Formation of shear interferograms in the diffusely scattered light by double-exposure recording of Gabor holograms for wave front control

V.G. Gusev

Tomsk State University

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The conditions of formation of shear interferograms in diffusely scattered light at double-exposure recording of Gabor holograms are analyzed in the parabolic approximation. It is shown both theoretically and experimentally that achromatic interference pattern characterizing a wave front under control is located in the hologram plane.

The method of control of a wave front shape was considered in Ref. 1 based on double-exposure recording of a lensless Fourier hologram of an opaque screen in diffusely scattered coherent fields. It was shown that if the objective speckle fields of the two exposures are matched in the plane of a photographic plate at the stage of hologram recording, then at the stage of hologram reconstruction the shear interference pattern characterizing the controlled wave front is located in the plane of the image of an opaque screen. At the same time, the interference pattern caused by the phase distortion of the reference wave due to aberrations of the forming optical system or aberrations of the spherical reference wave is located in the hologram plane. Since the spatial filtering of the diffraction field is being performed at the stage of reconstruction of a double-exposure Fourier hologram, these interference patterns are recorded independently. The formation of these interference patterns was analyzed using the third order approximation. Analysis showed that the range of sensitivity of an interferometer in the case of off-axis hologram recording is limited because of the off-axis aberrations of the reference spherical wave.[2] These aberrations increase with the increase of the angle between the axis of the spatially bounded reference wave and the normal to the plane of the photographic plate.

To extend the range of sensitivity of an interferometer, we consider here the peculiarities of formation of a shear interferogram in diffusely scattered fields for wave front control in the Fresnel approximation for the case of double-exposure recording of the Gabor hologram of an amplitude scatterer.

As shown in Fig. 1*a*, the amplitude scatterer *1* located in the plane (x_1, y_1) is illuminated by a coherent convergent quasi-spherical wave with the radius of curvature R. For the first exposure, the scattered radiation with a coherent background is recorded on the photographic plate *2* located in the plane (x_2, y_2) at a distance l. Before the repeated exposure, as in Ref. 1, the tilt of the controlled wave front is changed, for example, in the plane (x, z), by an angle α, and the plate is displaced by $b = l \sin \alpha$ in the same direction along the axis x. Then, in the Fresnel approximation, accurate to constant factors, the distribution of the complex amplitude of the field corresponding to the first and second exposures in the plane (x_2, y_2) for $R > l$ can be written as

$$u_1(x_2, y_2) \sim \exp\left[\frac{ik}{2l}(x_2^2 + y_2^2)\right]\left\{[\delta(x_2, y_2) - F(x_2, y_2)] \otimes \right.$$
$$\left. \otimes\, \Phi(x_2, y_2) \otimes \exp\left[-\frac{ikR}{2(R-l)l}(x_2^2 + y_2^2)\right]\right\}, \quad (1)$$

$$u_2(x_2, y_2) \sim \exp\left\{\frac{ik}{2l}[(x_2 + b)^2 + y_2^2]\right\} \times$$
$$\times \left\{[\delta(x_2, y_2) - F(x_2, y_2)] \otimes \exp\left(\frac{ikax_2}{l}\right)\Phi(x_2, y_2) \otimes \right.$$
$$\left. \otimes \exp\left[-\frac{ikR}{2(R-l)l}(x_2^2 + y_2^2)\right]\right\}, \quad (2)$$

where $\otimes$ denotes convolution; $\delta(x_2, y_2)$ is the delta function; k is wave number; $F(x_2, y_2) = \iint_{-\infty}^{\infty} t(x_1, y_1) \times \exp[-\frac{ik}{l}(x_1x_2 + y_1y_2)]\,dx_1dy_1$ is the Fourier transform of the amplitude $t(x_1, y_1)$ of absorption by the scatterer being a random real function of coordinates; $\Phi(x_2, y_2) = \iint_{-\infty}^{\infty} \exp -i\varphi(x_1, y_1) \times \exp[-\frac{ik}{l}(x_1x_2 + y_1y_2)]\,dx_1dy_1$ is the Fourier transform of the complex function; $\varphi(x_1, y_1)$ is the determinate function characterizing phase distortions of the controlled wave front of the coherent radiation illuminating the scatterer, for example, due to aberrations of the optical system; a is the shift of the wave front at the change of its tilt angle before the repeated exposure.

