distance between particle centers in model; r_t, τ_t, ε_t, reflection, transmission, and absorption coefficients of two-dimensional model of a dispersion medium respectively; τ_n, r_n, transmission and reflection coefficients of a stack of n identical planes; ε_m, R_m, emissivity and reflection coefficient of surface of disperse system; q_b, q'_{bs}, q'_p, q'_{bm}, q''_{bm}, δ'_p, δ'_m, surface densities of radiation fluxes in cell; $\varphi_{\alpha-\beta}$, angular coefficients; a_1–a_7, coefficients used in solving system (5); S_m, S_b, areas of faces m and e, f, g, h, e', f', g', h' of cell respectively; Q_{ref}, Q_{abs}, Q_{trans}, Q_{in}, reflected, absorbed, transmitted, and incident radiation fluxes.

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POROUS MIXERS FOR GASDYNAMIC LASERS WITH SELECTIVE THERMAL EXCITATION

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Results of experimental studies are presented pertaining to the characteristics of a gasdynamic laser with selective thermal excitation and with the mixing device made of porous material.

Several interesting new methods of mixing the streams in gasdynamic lasers with selective thermal excitation have been proposed in recent years [1-3]. In the first study [1] nitrogen from air was mixed with CO_2 aerosol, in the second study [2] the "subcritical" mode of adding the radiating component to the mixture was considered, and in the third study [3] designs of mixers for adding it to a supersonic supporting stream were developed. Although many designs already exist, it is now still difficult to decide on the final choice of mixer

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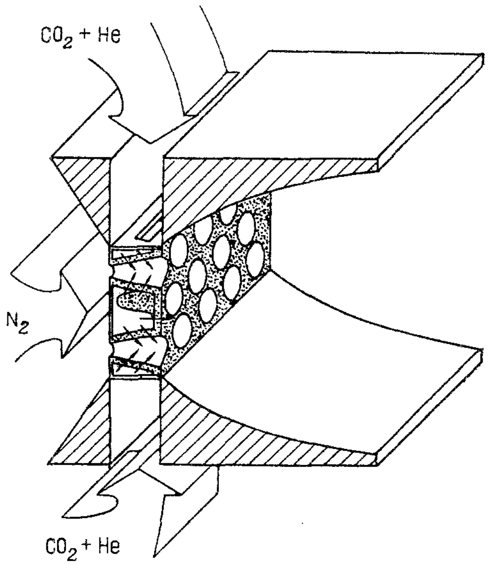

Fig. 1. Basic schematic diagram of the porous mixer for gasdynamic lasers with selective thermal excitation.

and the problem of "optimum" mixing arrangement in gasdynamic lasers with selective excitation still remains crucial. Furthermore, most mixers already developed are not very technological for use in multimodal gasdynamic lasers so that the search for more technological ways to build mixing devices is an urgent task for scientists.

In this report will be presented the results of an experimental study pertaining to the characteristics of a gasdynamic laser with the distinctive feature of a porous mixing device. One could expect that the level of gasdynamic perturbations within the injection zone will be much lower with injection of the stream of the radiating component through a porous structure than in mixers where it is injected through slits or holes of finite size. Indeed, the degree of stream turbulization and the level of gasdynamic perturbations should become lower as the dimensions of an "elementary" jet in the injected stream decrease. In order to maintain the given flow rate of the radiating component, however, it is necessary to increase the number of such slender jets. Accordingly, so as to reduce the "scale" of the initial nonuniformity, a mixing device was used in the earlier experiments [3] where 40 jets of CO_2 + He gas mixture approximately 1 mm in diameter each could be injected. In the "honeycomb" nozzle module [4] were mixed 477 jets of CO_2 + N gas mixture. Injection through porous walls of a nozzle makes it possible to reduce the jet size to the size of pores in the material and also to regulate the distribution of the flow rate of the injected component, by varying the thickness of the porous wall, so that the concentration of the radiating gas in the main stream can be optimally distributed.

