THE EFFECTIVENESS WITH WHICH AN INVERSION MEDIUM APPEARS IN TURBULENT DIFFUSION

S. A. Novopashin

UDC 532.5.517.4+621.378.8

A dimensionless diameter is proposed to characterize the dynamics of the inversion population in the case of turbulent gas-flow mixing.

The fundamental possibility of achieving inversion in gasdynamic lasers in the case of mixing [1] is based on the differences in the relaxation velocities (excitation) of the upper and lower levels of laser transition. For the effective generation of an inversion medium it is necessary to mix the components to molecular levels within periods of time shorter than the relaxation times. The absence of a rigorous theory to explain turbulent mixing prevents us from calculating the dynamics of the molecular energy level populations under these conditions.

Let us examine the mixing of adjacent layers of a fluid. The surface separating these layers in the case of a turbulent regime acquires a "crumpled" appearance or, in the usual terminology, it becomes a fractal object. The molecular structure of a real physical medium, as well as the intermolecular forces, lead to the existence of a minimum scale (the dimension of the mole). However, mixing to the molecular level is accomplished by diffusion processes. Within the time T the surface separating the layers of the fluid is "spread out" over a distance on the order of $\sqrt{DT}$. As a condition for the effective generation of an inversion medium we require that the mixing to the molecular level take place within a time smaller than τ. The magnitude of τ is defined as the greater of the relaxation (excitation) time which characterizes the duration of the existence of the inversion in a totally mixed medium. Thus, this sought condition can be written in the following form:

$$d/\sqrt{D\tau}\leqslant 1.$$

Let us express all of the quantities in terms of the mean free path λ, the time t between collisions, and the quantity $N = \tau/t$ of collisions necessary for relaxation, and the Knudsen number $Kn = \lambda/d$. For the quantity $D\tau$ we obtain $D\tau = \lambda(\lambda/t)tN = \lambda^2N$. After substitution into the original relationship and squaring, we obtain

$$\mathrm{Kn}^2N\geqslant 1.$$

Let us assume that Kn is a quantity on the order of 10^{-2} [2] (this value has been obtained for the turbulent flow regime in the mixing layer of a supersonic nitrogen jet). From this we find that the effective generation of an inversion medium in turbulent mixing is possible for systems with $N \geq 10^4$. It is not difficult to see that for a gasdynamic CO_2 laser used for mixing this condition is satisfied for the relaxation times of the upper laser level on collisions with He, CO_2, and N_2, as well as for the excitation times of the lower laser level on collision with oscillation excited nitrogen [1, 3].

NOTATION

D, coefficient of diffusion; d, minimum fractal dimension.

LITERATURE CITED

1. R. I. Soloukhin and N. A. Fomin, Gasdynamic Mixing Lasers [in Russian], Minsk (1984).
2. S. A. Novopashin, A. L. Perepelkin, and V. N. Yarygin, Pis'ma Zh. Teor. Éksp. Fiz., 44, No. 7, 318-319 (1986).
3. B. F. Gordien, L. I. Osipov, and L. A. Shelepin, Kinetic Processes in Gases and Molecular Lasers [in Russian], Moscow (1980).

Institute of Thermophysics, Siberian Branch, Academy of Sciences of the USSR, Novosibirsk.
Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 57, No. 4, pp. 566-567, October, 1989. Original article submitted May 12, 1988.

0022-0841/89/5704-1159$12.50