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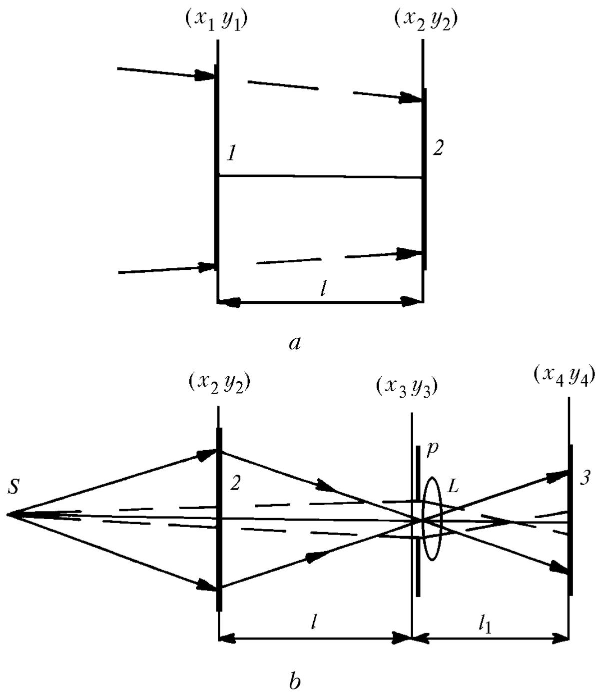


Fig. 1. Optical arrangement of recording (*a*) and reconstruction (*b*) of a double-exposure Gabor hologram: amplitude scatterer *1*, photographic plate – hologram *2*, plane of interferogram recording *3*, lens *L*, spatial filter *p*, point source of light *S*.

For $t(x_1, y_1) \ll 1$ (Ref. 3) let us find the complex amplitude $\tau(x_2, y_2)$ of transmittance of the double-exposure Gabor hologram provided that it was recorded within the region of a linear response of a photographic material to the exposure. Based on Eqs. (1) and (2) and neglecting the regular component, which occupies a small space in the plane of recording of the interference pattern (Fig. 1*b*), we have:

$$\tau(x_2, y_2) \sim \{\Phi^*(x_2, y_2) \otimes \exp[\frac{ik\mu}{2l}(x_2^2 + y_2^2)]\} \times$$
$$\times \{F(x_2, y_2) \otimes \Phi(x_2, y_2) \otimes \exp[-\frac{ik\mu}{2l}(x_2^2 + y_2^2)]\} +$$
$$+ \{\exp(-\frac{ikax_2}{l})\, \Phi^*(x_2, y_2) \otimes \exp[\frac{ik\mu}{2l}(x_2^2 + y_2^2)]\} \times$$
$$\times \{F(x_2, y_2) \otimes \exp(\frac{ikax_2}{l})\, \Phi(x_2, y_2) \otimes$$
$$\otimes \exp[-\frac{ik\mu}{2l}(x_2^2 + y_2^2)]\} + \text{complex conjugate}, \quad (3)$$

where $\mu = R/(R - l)$ is the scaling coefficient.

At the stage of hologram reconstruction, the first two terms in Eq. (3) determine the following diffraction of waves in the (–1) diffraction order for the first and second exposures. The complex conjugate terms correspond to the diffraction of waves in the (+1) order.

Using the integral representation of the convolution, we can write Eq. (3) in the form

$$\tau(x_2, y_2) \sim \{\exp[\frac{ik\mu}{2l}(x_2^2 + y_2^2)]\} \times$$
$$\times \Big\{[\exp i\varphi(\mu x_2, \mu y_2) \otimes \exp[-\frac{ik\mu}{2l}(x_2^2 + y_2^2)]] \times$$
$$\times [F(x_2, y_2) \otimes \Phi(x_2, y_2) \otimes \exp[-\frac{ik\mu}{2l}(x_2^2 + y_2^2)]] +$$
$$+ [\exp i\varphi(\mu x_2 + a, \mu y_2) \otimes \exp[-\frac{ik\mu}{2l}(x_2^2 + y_2^2)]] \times$$
$$\times [F(x_2, y_2) \otimes \exp(\frac{ikax_2}{l})\, \Phi(x_2, y_2) \otimes$$
$$\otimes \exp[-\frac{ik\mu}{2l}(x_2^2 + y_2^2)]]\Big\} + \text{complex conjugate}. \quad (4)$$

