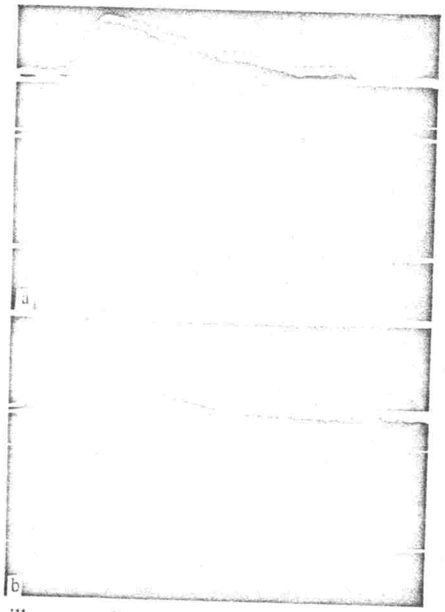

FIG. 2. Oscillograms of emission (top) and absorption (bottom) of xenon in the region of $\lambda = 10.6\mu$, $p_1 = 3$ mm Hg, interval between time markers $\Delta t_L = 66.7\ \mu$sec; a–M = 11.2, b–M = 12.7.

in Fig. 2. On each of the oscillograms are given the distributions of the absorptivity (lower curve) and of the radiation intensity (upper curve). At some instant of time (marked by a pulse from the piezoelectric pickup), the shock-wave front arrives at the sighting windows, followed by a gradual growth of the emission and absorption signals. After a certain time, which depends on the Mach number of the shock wave, these signals reach their maximum values, and subsequently decrease.

Since the emission and absorption of the radiation by the plasma behind the shock-wave front at $\lambda = 10.6\ \mu$ are connected principally with free-free transitions of the electrons, it follows, as will be shown below, that the profile of the square of the electron density duplicates in the main the shape of the oscillograms of the emission and absorption. Bearing this in mind, it is possible to explain the oscillographic curves qualitatively.

The sensitivity of the method developed here does not make it possible to trace the appearance of the electrons in the region of atom-atom collisions, but the region of cascade ionization, accompanied by a sharp increase of the emission and absorption of infrared radiation, is registered with sufficient reliability. The time delay in the appearance of the cascade behind the front of the shock wave depends on the Mach number of the shock wave. After the equilibrium state (the maximum on the oscillographic curves) is reached, the gas begins to cool in time, the density of the electron decreases, and consequently the emission and absorption of the plasma decrease.

Since the time of establishment of the Maxwellian distribution for electrons, under the conditions of our experiments, is approximately 10^{-11} sec, which is much less than the time required to reach equilibrium ionization, we can use Kirchhoff's law for a quantitative analysis of the results.

For a homogeneous plasma layer of thickness l, the connection between the radiation intensity I and the absorption coefficient κ' is given by

$$I(\nu, T_e) = I_{\nu p}(T_e)\,(1 - e^{-\kappa' l}); \tag{1}$$

Here $I_{\nu p}(T_t)$ is the intensity of black-body radiation (erg/cm²-sec-sr), T_e is the electron temperature, and κ' is the absorption coefficient corrected for the stimulated emission, i.e., $\kappa' = \kappa(1 - \exp[h\nu/kT_e])$, where κ is the true absorption coefficient. It is known that the quantity $1 - e^{-\kappa' l}$ is equal, under the conditions of a continuous spectrum, to the absorptivity of the substance $A(\nu, T_e)$. Therefore expression (1) can be rewritten in the form

$$\frac{I(\nu, T_e)}{A(\nu, T_e)} = \frac{2h\nu^3}{c^2}\,\frac{1}{e^{h\nu/kT_e} - 1}. \tag{2}$$

Formula (2) will henceforth be used to determine the profile of the electron temperature T_e from the data on the emission and absorption of the plasma. It was assumed here that at the maximum of the oscillographic curves, the temperature T_e is equal to the equilibrium temperature calculated from the conservation law, the equations of state, and the Saha equations.

Knowing the dependence of T_e and κ' on the time, it is possible to determine the electron density profile n_e. To this end we use the formula for the absorption coefficient with allowance for stimulated emission:

$$\kappa' = \frac{16\pi^2 e^2}{3\sqrt{3}\,ch\,(2\pi m)^{3/2}}\,\frac{n_e^2(1 - e^{-h\nu/kT_e})}{(kT_e)^{1/2}}\,g, \tag{3}$$

where g is the Gaunt factor and the remaining symbols are standard.

Different authors [9,10] give different expressions for the Gaunt factor. However, the calculation based on these formulas for the conditions of our experiment yields approximately the same value ($g \sim 2$).

We now find the connection between the ionization rate $(dn_e/dt)_i$ and the change in the number of electrons behind the front of the shock wave, which is due to two causes—the change of the gas density and the ionization processes. We start from the continuity equation for the j-th component of matter in the volume element:

$$\frac{dn_j}{dt} = \frac{\partial n_j}{\partial t} + v\frac{\partial n_j}{\partial x} = -n_j\frac{\partial v}{\partial x} + \left(\frac{dn_j}{dt}\right)_i, \tag{4}$$

where v is the velocity of the volume element of the gas and $(dn_j/dt)_i$ is the rate of the ionization process.

For a steady-state one-dimensional flux behind the shock wave, from the continuity and energy-conservation equations

$$\rho_1 D = \rho_2 v,$$
$$\frac{5}{2}\frac{k}{m_a}T_1 + \frac{D^2}{2} = \frac{5}{2}\frac{k}{m_a}(T_a + \xi T_e) + \frac{v^2}{2} + \xi\frac{J}{m_a} \tag{5}$$

and the equation of state

$$p = (n_a + n_e)\,k\,(T_a + \xi T_e) \tag{6}$$

Under the assumption that $(\rho_1/\rho_2)^2 \ll 1$, $(5/2)kT_1 \ll m_a D^2/2$, and $\xi T_e \ll T_a$, we can obtain the following approximate relation:

$$\frac{dn_e}{dt} = \frac{m_a D^2}{5kT_a}\left(\frac{dn_e}{dt}\right)_i, \tag{7}$$

where ρ_1 and ρ_2 is the density of the gas ahead of the jump and behind it, D is the velocity of the shock wave,