FORMATION OF SHEAR INTERFEROGRAMS USING DIFFUSELY SCATTERED LIGHT BASED ON DOUBLE–EXPOSURE RECORDING OF A LENS FOURIER HOLOGRAM

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A shear interferometer based on double–exposure recording of a lens Fourier hologram of a mat screen is analyzed. It is shown both theoretically and experimentally that spatial filtering in the hologram plane results in the formation of an interference pattern characterizing the phase distortions of the illuminating wavefront and wave aberrations due to lens.

The method of double–exposure recording of a lens Fourier hologram of a mat screen, which can be used to form shear interferograms in fringes of infinite width using diffusely scattered fields when performing spatial filtering, was first implemented in Ref. 1. To do this, the mat screen placed in the front focal plane of a positive lens was illuminated by coherent radiation with a quasiplanar wavefront and the Fourier hologram was recorded during the first exposure with the use of the off–axis reference beam. Prior to the second exposure of a photographic plate, placed in the back focal plane of the lens, the phase changes induced in the light wave due to the displacement of the mat screen in its plane were compensated by means of the change in the tilt angle of a quasiplanar reference wavefront. As a result, reconstructed subjective speckle fields of the two exposures appear to be superimposed in the hologram plane with the total tilt angle between them determined by the amount of displacement of the mat screen prior to the second exposure of the photographic plate. On the one hand, this results in localization of the interference pattern in the hologram plane because of the phase distortions of the reference wavefront. On the other hand, subjective speckle fields of two exposures also coincide in the Fourier plane of the objective placed behind the hologram, resulting in the formation of the interference pattern characterizing the wave aberrations due to lens and phase distortion of the wavefront illuminating the mat screen. It then follows that one can distinguish the phase distortions of the reference wavefront and wave aberrations due to lens from the phase distortions of the illuminating wavefront. Formation and recording of the holographic shear interferograms were extended to the cases of the Fourier image of the mat screen in the plane of photographic plate with the use of a positive lens, when the mat screen was illuminated by diverging and converging spherical waves.[2,3] In this case, the well–known in optics manufacture possible formation of a nonaberrational spherical wave allows one to control the wave aberrations due to lens over the field.

Some salient features of reconstruction of the complex amplitude of the double–exposure field based on the coincidence of their subjective speckles in the plane of the photographic plate during the recording of the lens Fourier hologram of the mat screen illuminated by a quasiplanar wave are analyzed in this paper.

According to Fig. 1*a*, the Fourier image of the mat screen *1* is formed in the plane of the photographic plate *2* with the positive lens L_1. It is produced during the first exposure by an off–axis reference wave (which is not shown in Fig. 1*a*). Prior to the second exposure, the tilt angle of the wavefront of radiation illuminating the mat screen is changed by α in the plane (x, z), and the photographic plate is displaced at an amount a along the x axis in its plane. At the reconstruction stage the hologram *2* (Fig. 1*b*) is illuminated by a coherent plane wave, and the interference pattern is recorded in the Fourier plane when performing spatial filtering in the hologram plane with the use of the opaque screen P_2 with a circular aperture.

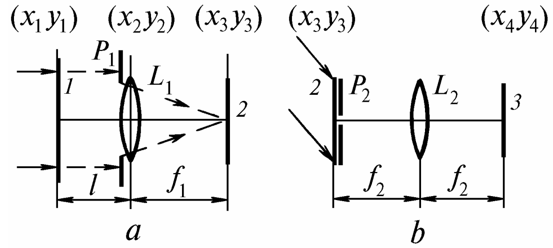

FIG. 1. The scheme used for recording (a) and reconstruction (b) of a double–exposure Fourier hologram of the mat screen: 1) mat screen, 2) photographic plate–hologram, 3) recording plane of the interferogram; L_1 and L_2 are lenses; P_1 is the aperture diaphragm; and, P_2 is the filtering diaphragm.