As follows from Eq. (4), the information on the controlled wave front is, on the one hand, in the distribution of an individual objective speckle over the hologram plane. On the other hand, it is distributed within the area occupied by the reference wave in the plane (x_2, y_2) (the overlap area of the fields of two exposures), where identical speckles coincide. By analogy with Ref. 1, it is obvious that when reconstructing the considered double-exposure Gabor hologram with the spatial filtering of the diffraction field in its plane, the shear interferogram in infinitely wide bands can be recorded. This interferogram is located in the image plane of the amplitude scatterer in the (–1) diffraction order and characterizes the controlled wave front. However, in this case the recorded interference pattern is distorted by a significant noise due to the diffraction of waves in the (+1) order. Therefore, let us consider the possibility of obtaining the information that is contained in the hologram plane.

Let the double-exposure Gabor hologram at the stage of its reconstruction be illuminated by a divergent spherical wave with the radius of curvature $r = R - l$ from a source of coherent radiation used at the stage of recording the hologram. This particular radius of curvature is chosen because it provides[4] for the maximum spatial resolution of the scatterer image formed in the (+1) diffraction order at reconstruction of the considered hologram. In the general case, we assume that the reconstructing wave has phase distortions characterized by the determinate function $\varphi_0(x_2, y_2)$. These distortions are caused, for example, by aberrations of the optical system. Then, in the used approximation neglecting the spatial boundedness of the field, the distribution of the complex amplitude of the field in the plane (x_3, y_3) (see Fig. 1*b*) is described by the equation

$$u(x_3, y_3) \sim \exp[\frac{ik}{2l}(x_3^2 + y_3^2)]\, \{\Phi_0(x_3, y_3) \otimes$$
$$\otimes \{[\Phi_1(x_3, y_3) \exp\frac{ik}{2\mu l}(x_3^2 + y_3^2)] \otimes$$
$$\otimes \exp[-\frac{ik}{4\mu l}(x_3^2 + y_3^2)] \otimes$$

$$\otimes\, t(-x_3, -y_3) \exp[-i\varphi(-x_3, -y_3)] \exp\left[\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right] +$$

$$+ \left[\Phi_2(x_3, y_3) \exp\left[\frac{ik}{2\mu l}(x_3^2+y_3^2)\right]\right] \otimes \exp\left[-\frac{ik}{4\mu l}(x_3^2+y_3^2)\right] \otimes$$

$$\otimes\, t(-x_3, -y_3) \exp[-i\varphi(-x_3 + a, -y_3)] \times$$

$$\times \exp\left[\frac{ik}{2\mu l}(x_3^2+y_3^2)\right] + \left[\Phi_3(x_3, y_3) \exp\left[-\frac{ik}{2\mu l}(x_3^2+y_3^2)\right]\right] \otimes$$

$$\otimes\, t(x_3, y_3) \exp i\varphi(x_3, y_3) \exp\left[-\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right] +$$

$$+ \left[\Phi_4(x_3, y_3) \exp\left[-\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right]\right] \otimes t(x_3, y_3) \times$$

$$\times \exp i\varphi(x_3 + a, y_3) \exp\left[-\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right]\Big\}\Big\}, \quad (5)$$

where Φ_0, Φ_1, Φ_2, Φ_3, and Φ_4 are Fourier transforms of the corresponding functions:

$$\exp i\varphi_0(x_2, y_2);\ \exp i\varphi(\mu x_2, \mu y_2);\ \exp i\varphi(\mu x_2 + a, \mu y_2);$$
$$\exp[-i\varphi(\mu x_2, \mu y_2)];\ \exp[-i\varphi(\mu x_2 + a, \mu y_2)]$$

for spatial frequencies kx_3/l; ky_3/l.

