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

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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

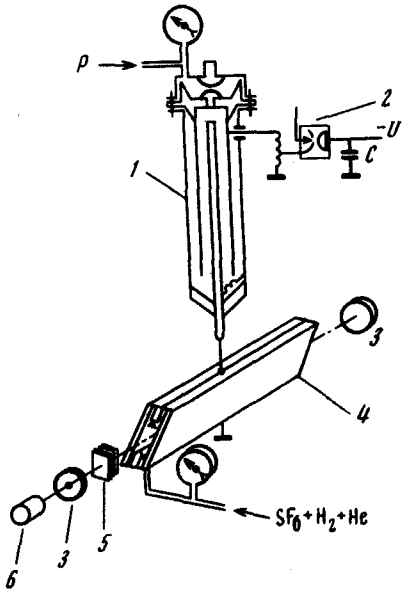

Fig. 1

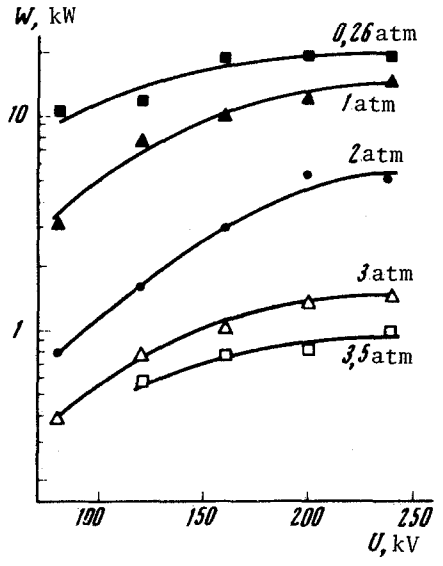

Fig. 2

Fig. 1. Experimental setup: a) coaxial Blumlein line, 2) charging curcuit, 3) laser mirrors, 4) laser cell, 5) set of teflon films 35 μ thick to measure the gain, 6) thermopile.

Fig. 2. Laser pulse power W vs charging voltage U of line at different mixture pressures.

reacts with the H_2 molecule to produce a vibrationally-excited HF molecule [3]. The high-pressure working cell was excited with negative-voltage pulses of amplitude up to 250 kV and duration 14 nsec, with repetition frequencies 0.05 - 1 Hz (Fig. 1). The voltage pulse was shaped with a Blumlein coaxial line [4] 100 cm long and with wave resistance 10 ohms, using castor oil as the dielectric. The surge capacitance of the line was 340 pF, and the maximum stored energy was 20 J. The laser cell was glued together of glass and metal with epoxy compounds. The upper electrode was a brass grid having end points separated and sharpened by chemical etching. The ends of the cell were cut at the Brewster angle and were sealed with thick NaCl plates. The distance between electrodes was 21 mm, and the active length 40 cm.[2)] We used in the experiments an $SF_6 + H_2 + He$ mixture with a large excess of helium in the system, without drawing the mixture through.

The dependence of the laser-pulse energy on the voltage at different total pressures of the $SF_6 + H_2 + He$ mixture and at fixed partial pressures of the SF_6 and H_2 (0.22 and 0.056 atm, respectively), is shown in Fig. 2. The plot of the generation-pulse energy has a tendency to saturate at 150 - 200 kV. The optimal excitation conditions are attained at a large excess of helium, particularly when the total mixture of the mixture exceeds approximately 2 atm and with a relative predominance of the SF_6. The gain and the generation-pulse energy decrease when the total mixture pressure increases ($P_{SF_6} + P_{He}$ = const). The absolute value of the gain remains relatively high, K = 0.02 cm^{-1} at P $\approx$ 3.5 atm. At a mixture pressure $\gtrsim$3.5 atm the instability of the generation -pulse energy increases, but generation is observed up to 5.5 atm. At a repetition frequency 0.2 Hz, the laser emission energy decreases 40% after 50 excitation pulses. When the laser mixture pressure is increased above 0.2 - 0.4 atm, a gradual decrease of the brightness of the diffuse structureless discharge takes place and there is a relative increase in the brightness of the spark channels.