The complex amplitude of a subject field produced during the first exposure in the plane (x, y) of the photographic plate in the Fresnel approximation, neglecting the constant amplitude and phase factors, takes the form

$$u_1(x_3, y_3) \sim \int\int_{-\infty}^{\infty}\int\int t(x_1, y_1) \exp i\,\varphi_1(x_1, y_1) \times$$
$$\times \exp\{i\,\kappa[(x_1 - x_2)^2 + (y_1 - y_2)^2]/2\,l\} \times$$
$$\times\, p_1(x_2, y_2) \exp i\,\varphi_2(x_2, y_2) \exp[-i\,\kappa(x_2^2 + y_2^2)/2 f_1] \times$$
$$\times \exp\{i\,\kappa[(x_2 - x_3)^2 + (y_2 - y_3)^2]/2 f_1\}\, dx_1\, dy_1\, dx_2\, dy_2, \quad (1)$$

where κ is the wave number, $t(x_1, y_1)$ is the complex amplitude of transmission of the mat screen and is a random function of coordinates, $\varphi_1(x_1, y_1)$ is the deterministic function characterizing the phase distortions of the quasiplanar illuminating wavefront, $p_1(x_2, y_2) \exp i\varphi_2(x_2, y_2)$ is the generalized pupil function[4] of the lens L_1 with the focal length f_1 taking into account the axial wave aberrations,

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and l is the distance between the mat screen and the principal plane (x_2, y_2) of the lens.

By well–known transformations, expression (1) can be represented in the form

$$u_1(x_3, y_3) \sim \exp[i\,\kappa(x_3^2 + y_3^2)/2 f_1] \times$$

$$\times\{\exp[-i\,\kappa(x_3^2+y_3^2)\,l/2 f_1^2]F[\kappa x_3/f_1, \kappa y_3/f_1]\otimes P_1(x_3,y_3)\},\quad(2)$$

where $\otimes$ denotes the convolution operation,

$$F[\kappa x_3/f_1, \kappa y_3/f_1] =$$

$$=\int\int_{-\infty}^{\infty} t(x_1, y_1)\exp i\varphi_1(x_1, y_1)\exp[-i\kappa(x_1x_3 + y_1y_3)/f_1]\mathrm{d}x_1\mathrm{d}y_1$$

is the Fourier transform of the transmission function of the mat screen taking into account the phase distortions of the illuminating wavefront, $P_1(x_3, y_3) = \int\int_{-\infty}^{\infty} p_1(x_2, y_2) \times \exp i\,\varphi_2(x_2, y_2)\exp[-i\,\kappa(x_2 x_3 + y_2 y_3)/f_1]\,\mathrm{d}x_1\,\mathrm{d}y_1$ is the Fourier transform of the generalized pupil function of the lens L_1.

On the basis of expression (2) we have the phase distribution of the diverging spherical wave with radius of curvature f_1, characterized by the quadratic term $\exp\left[i\kappa\left(x_3^2 + y_3^2\right)/2f_1\right]$, and the Fourier transform of the input function. In this case each point of the Fourier transform spreads to the circle whose diameter is determined by the width of the function $\exp[-i\,\kappa(x_3^2 + y_3^2)\,l/2\,f_1^2] \otimes P_1(x_3, y_3)\} =$

$$= \int\int_{-\infty}^{\infty} \exp[i\,\kappa(x_2^2+y_2^2)/2l]\,p_1(x_2, y_2)\exp i\,\varphi_2(x_2, y_2) \times$$

$\times \exp[-i\,\kappa(x_2 x_3 + y_2 y_3)/f_1]\,\mathrm{d}x_2\,\mathrm{d}y_2$, which is the result of diffraction of the diverging spherical wave with radius of curvature l by the pupil of the lens L_1.

