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CHEMICAL LASER OPERATING ON BRANCHED CHAIN REACTION OF FLUORINE WITH HYDROGEN

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The principal feasibility of developing lasers based on chemical reactions has been examined in detail recently [1,2]; examples of such an analysis are the papers of Tal'roze [3] and Oraevskii [4]. It was reported [5-7] that laser action was realized in vibrationally-excited HC* and HF* in photochemical chain reactions. The rate of population of the "upper" level in such reactions does not exceed $W_0\nu$, where W_0 is the photo-initiation rate and ν is the length of the chain. An analysis of the data of [5-7] shows that in practice a small number of links of the chain is effective in the population of the "upper" level, and the inversion and generation occur only at sufficiently rapid photo-initiation W_0, so that as a result the principal fraction of the total energy loss in the generator is due to the electric energy lost in the flash lamp, and one can speak in this case of a chemical laser only by stretching the point somewhat.

The main difficulties in creating a "truly" chemical laser are connected, in particular, with the fact that the reaction should proceed at a sufficiently rapid rate, i.e., it should have a small activation energy, and at the same time the reacting mixture should be able to fill the volume of the optical resonator before the start of the reaction. These two requirements are apparently best satisfied by branched chain reactions which have ignition limits - curves in coordinates of pressure (P) and temperature (T) (Fig. 1) - which separate the regions of values of P and T in which the reaction does not occur in practice (shown shaded in the figure) from the regions in which the reaction is explosive [8]. One of the characteristic reactions of this type is the reaction of hydrogen with fluorine, for which Semenov and Shilov [9] established the existence of a first (I) and second (II) ignition limit. In addition, it is possible to realize in this reaction also a third (III) chain ignition limit.

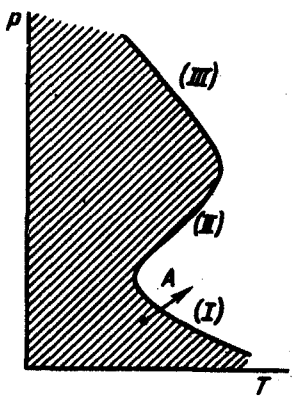

Fig. 1

An investigation of the mechanism of this reaction [10] has shown that the branching occurs in it in reactions of vibrationally-excited hydrogen fluoride. In this case it is to be expected that inside the ignition region the accumulation of products at the upper level will first be proportional to $ae^{t/\tau}$, where a is a quantity that depends on the rate of initiation and τ is the characteristic branching time of the reaction.

The authors investigated a mixture of fluorine with hydrogen of approximately stoichiometric composition near the first ignition limit. The passage through the limit (see arrow A in Fig. 1) is by means of an electric discharge with an energy (Q_E) lower 1.5 - 2 or-

ders of magnitude than the reserve of chemical energy. The reaction vessel was a tube with calcium-fluoride windows mounted at the Brewster angle. Generation was obtained at many lines of the vibrational bands of the HF* molecule in the wave-number range 3600 - 4200 cm^{-1}, corresponding to the vibrational transitions in the HF molecule. Figure 2 shows the oscillograms of the chemiluminescence pulses (a) and generation pulses (b) at the transition P_4 of the 2 - 1 vibrational band (the scale of oscillogram b is 100 times larger than that of a). The generation pulse duration at half-height was ~5 μsec. A calorimeter was used to measure the total energy Q_L of the light in the pulse. It is possible to introduce the concepts of "electric" and "chemical" efficiencies of such a laser: the electric efficiency is $K_E = Q_L/Q_E$ and the chemical efficiency is $K_C = Q_L/\eta Q_C$, where η is the degree of burnup of the mixture and Q_C the reserve of chemical energy. Estimates based on the results of the experiments yielded K_E = 2 - 10% and $K_C \gtrsim 0.2\%$. These quantities exceed by several orders of magnitude the efficiencies attained in known photochemical pulsed lasers. Apparently we have come in this case much closer to a truly chemical laser, if we take $K_E \geq 100\%$ as the criterion for such a laser.

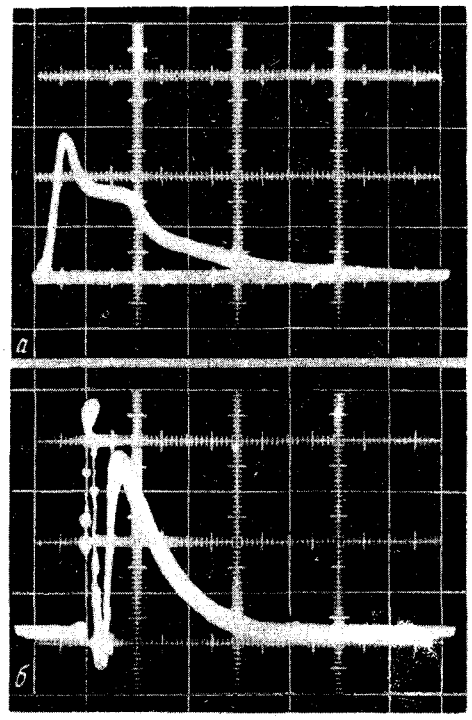

Fig. 2. Oscillograms of pulses: a - chemiluminescence, sweep 50 μsec/cm; b - generation, sweep 5 μsec/cm.

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THRESHOLD BEHAVIOR OF THE CROSS SECTION FOR THE EXCITATION OF Cs II RESONANCE LINES IN THE PROCESS $Cs^+ + He$

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In the present investigation we have observed experimentally that the approach of the turning points and of the pseudointersection point of the potential terms of the quasimolecule