The basic layout of the mixer used in this study is shown schematically in Fig. 1. The mixing device has several distinctive features:

1. injection of the radiating component (CO_2) mixed with helium occurs through the porous walls of the array of profiled conical nozzles;
2. the wall thickness increases from 2 mm at the critical section to 3.5 mm at a distance of 1.67 bores away from that section, such a profile of the porous walls having been selected for the purpose of achieving the maximum rate of gas flow through the porous material and ensuring a sufficient mechanical strength of the blank subject to heavy impact loads during fabrication;
3. the array of porous nozzles is molded into a metal bracket.

Owing to the said design features of the nozzle array, injection of CO_2 + He mixture into a supersonic N_2 stream occurred mainly within a narrow nozzle zone between 0.3 and 1.67 bores from the critical section. At the exit from the array of mixer nozzles there occurred subsequent cooling and acceleration of the gas stream as a result of additional expansion. The overall area of the exit section was 16.8 times larger than that of the critical section.

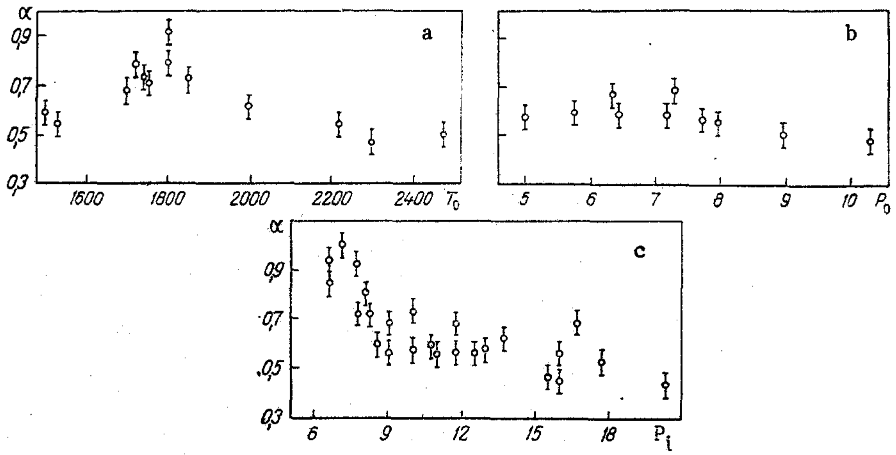

Fig. 2. Dependence of the gain α (m^{-1}) on (a) the stagnation temperature T_0(°K), (b) the stagnation pressure P_0 (atm) in the main stream and (c) the stagnation pressure P_i (atm) in the injected stream: (a) P_i = 8 atm and P_0 = 7 atm; (b) P_i = 11 atm and T = 1800°K; (c) P_0 = 7.5 atm and T_0 = 1800°K.

The porous material consisted of 0.2-0.315-mm-diameter balls of grade BrOF10-1 sintered bronze, with a porosity of 35-40% and a permeability $K = 10^{-7}$ cm^2. The porous nozzles were produced by sintering with gravity feed.

The device was built in a special-purpose mold made of grade Kh18N9T stainless steel. Sintering was done in an electric transfer furnace in an atmosphere of dissociated ammonia. The temperature was varied here between 830 and 860°C, depending on the size fraction of the powder particles. The sintering time was 1 h in all cases. Noteworthy are the simplicity and the technological characteristics of this nozzle manufacturing process: first of all, several identical nozzles can be produced with the same die and, secondly, the resulting nozzle surface does not require any additional mechanical treatment.

The performance of this porous mixing device was checked on a gasdynamic pulse-duty test stand using a shock tube with a channel of square (5 × 5 cm) cross section with the pressure in the reflected wave 5-15 atm and the stagnation temperature 800-4000°K at gas flow rates of 0.1-0.3 kg/sec.