Because the width of the function $P_1(x_3, y_3)$ is of the order of $\lambda f_1/d_1$ (see Ref. 5), where λ is the wavelength of a coherent light source used for recording and reconstructing of the hologram and d_1 is the diameter of the pupil of the lens L_1, we assume that phase change of the converging spherical wave with radius of curvature f_1^2/l in expression (2) is no more than π within the existence domain of the function $P_1(x_3, y_3)$. In this case we may take the quadratic phase factor $\exp\left[-i\kappa\left(x_3^2 + y_3^2\right)l/2f_1^2\right]$ outside the convolution integral of the function $P_1(x_3, y_3)$ for the region in the plane of the photographic plate whose diameter $D \le d_1 f_1/l$ and obtain

$$u_1(x_3, y_3) \sim \exp[i\,\kappa(x_3^2 + y_3^2)\,(f_1 - l)/2 f_1^2] \times$$

$$\times \{F[\kappa x_3/f_1, \kappa y_3/f_1] \otimes P_1(x_3, y_3)\}.\quad(3)$$

As follows from expression (3), in the above–indicated region we have the Fourier transform of the input function convoluted with the function of an amplitude impulse response of the lens L_2 multiplied by the quadratic phase factor characterizing the phase distribution of the spherical wave with radius of curvature $r = f_1^2/(f_1 - l)$. Therewith, this factor characterizes the phase distribution of the diverging spherical wave for $l < f_1$, and the Fourier–transform extent increases in the plane of the photographic plate with the decrease of the distance l between the lens and mat screen. When $l = 0$, $D = \infty$, because the spatial spectrum of the plane waves scattered by the mat screen is not bounded by the lens L_1. If $l_1 = f_1$, the radius of curvature $r = \infty$, and the spatial extent of the Fourier–transform in the plane of the photographic plate corresponds to the pupil diameter of the lens L_1. When $l_1 > f_1$, the quadratic phase factor in expression (3) characterizes the phase distribution of the converging spherical wave, and the spatial extent of the Fourier transform becomes smaller than the pupil diameter of the lens L_1, decreasing with further increase of the distance between the lens and mat screen. In all above–considered instances the Fourier transform is scaled by one and the same factor $1/\lambda f_1$, and the scale of the amplitude impulse response is identical to that of the Fourier transform of the input function as opposed to the case of the illumination of the mat screen by radiation of diverging or converging spherical wave (see Refs. 2 and 3).

The complex amplitude distribution of the subject field corresponding to the second exposure in the plane (x_3, y_3) of the photographic plate takes the form

$$u_2(x_3, y_3) \sim \int\int\int\int_{-\infty}^{\infty} t(x_1, y_1)\exp i\,\varphi_1(x_1+b, y_1) \times$$

$$\times \exp(i\,\kappa x_1 \sin\alpha)\exp\{i\,\kappa[(x_1 - x_2)^2 + (y_1 - y_2)^2]/2\,l\} \times$$

$$\times p_1(x_2, y_2)\exp i\,\varphi_2(x_2, y_2)\exp[-i\,\kappa(x_2^2 + y_2^2)/2 f_1] \times$$

$$\times \exp\{i\kappa[(x_2 - x_3 - a)^2 + (y_2 - y_3)^2]/2 f_1\}\,\mathrm{d}x_1\mathrm{d}y_1\mathrm{d}x_2\mathrm{d}y_2,\quad(4)$$

where b is the reference wavefront shear due to change in the wavefront tilt prior to the second exposure.

If the condition $\sin\alpha = a/f_1$ is fulfilled, then expression (4) can be brought to a form

$$u_2(x_3, y_3) \sim \exp\{i\,k[(x_3+a)^2 + y_3^2]/2 f_1\} \times$$

$$\times \{\exp\{-i\,\kappa[(x_3+a)^2 + y_3^2]\,l/2 f_1^2\} \times$$

$$\times \{F[\kappa x_3/f_1, \kappa y_3/f_1] \otimes \Phi(x_3, y_3)\} \otimes P_1(x_3, y_3)\},\quad(5)$$

where $\Phi(x_3, y_3) = \int\int_{-\infty}^{\infty} \exp i\,[\varphi_1(x_3+b, y_3) - \varphi_1(x_3, y_3)] \times \exp[-i\,\kappa(x_1 x_3 + y_1 y_3)/f_1]\,\mathrm{d}x_1\,\mathrm{d}y_1$ is the Fourier transform of the corresponding function.

