \mathbf{H} = (0,\ H_{\rho 0},\ H_{\varphi 0}),$$

where

$$E_{x0}(\rho, \varphi) = E_{x0} e^{ik\rho\cos(\varphi - \varphi_0)};$$

φ_0 is the angle of incidence reckoned from the face $\varphi = 0$ (Fig. 1).

Then the field inside the wedge will have the same polarization and nonzero field components $\mathbf{E} = (E_x, 0, 0)$ and $\mathbf{H} = (0, H_\rho, H_\varphi)$, where H_ρ, H_φ are cylindrical field components. The field can be represented as a set of plane refracted waves and an edge wave in the form of a Sommerfeld integral

$$E_x(\rho, \varphi) = \sum_j A_j e^{ik\rho\sqrt{\varepsilon\mu}\cos(\varphi - \psi_j)} + \int_{G_0} e^{ik\rho\sqrt{\varepsilon\mu}\cos(\varphi - \eta)} f(\eta)\, d\eta;$$

$$H_\varphi(\rho, \varphi) = -\sqrt{\frac{\varepsilon}{\mu}}\left\{\sum_j A_j e^{ik\rho\sqrt{\varepsilon\mu}\cos(\varphi - \psi_j)}\cos(\psi_j - \varphi) + \int_{G_0} e^{ik\rho\sqrt{\varepsilon\mu}\cos(\varphi - \eta)}\cos(\eta - \varphi)\cdot f(\eta)\, d\eta\right\}; \qquad (1.1)$$

$$H_\rho(\rho, \varphi) = \sqrt{\frac{\varepsilon}{\mu}}\left\{\sum_j A_j e^{ik\rho\sqrt{\varepsilon\mu}\cos(\varphi - \psi_j)}\sin(\psi_j - \varphi) + \int_{G_0} e^{ik\rho\sqrt{\varepsilon\mu}\cos(\varphi - \eta)}\sin(\eta - \varphi)\cdot f(\eta)\, d\eta.\right.$$

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