11. V. V. Lebedev, A. S. Provorov, B. I. Troshin, V. P. Chebotaev, and A. A. Chernenko, "Laser on magnesium vapor at λ = 518 nm using resonant pumping," Pis'ma Zh. Tekh. Fiz., 6, No. 22, 1364-1367 (1980).

TWO PROCESSES THAT LOWER THE EMISSION ENERGY OF AN ELECTRIC-DISCHARGE KrF LASER

A. M. Razhev

Results are reported of an experimental investigation of the processes that lower the emission energy of an electric-discharge excimer KrF laser operating on mixtures containing F2 and NF3. The existence is demonstrated of two processes, reversible and irreversible, that lower the KrF-laser emission energy as the number of excitation pulses is increased (without continuous replenishment of the mixture) and as the pulse repetition frequency is increased. The irreversible process is connected with the decrease of the concentration of initial halogen-containing gas in the mixture as a result of interaction between the halogen atoms and the chamber material. The reversible process is due to the long reduction time of the halogen-containing molecule (~1 sec for F2) and influences the laser emission energy only at pulse repetition frequencies that exceed the reciprocal time of reduction of these molecules. If complex halogen-containing molecules (NF3, SF6, ...) are used, the pulse-repetition regime is realized because of the radicals that are produced. The use of such molecules, however, affects adversely the service life of the excimer gas mixture.

A high-power pulsed discharge and intrinsic laser emission cause substantial changes of the chemical composition of the gas mixture of excimer lasers. These changes can be stable, irreversible or reversible. Elucidation of the mechanism that lowers the emission energy of excimer electric-discharge lasers is therefore particularly vital for the development
Fig. 1. Dependence of the emission energy, per liter of mixture, of KrF, XeCl, and KrCl lasers on the number of excitation pulses. Total volume of discharge chamber $V \approx 200 \, \text{cm}^3$; active volume $v = 0.5 \times 1.5 \times 58 \, \text{cm}$; GIN-1 pulse-generator voltage $U = 50 \, \text{kV} (C_0 = 10.2 \, \text{nF})$. 1) XeCl laser—He:Xe:HCl; 2) KrCl laser—He:Kr:HCl; 3) KrF laser—He:Kr:NF$_3$; 4) KrF laser—He:Kr:F$_2$.

of laser installations of high average emission power, operating at high pulse-repetition frequencies.

Since the operating lifetime of the inert-gas fluoride mixture ArF, KrF, XeF lasers is considerably lower than that of inert-gas KrCl and XeCl lasers (Fig. 1), the processes that lower the emission energy were investigated in the present study only for inert-gas fluoride lasers, particularly the KrF laser.

**EXPERIMENTAL SETUP**

The electric diagram of the employed experimental setup is shown in Fig. 2. The laser chamber permitted excitation of the gas mixtures He:Kr:XY (XY = F$_2$, SF$_6$, NF$_3$) with pressures up to 6 atm. The mixtures were excited by a transverse electric discharge after preliminary ionization of the region either by a transverse discharge through a dielectric [1] or by UV spark radiation from one side [2]. The discharge chambers for both preionization methods were made of glass and aluminum electrodes secured by epoxy resin. The gas mixtures were excited by electric pulses of amplitude $U = 20-55 \, \text{kV}$ and duration $t_{\text{pu}} \leq 10 \, \text{nm}$ from a pulsed-voltage generator (GIN-1) [3] of capacitance 10.2 nF. Depending on the type of the active medium and on the geometry of the discharge chamber, the laser could operate at a pulse repetition frequency from 0.1 to 400 Hz without replenishment of the gas mixture, or with adjustable replenishment rate from 0.1 to 5 (liter·atm)/min.

**RESULTS**

Figure 1 shows the decrease of the emission energy $E$ with increasing number $n$ of the excitation pulses of XeCl and KrCl lasers using the mixtures He:Xe:HCl and He:Kr:HCl, respectively (curves 1 and 2), and of a KrF laser using the mixtures He:Kr:F$_2$ and He:Kr:NH$_3$ (curves 3 and 4). In these experiments, the laser operated without replenishing the gas-mixture molecules in the active medium. It can be seen that the manner in which the emission energy decreases is different for each laser, and the gas-mixture operating lifetime, defined as the time required for the emission energy to decrease to the 0.5 level, depends on the type of halide molecule used in the mixture. Thus, for example, in XeCl and KrCl lasers, which used the same HCl molecule, the dependences of the emission energy on the number of the excitation pulses are similar, whereas in one and the same KrF laser, but with mixtures containing F$_2$ (curve 3) and NF$_3$ (curve 4) these dependences are qualitatively different not only from one another, but also from the lasers using the XeCl and KrCl mole-