Since $\Phi_0 \simeq \Phi_1 \simeq \Phi_2 \simeq \Phi_3 \simeq \Phi_4 \simeq \delta(x_3, y_3)$, it follows from Eq. (5) that the real image of the amplitude scatterer is formed in the (+1) diffraction order. At the same time, the shear interference pattern in the bands of infinite width is formed in the plane (x_3, y_3). This pattern characterizes the controlled wave front because identical speckles of the two exposures coincide.[1] For the (−1) diffraction order, the distribution of the complex amplitude of the field in the (x_3, y_3) plane corresponds to the convolution of functions:

$$\exp\left[-\frac{ik}{4\mu l}(x_3^2 + y_3^2)\right] \otimes \left[\exp - i\varphi(-x_3, -y_3) +\right.$$

$$\left.+ \exp[-i\varphi(-x_3 + a, -y_3)]\right] t(-x_3, -y_3) \times$$

$$\times \exp\left[\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right].$$

Let the diffraction field in the plane (x_3, y_3) (see Fig. 1*b*) be spatially filtered with an opaque screen p having a round aperture with the center at the optical axis. If the diameter of the filtering aperture does not exceed the width of an interference fringe for the interference pattern lying in the plane of the real image of the amplitude scatterer, then the function $\exp[-i\varphi \times (-x_3,-y_3)] + \exp[-i\varphi(-x_3 + a,-y_3)]$ can be assumed constant within the filtering aperture in the distribution of the complex amplitude in the (−1) diffraction order, because this function varies slowly with coordinate. Then the distribution of the amplitude of the diffraction field at the exit from the spatial filter takes the form

$$u(x_3, y_3) \sim \exp\left[\frac{ik}{2l}(x_3^2 + y_3^2)\right]\Big\{\Phi_0(x_3, y_3) \otimes$$

$$\otimes \Big\{\left[\Phi_1(x_3, y_3) + \Phi_2(x_3, y_3)\right] \exp\left[\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right] \otimes$$

$$\otimes \exp\left[-\frac{ik}{4\mu l}(x_3^2+y_3^2)\right] \otimes t(-x_3,-y_3) \exp\left[\frac{ik}{2\mu l}(x_3^2+y_3^2)\right] +$$

$$+ \left[\Phi_3(x_3, y_3) + \Phi_4(x_3, y_3)\right] \exp\left[-\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right] \otimes$$

$$\otimes\, t(x_3,-y_3) \exp\left[-\frac{ik}{2\mu l}(x_3^2 + y_3^2)\right]\Big\}\Big\}. \quad (6)$$

The focusing lens L in Fig. 1*b* forms real image of the hologram *2* in the plane (x_4, y_4). Assume that it is in the plane (x_3, y_3) and form the image with the unit magnification, i.e., $l_1 = l$. Then, within the approximation used, the distribution of the complex amplitude of the field in the recording plane *3* is described by the equation

$$u(x_4, y_4) \sim \exp\left[\frac{ik}{2l}(x_4^2 + y_4^2)\right]\Big\{\Big\{\exp i\varphi_0(-x_4, -y_4) \times$$

$$\times \Big[\left[\exp i\varphi(-\mu x_4, -\mu y_4) + \exp i\varphi(-\mu x_4 + a, -\mu y_4)\right] \times$$

$$\times \left[F_1(x_4, y_4) \otimes \exp\left[-\frac{ik\mu}{2l}(x_4^2 + y_4^2)\right]\right] \times$$

$$\times \exp\left[\frac{ik\mu}{l}(x_4^2 + y_4^2)\right] +$$

$$+ \left[\exp[-i\varphi(-\mu x_4, -\mu y_4)] + \exp[-i\varphi(-\mu x_4 + a, -\mu y_4)]\right] \times$$

$$\times \left[F_2(x_4, y_4) \otimes \exp\left[\frac{ik\mu}{2l}(x_4^2 + y_4^2)\right]\right] \times$$

$$\times \exp\left[\frac{ik\mu}{2l}(x_4^2 + y_4^2)\right]\Big]\Big\} \otimes P(x_4, y_4)\Big\}, \quad (7)$$

where

$$F_1(x_4, y_4) = \iint_{-\infty}^{\infty} t(-x_3,-y_3) \exp\left[-\frac{ik}{l}(x_3x_4+y_3y_4)\right] dx_3 dy_3;$$

$$F_2(x_4, y_4) = \iint_{-\infty}^{\infty} t(x_3, y_3) \exp\left[-\frac{ik}{l}(x_3x_4+y_3y_4)\right] dx_3 dy_3;$$

$$P(x_4, y_4) = \iint_{-\infty}^{\infty} p(x_3, y_3) \exp\left[-\frac{ik}{l}(x_3x_4+y_3y_4)\right] dx_3 dy_3$$

are Fourier transforms of the corresponding functions; $p(x_3, y_3)$ is the transmission function of the opaque screen with a round aperture.[5]

