is possibly connected with the electron-phonon interation, which leads to an excitation damping $\sim(\hbar\omega)^3/\omega_D^2$ [6].

The temperature dependence $\sim T^2$ is to be expected for the electron-electron interaction. However, the frequency dependence of the factor preceding T^2 remains so far unexplained.

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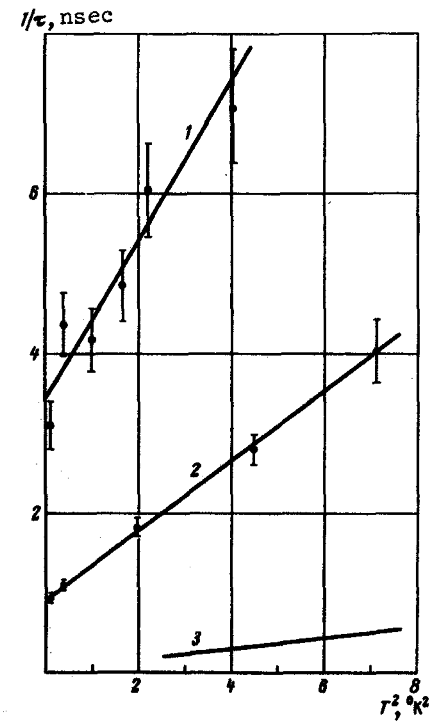

Fig. 3. Plot of $\tau^{-1}(T^2)$: 1 - f = 37.1 GHz, 2 - f = 18.74 GHz, 3 - $\tau^{-1}(T^2) - \tau_0^{-1}$ plotted from the data of [5], f ∿ 10 MHz.

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PRODUCTION OF MULTIPLY-CHARGED IONS BY INTERACTION BETWEEN A POWERFUL LASER PULSE AND A SOLID

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We have investigated the high-temperature plasma produced when laser radiation acts on a substance, at a maximum power $W_{max} \sim 2$ GW.

The radiation block consisted of a 10 × 130 mm neodymium glass (laser) and two amplifiers with 30 × 306 (with Brewster angle) and 30 × 260 rods.

The radiation flux density, using a lens with f = 5 cm, was $\sim 10^{13}$ W/cm². The analyzing instrument was a time-of-flight mass spectrometer with superimposed E and H fields [1].

The investigated targets were made of Co_{59}^{27}, $Ag_{107-109}^{47}$, Ta_{181}^{73}, W_{184}^{74}, Bi_{209}^{83}. The maximum charges of the ions of these elements were Ag^{+16}, Ta^{+20}, W^{+19}, and Bi^{+19}.

A charge multiplicity up to 25 was obtained with the Co_{59}^{27} target. Figure 1 shows the experimental oscillograms of the ion pulses of Co_{59}^{27}. The ions with large charges were identified by means of the left end point of the oscillogram and by the assumed location in the mass oscillograms. Owing to the insufficient resolution of the ions with $z \sim 20$, certain difficulties arise in the registration. The accuracy with which the ion charge was determined in the region of $z = 20 - 25$ amounts to $\Delta z = \pm 1$ for a sweep of 50 μsec, $\Delta z = \pm 2$ for 100 μsec, and $\Delta z = \pm 3$ for 300 μsec.

The statistically reduced oscillogram shown in Fig. 2a contains in its left part a group of signals corresponding to ions with charges 15 - 23.

A similar group of signals might be produced also by the ions of the light impurities C, N, and O. We shall advance below arguments that show, in our opinion, that the light impurities cannot cause in this case the presence of the indicated group.

1. Ions of the impurities (C_{12}, N_{14}, O_{16}) were registered on the oscillograms and the signal amplitudes decreased with increasing charge, as seen from Fig. 2b. An analysis of the energy spectra and of the mass oscillograms of a large number of substances (for ions with charge multiplicity up to 6) has disclosed the general tendency of the dependence of the ion-signal amplitude on the charge of the ion. Such a