In the employed approximation the distribution of the complex amplitude of the reference wave field during the first and second exposures can be expressed as

$$u_{01} \sim \exp\{[i\,\kappa(x_3^2 + y_3^2)/2\,r] + i\,\kappa\,x_3\sin\theta + i\,\varphi_3(x_3, y_3)\},$$

$$u_{02} \sim \exp\{i\,\kappa[(x_3 + a)^2 + y_3^2]/2\,r + i\,\kappa(x_3 + a)\sin\theta +$$

$$+ i\,\varphi_3(x_3 + a, y_3)\},$$

where θ is the tilt angle of the spatially bounded reference beam to the plane of the photographic plate, $\varphi_3(x_3, y_3)$ is the deterministic phase function characterizing the phase distortions introduced in the reference wavefront by the aberrations of the illuminating optical system.

Let us next take the linear dependence of an amplitude coefficient of hologram transmission on the intensity, and let the hologram be illuminated by a plane coherent wave in the direction of propagation of the reference wave (see Fig. 1*b*). Then the distribution of double–exposure diffraction field in the hologram plane takes the form

$$u(x_3, y_3) \sim \exp - i\,\varphi_3(x_3, y_3)\,\{F\,[k\,x_3/f_1,\ \kappa\,y_3/f_1] \otimes P_1(x_3, y_3)\} +$$

$$+ \exp - i\,\varphi_3(x_3 + a, y_3)\,\{F\,[\kappa\,x_3/f_1,\ \kappa\,y_3/f_1] \otimes \Phi_1(x_3, y_3)\} \otimes$$

$$\otimes \exp(i\,\kappa\,a\,x_3\,l/f_1^2)\,P_1(x_3, y_3)\}. \tag{6}$$

The change in the tilt angle of the illuminating wavefront prior the second exposure results in the shift of subjective speckles in the focal plane[6] of the lens L_1, which is compensated by the displacement of the photographic plate in the above–considered case. Actually because $\Phi(x_3, y_3) \simeq \delta(x_3, y_3)$, where $\delta(x_3, y_3)$ is the Dirac delta–function, it then follows from expression (6) that subjective speckle fields of two exposures with relative tilt angle $\beta = al/f_1^2$ between them coincide in the hologram plane, and information about the phase distortions introduced in the light wavefront by the lens L_1 and about distortions of the illuminating radiation wavefront is embedded in the amplitude–phase distribution of an individual subjective speckle in the hologram plane. It then follows that the interference pattern due to reference wave aberrations is localized in the hologram plane.[1] When the opaque screen p_2 (Fig. 1*b*) with a circular aperture centred on the optical axis is positioned in the hologram plane and the width of an interference fringe in the interference pattern localized in the hologram plane exceeds the diameter of the filtering aperture, the diffraction field in the plane of spatial filtering is given by the expression

$$u(x_3, y_3) \sim p_2(x_3, y_3)\,\{F\,[\kappa\,x_3/f_1,\ \kappa\,y_3/f_1] \otimes P_1(x_3, y_3) +$$
$$+F[\kappa\,x_3/f_1, \kappa\,y_3/f_1] \otimes \Phi(x_3, y_3) \otimes \exp(i\kappa a\,x_3 l/f_1^2) P_1(x_3, y_3)\}, \tag{7}$$

where $p_2(x_3, y_3)$ is the transmission function of the screen with circular aperture.[7]

Let the light field in the back focal plane of the lens L_3 (see Fig. 1*b*) with the focal length f_2 be represented as a Fourier integral of the light field in the plane of spatial filtering. By using the properties of the Fourier transform, we obtain

$$u(x_4, y_4) \sim \{t\,(-\mu x_4, -\mu y_4) p_1(-\mu x_4, -\mu y_4) \exp i[\varphi_1(-\mu x_4, -\mu\,y_4) +$$

$$+ \varphi_2(-\mu x_4, -\mu y_4) + t\,(-\mu x_4, -\mu y_4)\,p_1(-\mu x_4 + a\,l/f_1, -\mu\,y_4) \times$$
$$\times \exp i[\varphi_1(-\mu x_4 + b, -\mu y_4) + \varphi_2(-\mu x_4 + a\,l/f_1, -\mu y_4)]\} \otimes P_2(x_4, y_4), \tag{8}$$

where $\mu = f_1/f_2$ is the scale factor of image transformation,

$$P_2(x_4, y_4) = \int\!\!\int_{-\infty}^{\infty} p_2(x_3, y_3) \exp[-\,i\kappa\,(x_3 x_4 + y_3 y_4)/f_2]\,\mathrm{d}x_3\,\mathrm{d}y_3$$

is the Fourier transform of the transmission function of the screen with circular aperture.

