HOLOGRAPHIC METHOD FOR TRANSFORMING COHERENT LIGHT FIELDS

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Fig. 1

Figure 1: Fig. 1

Abstract

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HOLOGRAPHIC METHOD FOR TRANSFORMING COHERENT LIGHT FIELDS

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The use of mirrors, lenses, and other optical elements makes it possible to carry out only the simplest transformations of light beams, for example rotation of the wavefront, its curvature, and changes in angular and linear magnification. However, in a number of cases, including the need to improve the output radiation of solid-state and liquid OKGs, it is important to obtain light fields with a prescribed phase distribution from a field with an arbitrary wavefront. Below we present a solution of this problem by holographic methods of recording and reproducing light beams (^{1}).

Fig. 1. Scheme of the method. a –recording of a hologram by interference of beams I and II; b –when the image is reconstructed by beam II, the radiation is transformed into beam I', coinciding in phase and direction with beam I; c –analogous transformation when beams I are combined

Let, in recording the hologram, two beams interfere,

$$A_1 \exp[i\varphi_1(x, y, z)]$$

and

$$A_2 \exp[i\varphi_2(x, y, z)]$$

(Fig. 1a). Then the transparency coefficient of the hologram contains an interference term of the form (^{2,3})

$$A_1 A_2 \exp[i(\varphi_1 - \varphi_2)] + A_1 A_2 \exp[-i(\varphi_1 - \varphi_2)]. \tag{1}$$

Figure 2

Figure 2: Figure 2

If the hologram is illuminated by one of the original beams, for example $A_2 \exp[i\varphi_2]$, with the same phase distribution as at the moment of recording, then the wave transmitted through the hologram will contain a term of the form $A' \exp[i\varphi_1]$. It is a wave differing from the wave $A_1 \exp[i\varphi_1]$ only in amplitude, but coinciding with it in phase and propagating in the same direction as the wave $A_1 \exp[i\varphi_1]$ (Fig. 1*b*). Similarly, one can obtain the wave $A'' \exp[i\varphi_2]$ (Fig. 1*c*)*. In particular, by recording the interference of the OKG radiation with a plane wave and placing the hologram, after processing, back in its previous position, one can transform the OKG radiation field into a plane wave, with accuracy up to diffraction distortion over the working area of the hologram.

The considerations expressed above were confirmed by a series of experiments. An expanded parallel beam of radiation from a helium-neon OKG ($\lambda = 0.63\,\mu$) was split by a semitransparent cube into two; into one of them (II) a bilens was introduced to model a complex wavefront (Fig. 2*a*). The two halves of the bilens transformed the beam incident on them into two converging beams, while in the interval between them the wavefront remained plane. The interference of beams I and II was recorded on a hologram mounted in a special holder, which ensured that after processing it could be returned to its former position with an accuracy of 0.01-0.02 mm. The accuracy of placement was monitored with a microscope.

When the hologram was illuminated by the complex beam II, as expected, its partial transformation into a beam with a plane wavefront occurred (Fig. 2*b*). Analogously, it was possible to obtain beam II by using a parallel beam for illumination. As follows from Fig. 2*b*,

* The elimination of aberrations of optical systems ($^{4-6}$) may be regarded as a special case of the proposed method.

Fig. 2. **a**—scheme for obtaining a hologram in experiments with a bilens: **K**—beam-splitting cube, **Z**—rotating mirror, **B**—bilens, **G**—hologram. **b**—field structure of the recording and reconstructed beams: **1**—far zone of the plane wave obtained when the hologram is illuminated by the complex wave **II**; **2, 3**—respectively, the far zone of the complex wave and its holographic image (in the focusing plane of the plane wave front of the central part of the field, defocused images of points **O** and **O′** are visible); **4, 5**—respectively, the field distribution of beam **II** in the plane **OO′** and its holographic image (a defocused image of the central part of the field is visible). The scale of photograph **1** is enlarged by a factor of 4 in comparison with **2** and **3**.

the field distribution of the reconstructed beams is practically the same as that of the original beams. Changes in the intensity ratio of the beams during recording, as well as in the type of hologram (amplitude or phase), practically affected only

Figure 3

Figure 3: Figure 3

the relative intensity of the reconstructed beams, while their phase front was preserved.

The elimination of irregular phase distortions of a parallel beam caused by optical inhomogeneities of a transparent medium, whose role was played by a ruby crystal, was also carried out. The hologram-recording scheme is analogous to Fig. 2a. Figure 3 shows the results of photometry of the far zones of radiation that had passed through the crystal and of a beam with a corrected wavefront. At different levels of relative intensity, the reduction in divergence is by a factor of 5-15.

In the last series of experiments, the proposed method

Fig. 3. **a** and **c**—passive divergence of a beam that has passed through a ruby crystal; **b** and **d**—divergence of a beam with a holographically transformed wavefront.

Fig. 4. *a*—far-field radiation zone of the OQG; *b*—far-field radiation zone of the OQG with a corrected wavefront; *c*—angular distribution of the radiation energy W of the ruby OQG before correction (1) and after correction (2) within a cone with vertex angle 2φ.

A reduction in the divergence of the radiation was obtained for the production ruby quantum generator "Razdan 2A." The hologram was recorded, according to the scheme of the preceding experiments, by a beam of light from a helium-neon OQG polarized in the same way as the radiation of the ruby OQG. After processing and obligatory bleaching, the hologram was placed back in its former position. Reconstruction was carried out by the radiation of the ruby laser itself, which was transformed by the hologram into a beam with substantially smaller divergence in the transverse direction (Fig. 4b).

The results obtained in the last experiment can be improved, since here one of the principal requirements of the method was not fully satisfied—the identity of the wavefront of the reconstructing beam with one of the recorded beams. Indeed, recording is carried out with a parallel beam of wavelength $\lambda_1 = 0.63\,\mu$, distorted as a result of a single pass through the specimen (the so-called passive divergence), whereas in reconstruction the output beam of the ruby OQG is used, with another wavelength $\lambda_2 = 0.69\,\mu$, whose wavefront (the so-called active divergence) is determined by the properties of the generated oscillation modes.

The proposed method may find broad application for obtaining coherent fields with a required wavefront configuration.

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