USE OF A LASER AS LIGHT SOURCE FOR AN INTERFERENCE STUDY OF TEMPERATURE AND CONCENTRATION FIELDS IN LIQUIDS

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The advantages of using a laser as a light source in an IAB-451 shadow instrument, used as a two-beam diffraction interferometer for studying temperature and studying temperature and concentration fields in liquids, are reported.

The IAB-451 shadow instrument is widely used to study gas-dynamic phenomena, combustion, and heat and mass transfer in gases. This instrument is used much less frequently for studying such processes in liquids [1, 2], but it has wide capabilities here, especially when it is converted (in a simple manner) into a two-beam diffraction interferometer [3]. This is done by replacing the slit and knife edge in the focal planes of objectives L_1 and L_2 of the instrument (Fig. 1) by transparent diffraction gratings R_1 and R_2, and by placing a field diaphragm D with two windows in the object plane. This diaphragm is used to form the two-beam interference field. Without going into detail on the operation of the two-beam diffraction interferometer, which was described in [3], we will show that the most suitable modification of this instrument is that in which the diaphragm windows are placed in a row. In this case the interference field has the maximum possible brightness and size. The width of the field-diaphragm windows should be related to the grating spacing d_n by

$$b = \frac{f\lambda}{d_n}. \quad (1)$$

The object is placed at one of the diaphragm windows, and the light passing through the other window forms the reference beam.

In our experiments, the object was a liquid in a cuvette placed at one of the diaphragm windows. The path difference between the two beams became so large that an interference pattern could not be obtained after the cuvette was inserted (when an ordinary light source, e.g., a DRSh-250 mercury lamp, was used), so a compensating cuvette equal in size to the working cuvette and filled with the same liquid had to be placed in the reference beam. The compensating cuvette must be separated by a distance b [given by Eq. (1)] from the working cuvette, and the liquid it contains must be under the same physical conditions (at the same temperature and, if a solution, at the same concentration, etc.). In this case, any temperature, concentration, or other perturbations in the test liquid cause interference changes in the image of the cuvette (when the interferometer is adjusted to an infinite band width), or they displace and deform the interference fringes existing prior to the perturbation in the test liquid (adjustment for finite band width). A compensating cuvette is also required for other interference setups used to study liquids [4].

A compensating cuvette is not necessary when a laser is used as light source, since its highly monochromatic radiation makes the size of the path difference between the two interferometer beams inconsequential. This is an important advantage, for it simplifies the construction of the experimental apparatus. In addition, the interferograms obtained with a laser are of higher quality than those obtained with an ordinary light source and an interference filter. Finally, in a calculation of the interferograms obtained with an ordinary light source and an interference filter, some average wavelength λ (averaged over the transmission band of the filter) must be used; this introduces a definite error into the experimental results.

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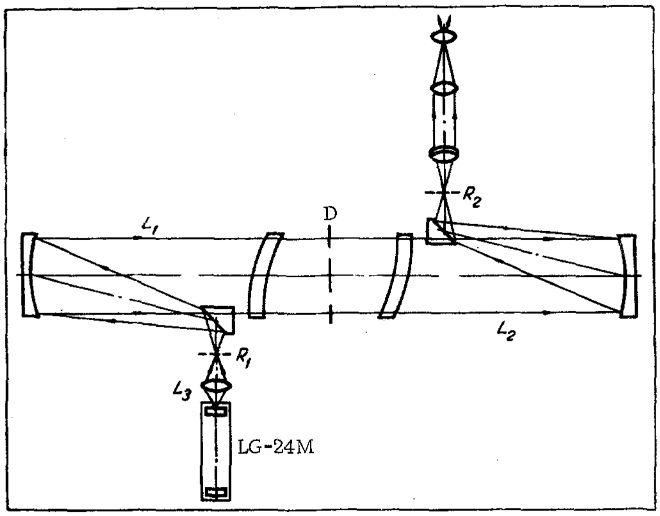

Fig. 1. Diagram of the two-beam diffraction interferometer based on the IAB-451 shadow instrument.

Fig. 2

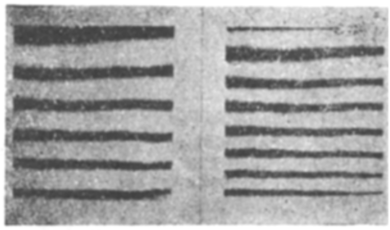

Fig. 3

Fig. 2. Interferogram of free thermal convection in a vertical layer of distilled water.

Fig. 3. Interferogram of thermal diffusion of an aqueous solution of ethanol.

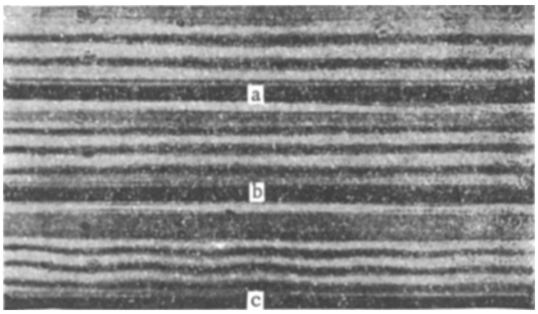

Fig. 4. Interferograms of the temperature field in a horizontal layer of distilled water.

The interferograms obtained with a laser are free of this disadvantage because of the highly monochromatic radiation of the laser.

In a study of the temperature and concentration fields in liquids with the IAB-451 instrument used as a diffraction interferometer, we used an LG-24M gas laser as light source [5]; with a lens L_3 of short focal length, the beam from this laser can be focused on the plane of the diffraction grating R_1 (Fig. 1).

As an example of the interferogram obtained with the IAB-451 instrument with a laser light source, we show in Fig. 2 an interferogram of free thermal convection in distilled water in a cell between whose vertical walls a temperature difference is maintained. Figure 3 shows an interferogram of the thermal diffusion in an aqueous solution of ethanol in a horizontal cell under the influence of a vertical temperature gradient (during the separation, the number of interference fringes increases).

Figure 4 shows interferograms of the temperature field in a horizontal layer of distilled water (the layer was 100 mm long and 5.7 mm thick, and the light beam passed 30 mm through the layer). The temperature field was calculated from the formula [4]

$$\Delta T = m\lambda/l \frac{dn}{dT}. \tag{2}$$

Figure 4a corresponds to Ra = 1380 = 1380 and a temperature difference of $\Delta T = 0.56°$ between the layer boundaries; Fig. 4b corresponds to Ra = 1500 and $\Delta T = 0.64°$; and Fig. 4c corresponds to Ra = 1840 and $\Delta T = 0.75°$. The distortion of the interference fringes in Fig. 4c indicates disruption of the linear temperature profile within the liquid layer and thus the transition from conduction to convection.

In conclusion, we note that this procedure of using a two-beam diffraction interferometer (based on the IAB-451 instrument) with a laser as light source may be useful for measuring temperature and concentration fields in studies of transfer processes in dropping liquids.

NOTATION

b	is the width of one diaphragm window;
f	is the local length of the objective L_2;
d_n	is the grating spacing;
λ	is the wavelength of the light used;
ΔT	is the temperature difference between the boundaries of the liquid layers;
m	is the number of interference fringes;
l	is the distance the light beam passes through the layer;
dn/dT	is the temperature coefficient of the refractive index of the liquid;
Ra	is the Rayleigh number.

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