If the period of functions $\exp i\varphi(-\mu x_4, -\mu y_4) + \exp i\varphi(-\mu x_4 + a, -\mu y_4)$ and $\exp[-i\varphi(-\mu x_4, -\mu y_4)] + \exp[-i\varphi(-\mu x_4 + a, -\mu y_4)]$ exceeds the size of a subjective speckle determined by the width of the function $P(x_4, y_4)$ at least by an order of magnitude[6] then they can be factored outside the sign of the convolution integral in Eq. (7). Since the speckle fields in the (−1) and (+1) diffraction orders correlate in the far zone for the Gabor hologram at the stage of its reconstruction[7,8] the intensity of the diffracted light add. Then the distribution of illumination in the plane (x_4, y_4) takes the form

$$I(x_4, y_4) \sim \{1 + \cos[\varphi(-\mu x_4 + a, -\mu y_4) - \varphi(-\mu x_4, -\mu y_4)]\} \times$$

$$\times \left\{ \left| \exp i\varphi_0(-x_4, -y_4) \exp \left[\frac{ik\mu}{l}(x_4^2 + y_4^2)\right]\left[F_1(x_4, y_4) \otimes \right.\right.\right.$$

$$\left.\otimes \exp\left[-\frac{ik\mu}{2l}(x_4^2 + y_4^2)\right]\right] \otimes P(x_4, y_4)\Big|^2 +$$

$$+ \Big|\exp i\varphi_0(-x_4, -y_4) \left[F_2(x_4, y_4) \otimes \right.$$

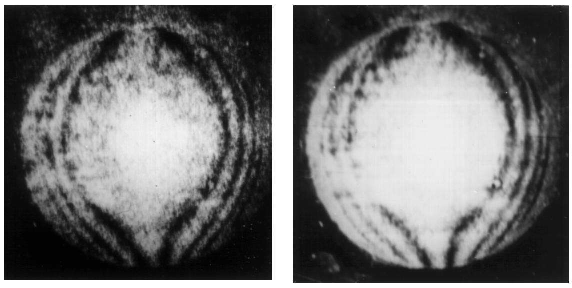
$$\left.\left.\otimes \exp\left[\frac{ik\mu}{2l}(x_4^2 + y_4^2)\right]\right] \otimes P(x_4, y_4)\Big|^2\right\}. \qquad (8)$$

It follows from Eq. (8) that the subjective speckle structure in the recording plane *3* (see Fig. 1*b*) is modulated by the interference fringes forming the shear interferogram in the bands of infinite width. This interferogram characterizes the controlled wave front. Phase distortions of the wave illuminating the hologram at the stage of its reconstruction do not change the interference pattern, because they are included in the speckle structure.

When a double-exposure Gabor hologram is reconstructed by a convergent quasi-spherical wave with the radius of curvature $r = l - R$, if $R < l$, then the real image of the amplitude scatterer constructed with the unit magnification is formed in the plane (x_3, y_3) (see Fig. 1*b*) spaced by l from the hologram.[9] In this case, the procedure of determining the distribution of illumination in the recording plane *3* keeps the same with the allowance made for the scaling coefficient $\mu = R/(l - R)$.

If the amplitude scatterer is illuminated by a coherent radiation of a convergent quasi-spherical wave with the radius of curvature R at the stage of double-exposure recording of the Gabor hologram, the reconstruction of the hologram by a convergent spherical wave with the radius of curvature $r = R + l$ leads to formation of the real image of the scatterer in the (+1) diffraction order with unit magnification at the distance l from the hologram. Owing to the performed spatial filtering of the diffraction field in this plane, the recorded distribution of the illumination in the plane of the real image takes the form of Eq. (8) for $\mu = R/(R + l)$.

