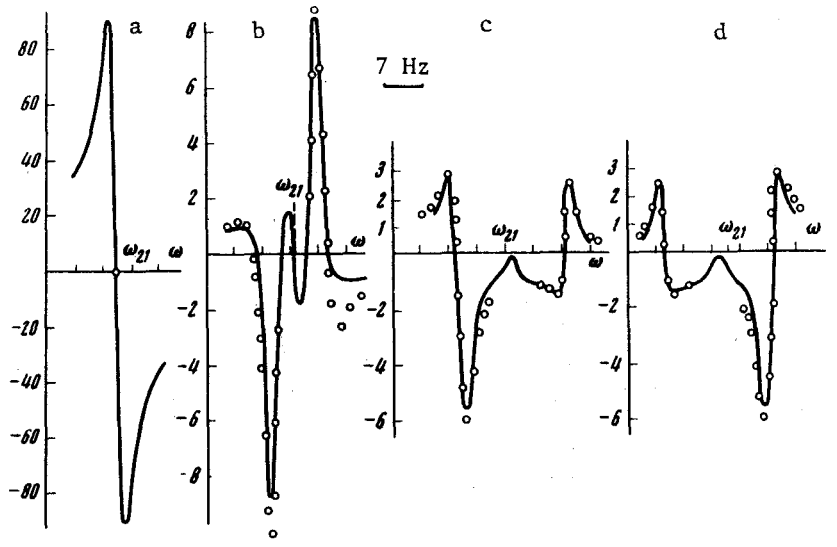

Fig. 3. Plot of real part of the susceptibility $\chi'(\omega)$ at the same parameters as in Fig. 2.

principal absorption doublets have an oscillator strength ~ 1, and the maximum attainable absorption coefficients are of the order of 10^4 cm^{-1} at a line width 0.03 cm^{-1}. Estimates show that when lasers of intensity on the order of 10^8 W/cm^2 is used, it is possible to obtain gains on the order of 10^2 cm^{-1} in a tuning range on the order of 100 Å relative to the atomic lines, at a gain line width on the order of 10^{-2} Å. An important question in connection with such amplifier, not investigated before, is the monochromaticity required of the exciting radiation. Experiments in this direction are now in the planning stage.

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INVESTIGATION OF IMPURITY DIFFUSION IN A TOKAMAK BY SPECIAL METHODS

V. I. Gervids and V. A. Krupin

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By comparing the experimental and calculated carbon impurity ion intensity lines in a Tokamak hydrogen plasma we show that the ions diffuse towards the pinch axis. We estimate the densities of the impurity-ion diffusion flux and the contribution of the impurities to the proton diffusion flux.

We measured the distributions of the absolute intensities I(r, t) of the lines of the ions C III, C IV, and C V of the carbon impurities and of the lines of hydrogen atoms over the cross section of the plasma filament in the TM-3 installation operating with an electron density $n_e \sim 5 \times 10^{12}$ cm^{-3} and a temperature $T_e \sim 300$ - 400 eV. At the indicated rather low electron densities, the line emission intensity is directly proportional to the concentration of the emitting ion n_k (k = 0, 1, ... z is the ionization multiplicity and z is the charge of the nucleus), and is governed together with the concentration, as follows directly from the equation for the conservation of the number of ions of a given kind [1]

$$\frac{\partial n_k(r,t)}{\partial t} = -\operatorname{div} j_k(r,t) + f_k(n_e, T_e, r, t) \qquad (1)$$

by three processes: a) the rate of population of the given ionization multiplicity f_k (ionization, recombination, etc.; the concrete form of f_k depends on the choice of the model of the population processes); b) by the diffusion of the impurity ions (div $\vec{j}_k$, where $\vec{j}_k$ is the density of the diffusion flux of the ion k), c) the entry of the impurity into the plasma from the periphery in the course of the discharge (it determines the boundary conditions, which will not be written out here).

The observed line intensities obviously correspond to the "complete" equation (1). To separate the contribution of the diffusion, we have calculated with an electronic computer the time dependences of the distributions of the intensities of these lines and of the concentrations of all the carbon ions without allowance for diffusion and for the entry of the impurity into the plasma (Eq. (1) without the diffusion term div $\vec{j}_k$). The calculations were performed in the corona approximation, which is valid at the densities indicated above (for details, including the form of the function f_k, see [2]; the distribution of the summary impurity density was assumed to be homogeneous). We chose for the calculations a parabolic distribution of n_e ($n_e(r, t) = 2\bar{n}_e(t)(1 - r^2/a^2)$), which agrees with the results of control experiments on the TM-3 installation. The distribution of the electron temperature $T_e(r, t)$ was also assumed parabolic. We used here the experimental time dependences of the mean values $\bar{n}_e(t)$ and $\bar{T}_e(t)$ (obtained from microwave and diamagnetic measurements). Typical experimental and calculated curves are shown in Fig. 1. The observed sharp discrepancy between the experimental and theoretical curves cannot be attributed to either inaccurate knowledge of the $T_e(r)$ dependence or to the error in the experimental determination of $\bar{T}_e$, since variation of $\bar{T}_e$ and of the form of the distribution $T_e(r)$ in a wide range (from parabolic to flat) has an insignificant effect on the form of the theoretical curves, retaining the rapid "burnout" at the center (see Fig. 1) and the maximum intensity on the periphery. It is likewise impossible to attribute the bell-shaped experimental curves to the entry of the neutral impurity atoms into the center and to diffusion of the impurity ions to the outside, for in our circumstances this would lead to the difficult-to-satisfy condition E(C I) $\geq$ 10 eV.

