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RECONSTRUCTION OF IMAGES OF TRANSPARENT AND REFRACTING OBJECTS BY MEANS OF PHASE HOLOGRAMS

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Abstract

Full Text

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PHYSICS

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The process of reconstructing the wave front of radiation from some object was first proposed in work (1). In recent years this process has been considerably improved. In the widely known work (2), first-order images reconstructed with the aid of amplitude-phase holograms are presented. To obtain high image quality the authors of work (2) used a photoemulsion with a resolving power of $\sim$ 2000 lines/mm. The brightness of images reconstructed with the aid of amplitude-phase holograms is not great. The brightness and contrast of the reconstructed images increase when phase holograms are used (3). The increase in brightness and contrast is obtained owing to the elimination of the background of amplitude modulation. Phase holograms make it possible to obtain qualitatively reconstructed images in the first three orders with comparatively small requirements on the resolving power of the photoemulsions. A phase hologram is free of the usual diffraction effects caused by imperfections of the emulsion surface and of the optical devices channeling the laser beam.

Fig. 1. Diagram of holographing in transmission.
1 –laser, 2-3 –lenses expanding the beam, 4 –object, 5, 6 –mirrors channeling the auxiliary beam, 7 –photographic film, α –angle between the main and auxiliary beams

The scheme we used for obtaining a hologram of transmitting objects is shown in Fig. 1. It makes it possible to reduce to a minimum the angle α between the main and reference beams, which is very important when working with photographic materials of low resolving power. As the angle α increases, the brightness of the reconstructed images of the higher orders falls. If emulsions with a resolving power of about 600 lines/mm are used, satisfactory results are

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Figure 2. Example of holography of a tonal object. Top—the object; bottom—the reconstructed real image in the first order and the reconstructed real images of the first and second orders.

Figure 2: Figure 2. Example of holography of a tonal object. Top—the object; bottom—the reconstructed real image in the first order and the reconstructed real images of the first and second orders.

Figure 3. Example of holography of transparent refracting objects—bubbles in glass: a—photographs of the objects, b—reconstructed images of the objects.

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obtained for values $\alpha < 15^{\circ}$. In view of the low power of the laser in the single-mode operating regime, the exposure for obtaining the hologram increases to several minutes. To avoid the harmful influence of vibrations on the quality of the holograms, the entire setup was placed on inflated automobile inner tubes.

Figure 2a presents an object—a positive photograph on film measuring 17×23 mm. The hologram of this object was obtained according to the scheme of Fig. 1 at $\alpha = 1^{\circ}40'$. Figure 2b shows the image reconstructed with the aid of a transparent phase hologram. The magnification of the reconstructed image was obtained owing to the divergence of the expanded laser beam. In obtaining the hologram, a helium-neon laser operating in the single-mode regime at a wavelength of 6328 Å was used. In Fig. 2b the real image reconstructed in two orders is clearly visible. Virtual images are observed visually up to the 4th order. Above Fig. 2b the zero order of the image is visible in the form of a light rectangle.

Fig. 2. Example of holography of a tonal object. Top—the object; bottom—the reconstructed real image in the first order and the reconstructed real images of the first and second orders.

Fig. 3. Example of holography of transparent refracting objects—bubbles in glass: **a**—photographs of the objects, **b**—reconstructed images of the objects.

Obtaining holograms of transparent refracting objects is of considerable applied interest. Of particular interest are holograms of bubbles in liquids or drops in vapors. On the basis of work ([4]), it may be assumed that wave-front reconstruction is entirely possible in these cases as well. To illustrate the possibilities of holograms of transparent refracting objects, bubbles in glass were chosen. In Fig. 3a an ordinary photograph of the bubbles is shown, and in Fig. 3b—a first-order image reconstructed by means of a phase hologram. In the reconstruction, a plane passing through the center of bubble A, having dimensions $87 \pm 5\,\mu$, was chosen; bubble B, of size $247 \pm 5\,\mu$, is located near this plane. The centers of bubbles D and C are respectively in front of and behind the plane of

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reconstruction, and therefore their images have low contrast. The sizes of these bubbles are respectively 275 ± 5 and $496 \pm 5\,\mu$. The distances in depth between bubble D and bubbles A, B, C are respectively equal to 10.7; 16.2; 19.2 mm.

The results obtained show the full possibility of obtaining holograms of bubbles and drops in volumes having a comparatively large extent along the line of sight.

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