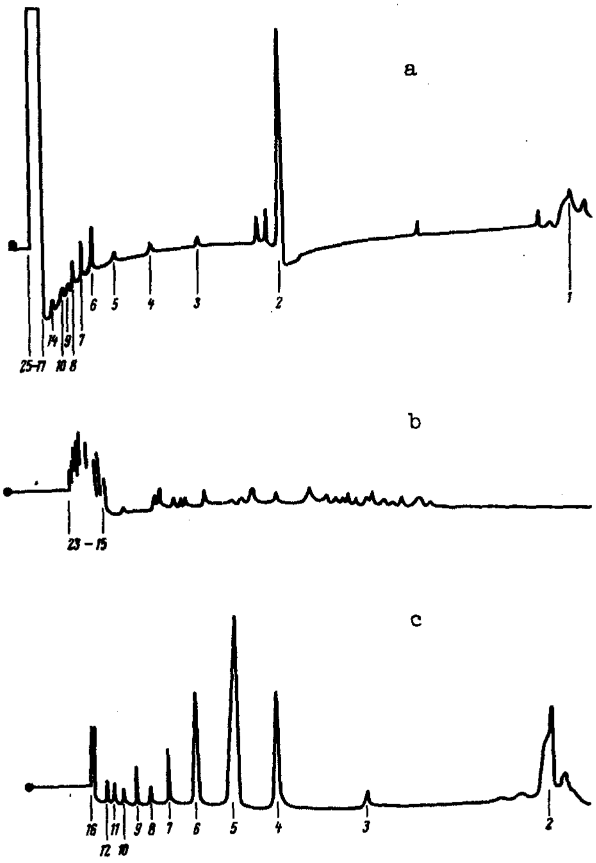

Fig. 1

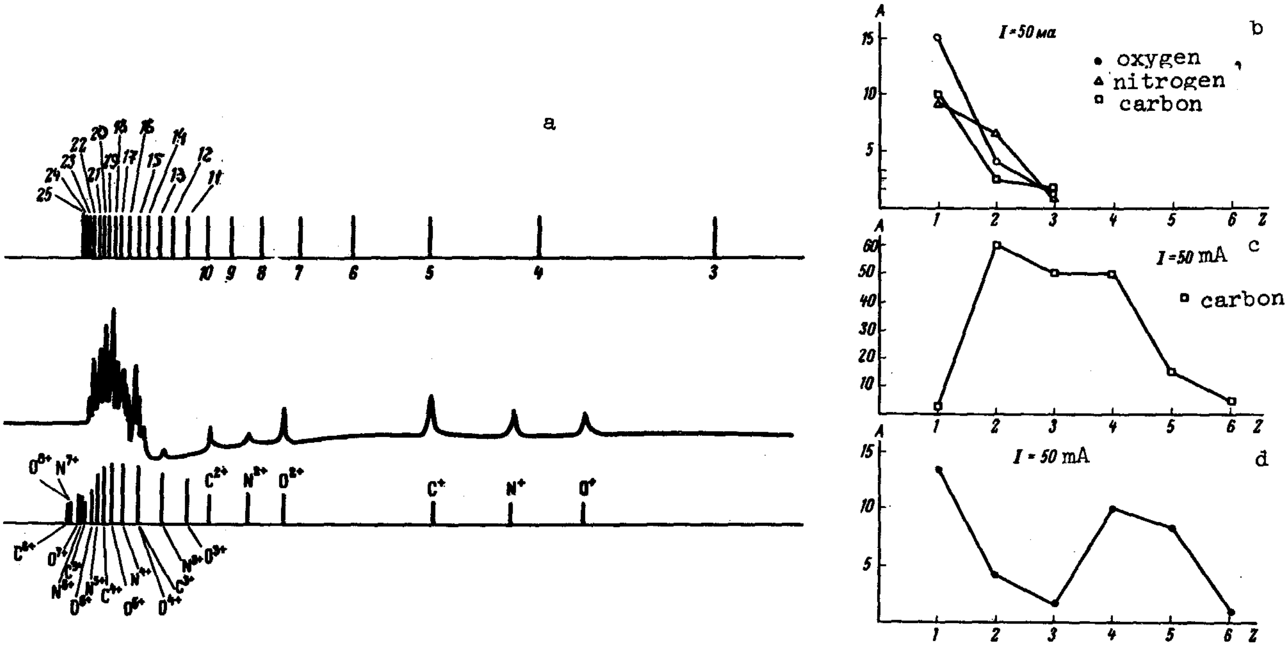

Fig. 2

dependence is shown for carbon in Fig. 2c. Assuming that the group of signals on the oscillogram is connected with the impurity ions, it is possible to plot a hypothetical A(z) dependence for these ions (Fig. 2d). However, the form of this dependence contradicts the experimental data (Fig. 2c).