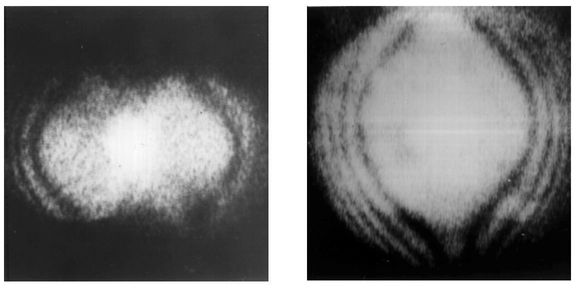
In the experiment, double-exposure Gabor holograms were recorded on Mikrat–VRL photographic plates using He–Ne laser radiation at the wavelength of 0.63 μm. As an example, Fig. 2*a* shows the shear interferogram in the bands of infinite width. The interferogram is located in the hologram plane. It mainly characterizes spherical aberrations of the convergent wave front with the diameter 40 mm and the radius of curvature $R = 1000$ mm. The interferogram was recorded as shown in Fig. 1*b* at spatial filtering of the diffraction field on the optical axis in the plane of the real image of the amplitude scatterer using the aperture diaphragm of 2-mm diameter. The hologram was recorded at $l = 320$ mm. Before the repeated exposure of the photographic plate, the wave front tilt angle was changed by $\alpha = 16'15'' \pm 3''$, and the plate was displaced by $b = (1.5 \pm 0.002)$ mm.



a *b*

Fig. 2. Interference patterns recorded at hologram reconstruction using a point-like source of monochromatic (*a*) and polychromatic light (*b*).

In addition to the above-mentioned localization of the interference pattern, this double-exposure Gabor hologram is characterized by the known properties. Thus, at spatial filtering of the diffraction field at a point on the edge of a hologram and on the shear axis, the interference pattern is located in the plane of the virtual image of the scatterer (left-hand side of Fig. 3*a*). The noise due to diffraction of waves of the two exposures in the (+1) order hinders observing the controlled interference pattern in the entire plane of its location. Besides, recording of diffracting speckle fields in the Fourier plane with the spatial filtering at the optical axis beyond the hologram plane is accompanied by an increase in the sensitivity of the interferometer (Fig. 3*b*) due to correlation of speckle fields in the (−1) and (+1) orders (Refs. 7 and 8).



a *b*

Fig. 3. Interference patterns located in the plane of the virtual image of the scatterer (*a*) and in the far diffraction zone (*b*).

It should be noted that, in contrast to the double-exposure Fourier hologram of the opaque screen,[1] the considered method of recording of the double-exposure Gabor hologram for wave front control is acceptable only in the case of formation of a shear interferogram in the bands of the infinite width. For this to take place, the condition that $\sin \alpha = b/l$ must be fulfilled accurate to the size of the objective speckle in the hologram plane at the stage of recording. Deviations from this condition lead to formation of the shear interferogram in the bands of finite width. However, in this case the recorded interference pattern has lower contrast at the stage of hologram reconstruction, because the periodic component of the interference pattern is located in the far diffraction zone due to mutual shift of identical speckles in the hologram plane. The image of an opaque screen in the case of double-exposure recording of the Fourier hologram is formed in the far diffraction zone as well. This provides for the formation of the shear interferogram both in the bands of infinite and finite widths using the diffusely scattered coherent fields.

Let the considered double-exposure Gabor hologram of the amplitude scatterer be reconstructed using a source of coherent light with the wavelength $\lambda_1 \neq \lambda$. Then, assuming that at spatial filtering of the diffraction field in the plane (x_3, y_3) (see Fig. 1*b*), because of the chromatic aberration of the image position determined by the value of lk_1/k, the aperture diameter of the spatial filter p is sufficient for $\varphi(\frac{k}{k_1}x_3 + a, \frac{k}{k_1}y_3) - \varphi(\frac{k}{k_1}x_3, \frac{k}{k_1}y_3) \leq \pi$ within it, the distribution of illumination in the plane (x_4, y_4) takes the form