Thus, the character of the difference between the experimental curve and the calculated ones shows that the term div j_k, which was not taken into account in the calculations, plays a rather important role, i.e., that under the experimental conditions there is a clearly pronounced diffusion of the impurity ions toward the axis of the plasma filament during the entire discharge. We note that the indicated characteristic differences of the experimental and calculated curves are observed also for other carbon ions, thus further confirming our conclusion.

Having established by the foregoing method the existence of impurity-ion diffusion towards the filament axis, we proceed to estimate the diffusion velocity.

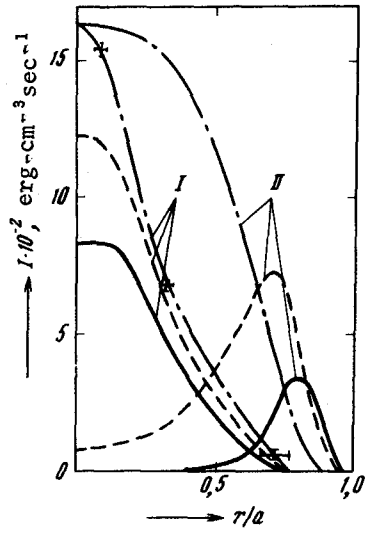

Fig. 1. Distribution of the intensity I(4, 5) of the 2271 Å line of the C V ion: I) experiment, II) calculation. The dash-dot, dashed, and solid curves are for 2.5, 4.5, and 7.5 msec after the start of the discharge. The calculated curves are normalized to the maximum of the experimental curve for 2.5 msec.

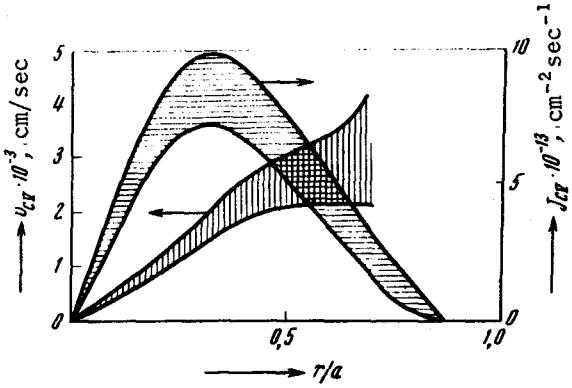

Fig. 2. Density of diffusion flux $j^r(r, t)$ (right-hand scale) and diffusion velocity $v^r(t)$ (left-hand scale) of C V ion at t = 4.5 msec. In both cases, the upper and lower limits correspond to a parabolic and a uniform distribution of $T_e(r)$.

The local values of $\vec{j}_k(r, t)$ and of the corresponding diffusion velocities $\vec{v}_k = \vec{j}_k/n_k$ from the experimentally determined functions $n_e(r, t)$, $T_e(r, t)$ and $I_{k-1}(r, t)$, $I_k(r, t)$, $I_{k+1}(r, t)$ are calculated with the aid of Eq. (1). Integrating the latter with respect to r, we obtain for the radial component of $\vec{j}_k$

$$j_k^r(r,t) = \frac{1}{r}\int_0^r \left(\frac{\partial n_k}{\partial t} - f_k\right) r'\,dr' \qquad (2)$$

($j_k^r > 0$ corresponds to diffusion towards the filament axis).

The results of calculations by formula (2) for the C V ions are shown in Fig. 2.

From the data obtained in our study of the diffusion of the carbon ions C IV and C V we estimated with the aid of the relation $kj_k^r \simeq j_{pk}^r$, which follows from [1, 2], the contribution j_{pk}^r made by the interaction of the protons and impurity ions of charge k to the density of the radial diffusion flux of the protons to the outside. For the region r/a = 0.25 - 0.5 we obtained $j_{p3}^r + j_{p4}^r \simeq (3 - 4) \times 10^{14}$ cm^{-2}sec^{-1}. For comparison we indicate that the density of the radial diffusion flux of the electrons to the outside, j_e^r, determined in the same regime from the fall-off of the electron density and of the rate of ionization of the hydrogen atoms [4], amounted to $(2 - 5) \times 10^{15}$ cm^{-2}sec^{-1} for the indicated region.

We note in conclusion that the described method of observing the diffusion of impurity ions and of estimating the local values of its velocity makes no assumptions whatever concerning any concrete diffusion mechanism. This circumstance obviously makes it possible, in principle, to choose between different diffusion mechanisms by comparing the results of the use of the given method with the corresponding theoretical relations.

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ELECTROCHEMICAL HIGH-PRESSURE HF LASER

V. N. Bagratashvili, I. N. Knyazev, Yu. A. Kudryavtsev, and V. S. Letokhov
Spectroscopy Institute, USSR Academy of Sciences
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Generation of an electrochemical HF laser at a gas pressure up to 5 atm was attained for the first time. The laser was excited with a high-voltage autonomous pulsed discharge of short duration in a mixture of SF_6, H_2, and He with a large excess of helium. We investigated the effect of the pressure on the energy characteristics of the laser and its gain.

One of the timely problems of laser physics is to determine the principles underlying the development of high-pressure gas lasers. Basov and co-workers [1] proposed an electro-ionization method of exciting dense gases, with gas pre-ionized by a beam of fast electrons. We report here for the first time the development of an electrochemical high-pressure HF laser excited by an autonomous high-voltage discharge of nanosecond duration[1]. This laser can serve as the basis for the development of a tunable-frequency source of coherent radiation in the 2.7 micron range.

The active medium of the HF laser is the gas mixture $SF_6 + H_2 + He$ excited by a fast discharge. During the course of the discharge, an F atom is detached from the SF_6 molecule and