2. The locations of ions with different charges are shown in Fig. 2a above the oscillograms. Ions with charge ∿20 should not be resolved (at an energy 30 - 40 keV), and the leading fronts of the signal correspond to the resolution limit of ∿0.1 μsec of the secondary electron multiplier. According to a calculation, the analyzed group should contain approximately ten signals of high-charge ions. Assuming that the group is made of signals from the impurity ions, it is possible to determine the number of the signals. Under this assumption, the number of signals in the group should be approximately 4, and the ions should be resolved. Actually, however, the number of signals in the analyzed group is certainly larger than 6.

3. In addition, if it is assumed that the analyzed group of signals is connected with the impurity ions, then the amplitudes of the ions (C, N. O)$^+$, (C, N, O)$^{++}$, and (C, N, O)$^{+++}$ at the corresponding maxima of the energy spectra of the impurities should be larger in comparison with the average amplitude shown on the oscillograms.

The considerations advanced in items 1 - 3 allow us to assume that Co ions with charge up to 25 were registered in the experiment.

4. The calculations of the ionization multiplicity was made under the assumption that the plasma is in thermodynamic equilibrium, and the approximate method of [2] is then applicable. The internal energy of the plasma is then determined by the formula

$$\epsilon = \left[\frac{3}{2} kT(1+z) + \sum^{z} I_i \right] = \frac{P}{\rho} \frac{1}{(\gamma' - 1)} \quad , \tag{1}$$

where I_i is the i-th ionization potential and $z = z(T,n)$ is the ionization multiplicity and is a function of the plasma temperature T and the density n. The quantity $\gamma' - 1$ is defined here by

$$\frac{1}{\gamma' - 1} = \frac{3}{2} + \frac{I(z)}{T} \frac{z}{1+z} \frac{1}{a} ; \quad a \lesssim z .$$

The second term in (1) takes into account the energy lost to the ionization of the multiply-charged ions; this energy becomes particularly large at large z.

The internal energy ε is determined from the solution for the stationary regime of plasma expansion [3, 4] with allowance for the dependence of the absorption coefficient in (γ' - 1), assuming that γ' is a slowly varying function of T and n (the slowness parameter of γ' - 1 is T/I ≃ 0.1). Substituting ε in (1), we obtain a system of equations for the determination of z and γ':

$$\frac{I(z)}{(\gamma' - 1)^{4/9}} = \beta_1 W^{4/9} d^{-2/3} \ln[z^{1/2} (\gamma' - 1)^{1/3} W^{1/3} \beta_2] , \tag{2}$$

$$\frac{1}{\gamma' - 1} = \frac{3}{2} + \frac{I(z)}{a} \frac{1}{(\gamma' - 1)^{4/9}} W^{-4/9} d^{2/3} \beta_1^{-1} \quad ,$$

where $\beta_1 \simeq 0.32\mu^{2/9}$ [eV-cm$^{2/3}$MW$^{-4/9}$] and $\beta_2 \simeq 5.6 \times 10^{+2}\mu^{1/6}$ [MW$^{-1/3}$].

The values of the ionization multiplicity depend on the form of the I(z) curve, which was obtained on the basis of the known experimental data (mainly for Co) and with the aid of the approximation formula of [5]. The results of the numerical solution of (2) yield $\gamma' \approx 1.2$ and $z \approx 25$, in agreement with experiment. The theoretical estimates for other substances lead to values that are higher than the experimental ones. This is possibly due to the possible non-equilibrium of the plasma when $q \gtrsim 10^{12}$ W/cm^2 [6] and to the inaccuracy with which the ionization potentials were approximated.

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ERRATA

In the article by V.V. Apollonov, Yu.A. Bykovskii, N.Y. Dgtyarenko et al., Vol. 11, No. 8, page 254, formula (1) should read

$$\epsilon = \left[\frac{3}{2} kT(1+z) + \sum^{z} I_i \right] N \equiv \frac{P}{\rho} \frac{1}{(\gamma' - 1)} .$$

In the same page, at the end of the next formula, read $a \lesssim 3$ in place of $a \lesssim z$.