A theoretical calculation of the gas flow through porous nozzle walls being rather difficult, the gas flow rate here was measured during pulse operation on the basis of known pressure changes in the forechamber of the supporting stream and known lengths of discharge time. Depending on the pressure in the forechamber, the flow rate of the injected component varied from 40 to 140 g/sec. The Mach number of the supporting stream varied over the range 0.02-0.1.

The stagnation temperature and pressure of hot nitrogen before discharge were determined from the equilibrium shock adiabat: the velocity of an incident shock wave was recorded with a digital frequency meter and by measurement the time interval between signals from two piezoelectric pressure transducers. The pressure of hot nitrogen immediately before the nozzle was measured with a pulse-type piezoelectric gauge.

For measuring the gain a scheme with a single passage of the laser beam through the active medium (5 cm long) was used. An industrial LG-22 CO_2 laser operating in a single mode with an emission power of approximately 1 W was used as the probing laser.

The spectral composition of the detectable radiation was limited to the 10.6 μm wavelength by means of a composite interference—dispersion filter. An infrared modulator with the active crystal "lighting up" upon application of a high-voltage (∿3 kV) pulse was used for reading and checking the output power level in the probing laser beam. For measuring very small amplifications (∿ 0.5m)$^{-1}$) in these experiments, furthermore, there was included a system of twice recording the reference signal and comparing the useful signal with the probing laser signal, after the latter had been attenuated to one-tenth magnitude.

The gain was measured at a distance of 50 mm from the critical section of the nozzle, within the central zone of the nozzle. Typical experimental data are shown in Fig. 2a-c.

The results of an experimental optimization of the main stream (N_2) in the forechamber are shown in Fig. 2a-b. These data indicate that the optimum stagnation temperature and pressure for nitrogen in a forechamber of the given design are $T_0 = 1800°K$ and $P_0 = 7.5$ atm. The dependence of the gain on the pressure of the supporting stream in the forechamber, measured under these conditions of optimum nitrogen stream parameters, is shown in Fig. 2c. The injected mixture here consisted of 10% CO_2 and 90% He. The injected gas in the forechamber was at room temperature.

The flow rate of the main component (nitrogen) under the conditions in Fig. 2c was 80 g/sec, while the flow rate of CO_2 + 9He was varied from 40 to 140 g/sec and the pressure of the supporting stream in the forechamber was varied from 5.5 to 20 atm. Under the optimum conditions ($P_0 = 7$ atm) the flow rate was 50 g/sec, corresponding to a 4.0% CO_2 gas content in a thoroughly mixed stream. An amplification of approximately 1 m^{-1} under these conditions is quite appreciable and indicates the feasibility of attaining in gasdynamic lasers, with selective excitation through porous mixers, operating modes characterized by low relaxation losses and a high output energy density.

Experiments were performed with the diameter of the critical section for a nitrogen stream $d^* = 3$ mm (overall area of the critical section 1.2 cm^2). No experiments were performed with $d^* < 3$ mm, since estimates of the "freeze in" efficiency η indicated that this efficiency would be almost 100% under optimum conditions. This estimate of η must be further refined, however, because it did not take into account the nonuniform distributions of:

1) the gain α over the nozzle section (the corresponding error can be eliminated by integrating the distribution of gain over the nozzle section);

2) the CO_2 gas concentration ξ_{CO_2} and the temperature (including vibrational temperatures) over the nozzle section (eliminating the corresponding errors requires additional direct measurements of ξ_{CO_2} and T_V profiles in the stream; temperatures T_V can be found, e.g., through measurement of the gain at several rotational lines [5]).

No such data are available at this time and, therefore, the estimates of "freeze in" efficiency in this study are based on uniform distributions of α, ξ_{CO_2}, and T_V (ξ_{CO_2} and T_V calculated according to the "instantaneous displacement" model [6]).