$$I(x_4, y_4) \sim \{1 + \cos[\varphi(-\mu x_4 + a, -\mu y_4) - \varphi(-\mu x_4, -\mu y_4)]\} \times$$
$$\times \{ \left| \exp\left[i \frac{(k_1 + k)\mu(x_4^2 + y_4^2)}{2l}\right] [F_1'(x_4, y_4) \otimes \right.$$
$$\left. \otimes \exp\left[-\frac{ik\mu}{2l}(x_4^2 + y_4^2)\right]\right] \otimes P'(x_4, y_4) \Big|^2 +$$
$$+ \left| \exp\left[i \frac{(k_1 - k)\mu(x_4^2 + y_4^2)}{2l}\right] [F_2'(x_4, y_4) \otimes \right.$$
$$\left. \otimes \exp\left[\frac{ik\mu}{2l}(x_4^2 + y_4^2)\right]\right] \otimes P'(x_4, y_4) \Big|^2 \}, \quad (9)$$

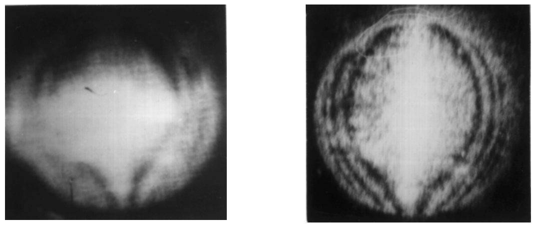
where

$$F_1'(x_4, y_4) =$$
$$= \iint_{-\infty}^{\infty} t(-\frac{k}{k_1}x_3, -\frac{k}{k_1}y_3) \exp\left[-\frac{ik_1}{l}(x_3x_4 + y_3y_4)\right] dx_3 dy_3;$$
$$F_2'(x_4, y_4) =$$
$$= \iint_{-\infty}^{\infty} t(\frac{k}{k_1}x_3, \frac{k}{k_1}y_3) \exp\left[-\frac{ik_1}{l}(x_3x_4 + y_3y_4)\right] dx_3 dy_3;$$
$$P'(x_4, y_4) = \iint_{-\infty}^{\infty} p(x_3, y_3) \exp\left[-\frac{ik_1}{l}(x_3x_4 + y_3y_4)\right] dx_3 dy_3$$

are Fourier transforms of the corresponding functions.

It follows from Eq. (9) that both the shape of interference fringes and their position keep unchanged. Only the distribution of illumination in the speckle structure modulated by the interference fringes changes. This circumstance allows reconstruction of the hologram with the use of a polychromatic light from a point-like source and recording of an achromatic shear interference pattern in the bands of infinite width located in the hologram plane and characterizing the controlled wave front. The interference pattern recorded with the use of a white light from a point source is shown in Fig. 2*b*. And if the contrast of the interference pattern shown in Fig. 2*a* keeps high as the diameter of the filtering hole increases in the plane (x_3, y_3) (see Fig. 1*b*) up to 20 mm, then the high contrast of the interference pattern shown in Fig. 2*b* is observed for almost halved diameter of the filtering aperture.

Assume that the hologram is reconstructed at the wavelength λ using two point sources of spatially incoherent light located symmetrically about the optical axis. Then two independent patterns will be located in the plane (x_3, y_3) (see Fig. 1*b*). The shape of interference fringes in each of the patterns will correspond to Fig. 2*a* with the distance between the centers $lc/(R - l)$, where c is the distance between the point sources. If the distribution of illumination within the diameter of the filtering aperture of a spatial filter corresponds to the zero interference order for each interference pattern, then the interference pattern located in the hologram plane will have high contrast in the recording plane *3*. Consequently, in the case of hologram reconstruction using a 1D extended source of white light with the length $C = 41$ mm, high contrast of the achromatic interference fringes will be observed for source orientation along the axis normal to the shear axis. This is demonstrated in Fig. 4 for the filtering aperture 2 mm in diameter.



a *b*

Fig. 4. Interference patterns recorded at hologram reconstruction with a 1D extended source of white light oriented along the shear axis (*a*) and normally to it (*b*).

Thus, the results show that, in contrast to Ref. 1, the shear interference pattern in the bands of infinite width that characterizes the controlled wave front is located in the plane of the double-exposure Gabor hologram of the amplitude scatterer. To record the interference pattern, spatial filtering of the diffraction field on the optical axis in the plane of formation of real image is needed. The possibility of using a white-light source at the stage of hologram reconstruction allows the interference pattern to be recorded with the speckle noise excluded.

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