The experimentally observed decrease of the laser-emission energy and of the gain with increasing partial pressure of the helium can be attributed to the increase of the impact width of the laser lines, and also to the decrease of the concentration of the active molecules, due to the overall decrease of the current in the homogeneous discharge. The characteristic time of deactivation of the excited molecules by collision with the helium, τ_{HF^*He}, apparently exceeds 2×10^{-5} sec-atm[3)], which is larger by three orders of magnitude than the time of deacti-

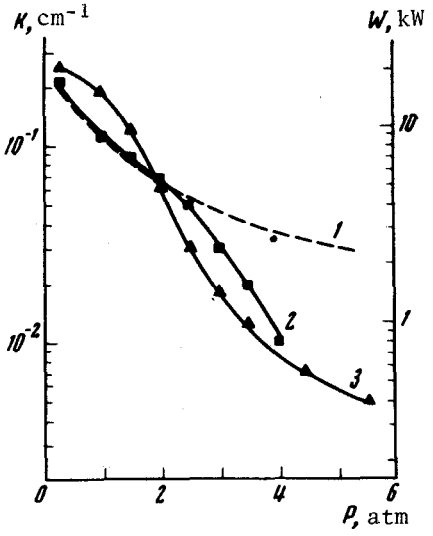

Fig. 3. Laser gain (curve 2) and generation pulse energy (curve 3) vs mixture pressure at $P_{SF_6} + P_{H_2} = 0.26$ atm and maximum line-charging voltage. Curve 1 corresponds to the dependence of the laser line width $\Delta\nu_{J'J''}$ on the mixture pressure.

vation of the HF molecule by hydrogen [5]. At a partial hydrogen pressure 0.05 atm, the deactivating influence of the helium can be neglected up to a pressure $P_{He} \approx 10$ atm.

The laser line width at $P_{He} \gtrsim 1$ atm and $P_{SF_6} + P_{H_2} \approx 0.2$ atm is determined by the helium pressure and is given by $(\Delta\nu) = (\delta_{SF_6}P_{SF_6} + \delta_{He}P_{He})$, where δ is the broadening parameter and $\delta_{He}/\delta_{SF_6} = 0.2$. The experimentally measured dependence of the laser gain on the pressure in the region $P \lesssim 2.5$ atm is satisfactorily described by the factor $C(\Delta\nu)^{-1}$, where C is a normalization factor (curves 1 and 2 of Fig. 3), and is connected mainly with the impact broadening of the laser lines by the helium. The faster decrease of the gain at $P \gtrsim 2.5$ atm is apparently due to the crease of the inverted population resulting from the decreased concentration of the dissociation products of the molecules SF_6 and H_2 in a homogeneous discharge with a lower current density.

The increase of the mixture pressure by increasing the hydrogen pressure is unprofitable because of the strong quenching action, with a char acteristic time $\tau_{HF^*H_2} = 55$ nsec-atm [5]. The addition of SF_6 for this purpose is also useless, because it makes the discharge worse.

The described experiments uncover a possibility of developing a laser that is tunable in a range near 2.7 microns. The parameter of broadening of the HF lines by helium is tentatively equal to 0.1 $cm^{-1}atm^{-1}$. This should ensure tuning within a range 0.5 - 0.6 cm^{-1} about the center of each of the rotational-vibrational lines of the bands (3, 2), (2, 1) etc. in the region 2.70 - 3.0 μ. A similar scheme can be used to construct a DF laser (3.7 - 4.0 μ), and also lasers using the isotopic molecules HCl^{35}, Hcl^{37}(3.6 - 4.0 μ), DCl^{35}, DCl^{37} (5.0 - 5.4 μ), and compounds of Br^{79} and Br^{81} (spectral regions 4.0 - 4.5 and 5.5 - 6.2 μ) [6]. The tuning range can be increased by replacing helium with Kr and Xe, which have larger ordering parameters (∿0.15 and ∿0.24 $cm^{-1}atm^{-1}$, respectively, for the (2, 0) transition [7]).

We note that the observed decrease of the gain of the HF laser with increasing mixture point of view is convenient from the point of view of developing a tunable laser, since the possibility of onset of superluminescent radiation with uncontrollable spectrum is greatly decreased.

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