With increasing concentration of CO_2 gas one would expect an almost linear increase in amplification [3]. According to the data in Fig. 2c, however, an increase of the injected stream P_i above 7 atm in the forechamber caused not an increase but a decrease of amplification α. This was probably due to an increase of relaxation losses in the stream as a result of a higher ratio of flow rates, that of the injected component to that of the main component. Indeed, owing to the high hydraulic resistance of a porous structure, the discharge velocity of the supporting gas through the porous mixer was very low: The Mach number in the injected component under a pressure of 7 atm, for instance, in the forechamber of the supporting stream was only $3 \cdot 10^2$ (sic). Calculations based on the "instantaneous displacement" model [6,7] indicate that with these parameters a supersonic flow should discontinue and a stream should stall. In this case apparently the stream did not stall altogether, however, inasmuch as mixing proceeded at a finite velocity. Under these conditions there could possibly develop local subsonic domains within the mixing zone in the stream where most of the dissipation of vibrational energy through relaxation occurs. Naturally, moreover, the level of gasdynamic perturbations and with it the level of relaxation losses will increase with higher flow rates of the injected component.

In summary, noteworthy are the excellent manufacturability of porous mixers and the feasibility of operating selectively excited gasdynamic lasers with porous mixing devices under conditions of low relaxation losses and correspondingly high output energy densities. Meanwhile, however, the low (subsonic) discharge velocity of the gas injected through a porous material gives rise to difficulties in organization of the regular gasdynamic operating mode when the injection rate is high.

NOTATION

K, permeability of the porous material; T_0, P_0, stagnation temperature and pressure of the mainstream; T_i, P_i, stagnation temperature and pressure of the injected stream; α, amplification of a weak signal; ξ, concentration; η, "freeze in" efficiency; and T_V, vibrational temperatures of CO_2.

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DEPENDENCE OF THE BREAKDOWN OF WATER DROPS ON THE PARAMETERS OF A CO_2 LASER PULSE

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Results of a theoretical study are presented pertaining to vaporization and explosion of water drops by a pulsed CO_2 laser, with the nonuniformity of internal heat generation taken into account.

It has been demonstrated in earlier studies [1-4] that a strongly nonuniform internal heat generation enhances appreciably the effect of radiation from high-intensity sources on water drops. Inasmuch as most experimental equipment used for exposing water drops to radiation operates in the pulse mode, the method used in those studies [1-4] is also applicable to studies concerning the vaporization of water drops by pulsed radiation at the $\lambda = 10.6$ μm wavelength and intensities corresponding to the gas-kinetic mode or the explosion mode [5,6].

As a basis for specific calculations, we will proceed by analogy to another study [7] and express the intensity of pulsed radiation being a function of time as the sum of two exponential terms. In order to account for the effect of a usually finite rise time of a pulse, we introduce into the analytical expression for the latter a linear relation between intensity and time during the initial buildup period.

We consider two pulse variants. The first variant will be described by the expressions

$$I(t) = \begin{cases} I_0 [A \exp(-\alpha_1 t_1) + B \exp(-\alpha_2 t_1)]\, t/t_1 & \text{at} \quad 0 \leqslant t < t_1, \quad (1) \\ I_0 [A \exp(-\alpha_1 t) + B \exp(-\alpha_2 t)] & \text{at} \quad t_1 \leqslant t \leqslant t_2, \quad (1a) \end{cases}$$

with the constant coefficient I_0 determined by the source power.

The second variant will be described by the expressions

$$I(t) = \begin{cases} I_0 [(A + B)\, t/t_1] & \text{at} \quad 0 \leqslant t < t_1, \quad (2) \\ I_0 [A \exp(-\alpha_1 (t - t_1)) + B \exp(-\alpha_2 (t - t_1))] & \text{at} \quad t_1 \leqslant t \leqslant t_2. \quad (2a) \end{cases}$$

Letting the variable pulse parameters assume values approximately corresponding to the experimental conditions [7-9], we obtain $A = 2$, $B = 1$, $\alpha_2 = 0.5 \cdot 10^6$ sec^{-1}, and $t_2 = 2$ μsec. At time $t_1 = 0$ the half-width of a pulse depends on α_1 and decreases by a factor of 8 as α_1

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