EXPERIMENTAL STUDY OF PROPAGATION OF THE VISIBLE AND IR RADIATIONS IN AIR ABOVE INHOMOGENEOUSLY HEATED SURFACES

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In this paper we measured spatial distribution of temperature and cross–section averaged velocities of convective air flows through inhomogeneously heated tubes. It is shown that certain regimes of heating of the tube surfaces can provide, in spite of a complicated character of gas flows, noticeable homogeneous temperature gradients as a result of not very intense heating. The resulting profiles of the air refractive index could be used to focus laser radiation.

The flows of gases and liquids through inhomogeneously heated tubes with the complicated spatial temperature distribution have aroused considerable interest, but in so doing a sophisticated treatment of such processes is extremely difficult.[1,2] At the same time the problem of development of hollow waveguides for powerful CW lasers operating in the IR range, such as CO_2 and CO (see Ref. 3), as well as development of alternative focusing elements of gaseous lens type[1] and problems of laser thermal diffusion in vertical tubes[4,5] call for more profound inquiries into the convective gas flows.

A set of experimental measurements of spatial distributions of temperature and velocities of convective air flows through inhomogeneously heated cylindrical tubes with different parameters has been performed by the authors.

Quartz capillaries were taken for the experiments, 25–50 cm in length and 1–2 cm in diameter. They were heated by a collection of special hollow cylindrical electrical heaters manufactured from Nichrome, slipped over the capillar, and heat–insulated on the outside.

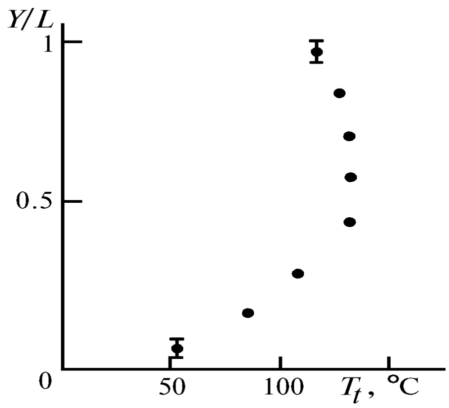

FIG. 1. Tube wall temperature versus the relative vertical coordinate.

Temperature was measured by a miniature chromel–aluminum thermocouple. We note that for vertical arrangement of tubes to an accuracy of 1°, the axial symmetry of measurable characteristics was observed. Even weak heating of the capillar to a temperature of about 50°C with the same energy contributions per unit length of the tube results in the inhomogeneous temperature distribution over the vertically arranged capillar due to onset of natural convection flows. With increasing of input power, this inhomogeneity became more pronounced; in this case the lower end of the tube maintained approximately room temperature. Typical profile of the tube wall temperature versus the relative vertical coordinate is shown in Fig. 1. It can be seen that the temperature of upper half of the capillar ($Y \gtrsim L/2$) is practically homogeneous and below it will be called the tube temperature T_t.

In the lower part the temperature nonlinearly increases according to approximately exponential law.

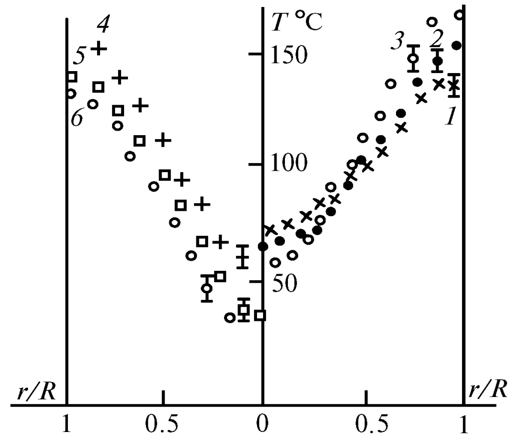

Fig. 2. Radial temperature distribution inside the cappilar for different distances from its upper end: h = 0(*1*), 6(*2*), 12(*3*), 18(*4*), 24(*5*), *and* 30 cm (*6*).

The radial temperature distributions inside the capillar are of considerable interest. For the tube of length $L = 50$ and inner diameter of 2 cm they are grouped in two families for different distances h from the upper end of the tube. It can be seen from this figure that in most of the volume of the capillar the radial temperature gradient changes insignificantly. This can be used, for example, to focus laser radiation, specifically in the development of hollow waveguides for lasers operating in the IR range. Based on the depicted dependences $T(r)$, the refractive index distribution $n(r)$ can be obtained and focusing system parameters can be calculated. We note that in most of the capillar the temperature gradient in the near–axis zone of the tube differs strongly from zero as a result of heating of a rising gas, and the function $n(r)$ differs from a quadratic one.

We note that proper selection of heating regime for $Y/L \gtrsim 0.1$ provides experimentally the linear increase of the temperature on the capillar axis as the convective air rises. Typical results of measurements are shown in Fig. 3.

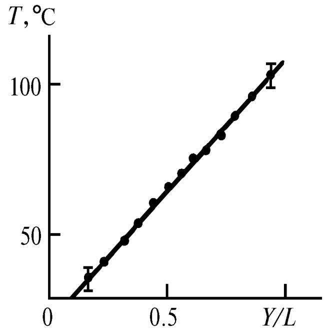

FIG. 3. Axial cappilar temperature versus the relative vertical coordinate.

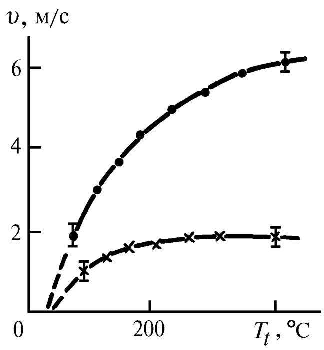

FIG. 4. Dependence of the cross–section averaged velocity at the exit from (1) *and inlet to* (2) *the capillar on the temperature of its walls.*

Depicted temperature distributions are formed in rising expanding and accelerating air flows.

Therefore measurements of the velocity of air flows are of great interest.

At the first stage specially graduated anemometers with different attachments were used to determine the cross–section averaged velocity of air flow υ through the capillar.

The dependencies of υ at the exit from (1) and inlet to (2) the capillar 2 cm in diameter and 50 cm in length on the temperature of the tube walls are shown in Fig. 4. The velocity at the exit from the capillar 25 cm in length is shown by dashed line. It can be seen that upon heating the velocity of incoming air saturates fastly enough, while the velocity of outgoing flow increases. At the temperature T_t, being approximately equal to 400°C, these velocities differ by more than 3 times.

Thus the results of experimental measurements of spatial distributions of temperatures and velocities of convective air flow through inhomogeneously heated tubes show that certain regimes of surface heating, in spite of the fact that the character of air flow is very complicated and accelerated, provide noticeable homogeneous temperature gradients as a result of not very intense heating.

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