Chemical laser initiated by IR radiation

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Using results on the photochemical action of IR radiation, experiments have been performed for the purpose of obtaining lasing in the system SF_6+H_2. Lasing of HF was obtained by using a pulsed CO_2 laser of energy 4–9 J. The energy of the HF laser was 10^{-3} J.

Investigations of the photochemical action of IR light[1,2] have shown that resonantly-absorbing molecules, e.g., N_2F_4 or SF_6, are rapidly excited by powerful laser radiation. This uncovers possibilities of sufficiently rapid initiation of chemical processes in chemical lasers. It was shown in[3] that amplification corresponding to the vibrational-rotational transitions of the HF molecules is observed in the medium that results from irradiating the mixture SF_6+H_2 by CO_2-laser radiation.

We have organized experiments for the purpose of obtaining lasing in the SF_6+H_2 system. To this end we assembled an experimental setup consisting of an initiating CO_2 laser, a diverting optical system, an irradiated cell, a resonator, and recording apparatus.

Figure 1 shows a diagram of the laser setup. The beam from the initiating CO_2 laser is incident on spherical mirror M_1 (curvature radius ~300 cm, center hole diam. 8 mm) and is focused on the cell C. The cell is 38 cm long, its inside diameter is 15 mm, and it is equipped with windows W_1 (sodium chloride) and W_2 (lithium chloride) oriented at the Brewster angles. The beam diameter at the center of the cell is minimal and amounts to ~3 mm (the divergence angle of the initiating laser is 2×10^{-3} rad). The cell C is contained in a resonator made up of gold mirrors M_2 and M_3. M_2 is flat and M_3 is spherical with a curvature radius ~250 cm. The distance between mirrors M_3 and M_2 is ~200 cm. The diameter of the resonator caustic does not exceed 4 mm, so that the hole in the mirror M_1 does not hinder the generation of oscillations in the resonator

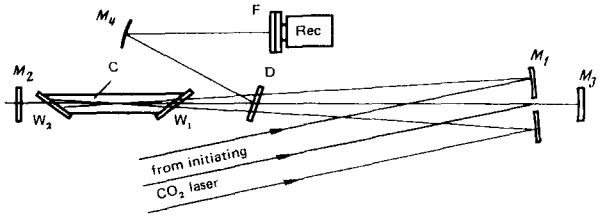

FIG. 1. Optical diagram of experiments on the feasibility of initiating the reaction in the system.

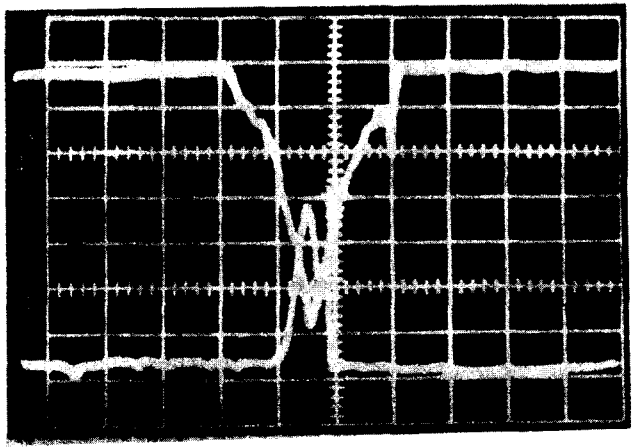

FIG. 2. Typical oscillograms of initiating CO_2 laser pulses (lower trace) and of HF lasing (upper curve). Time scale 5 μsec/division.

M_2M_3. The radiation is extracted from the resonator through a plane-parallel plate D (sodium chloride). The radiation leaving the resonator M_2M_3 is focused with the aid of mirror M_4 (curvature radius ~50 cm) on the receiving area of the photoresistor (germanium doped with gold, working temperature 77 °K). The filters F (plates of quartz, germanium, and lithium fluoride) make it possible to separate the radiation band from 2500 to 5000 cm^{-1}.

We investigated the system $SF_6 + H_2$. Lasing on the HF molecules was obtained in the mixture-pressure interval 4—50 Torr (70% SF_6, 30% H_2) at the following parameters of the initiating pulse: pulse energy 4—9 J, pulse duration 4—7 μsec, initiating-beam diameter ~3 mm.

Figure 2 shows typical oscillograms of the initiating CO_2 laser radiation pulse (lower oscillogram) and of the HF lasing (upper oscillograms).

During the course of the study of the HF laser it was established that when the $SF_6 + H_2$ mixture pressure is increased from 4 to 15 Torr, the lasing pulse duration decreases from 4 to 1.3 μsec. No lasing was registered at a mixture pressure 24 Torr and higher.

In addition, we have noted that when the intensity of the initiating radiation is increased, the delay of the lasing pulse relative to the start of the initiating pulse increases, and the lasing duration decreases.

The deterioration of the resonator Q shortens the HF-lasing pulse. In an experiment in which the $SF_6 + H_2$ mixture was diluted with nitrogen (9 Torr SF_6, 3 Torr H_2, and 300 Torr N_2), no HF lasing could be produced.

The lasing energy was measured in experiments in which the pressure of the $SF_6 + H_2$ mixture was ~4 Torr. The energy amounted to 0.6 mJ. Addition of fluorine to the $SF_6 + H_2$ system (3 Torr of SF_6, 1 Torr of H_2, and 1 Torr of F_2) led to an increase in the lasing energy by approximately 4 times, thus indicating the chain character of the reaction that leads to the production of the inversion.

Further investigations of chemical lasers initiated with IR radiation will be aimed at finding new effects of the operating mixtures and at optimizing the laser parameters.

[1]N. G. Basov, E. P. Markin, A. N. Oraevskiĭ, and A. V. Pankratov, Dokl. Akad. Nauk SSSR **198**, 1043 (1971) [Sov. Phys.-Dokl. **16**, 445 (1971)].

[2]N. G. Basov, E. P. Markin, A. N. Oraevskiĭ, A. V. Pankratov, and A. N. Skachkov, ZhETF Pis. Red. **14**, 251 (1971) [JETP Lett. **14**, 165 (1971)].

[3]John L. Lymon and Reed J. Jensen, J. Phys. Chem. **77**, No. 7 (1973).