As follows from expression (8), if the diameter D_0 of illuminated spot on the mat screen satisfies the condition $D_0 \le d_1$, then within the region of overlap of images of the pupil of the lens L_1 the identical subjective speckles of the two exposures coincide. It then follows that the interference pattern is localized in the Fourier plane[1] (x_4, y_4). Indeed, if in expression (8) the period of the function $\exp i[\varphi_1(-\mu x_4, -\mu y_4) + \varphi_2(-\mu\,x_4, -\mu\,y_4)] + \exp i\,[\varphi_1(-\mu\,x_4 + b, -\mu\,y_4) + \varphi_2(-\mu\,x_4 + a\,l/f_1, -\mu\,y_4)]$ exceeds the size of a speckle in the recording plane *3* (Fig. 1*b*) determined by the width of the function $P_2(x_4, y_4)$, at least by an order of magnitude,[8] we may take this function outside the convolution integral. In this case a superposition of the correlating speckle fields of two exposures results in the following illumination distribution:

$$I(x_4, y_4) \sim \{1 + \cos[\varphi_1(-\mu\,x_4, -\mu\,y_4) + \varphi_2(-\mu\,x_4, -\mu\,y_4) -$$

$$- \varphi_1(-\mu\,x_4 + b, -\mu\,y_4) - \varphi_2(-\mu\,x_4 + a\,l/f_1, -\mu\,y_4)]\} \times$$

$$\times |t\,(-\mu\,x_4, -\mu\,y_4) \otimes P_2(x_4, y_4)|^2. \tag{9}$$

Expression (9) describes the speckle structure modulated by the interference fringes. The interference pattern has the form of a lateral shear interferogram in fringes of infinite width and characterizes the axial wave aberrations due to the lens L_1, as in Ref. 1, and phase distortions introduced in the illuminating wavefront. In this case, in contrast to Refs. 1, 2, and 3, the sensitivity of the shear holographic interferometer to wave aberrations due to the lens L_1 is the higher, the larger is the distance between the mat screen and the lens, and it is equal to zero at $l = 0$. It is explained by the fact that the tilt angle between the speckle fields of two exposures coinciding in the hologram plane is equal to zero at $l = 0$. If $\varphi_1(-\mu\,x_4 + b, -\mu\,y_4) - \varphi_1(-\mu\,x_4, -\mu\,y_4) \le \pi$ within the region of overlap of the images of the pupil of the lens L_1, the interference pattern for $l > 0$ characterizes the axial wave aberrations due to the lens L_1, as in the particular case of double–exposure recording of the lens Fourier hologram discussed in Ref. 9.

The displacement of the center of filtering aperture in the hologram plane along the x axis within the diameter D results in the formation in the recording plane *3* (Fig. 1*b*) of the interference pattern, characterizing additionally the off–axis wave aberrations due to the lens L_1 (see Refs. 2 and 3) caused by diffraction of the off–axis plane wave (propagating at the angle to the optical axis, for which $\tan\gamma = x_0/f_1$) by the pupil of the lens, where x_0 is the coordinate of the center of filtering aperture along the x axis.

Let spatial filtering of the diffraction field in the hologram plane be performed on the x axis, when the distance from the optical axis is more than $D/2$. Then its distribution at the exit from the filtering diaphragm takes the form

$$u(x_3, y_3) \sim p_2(x_3 + x_0, y_3)\,\exp[i\,\kappa\,(x_3^2 + y_3^2)\,l/2\,f_1^2] \times$$

$$\times \{\exp[-i\,\kappa\,(x_3^2 + y_3^2)\,l/2\,f_1^2]\,\{F\,[\kappa x_3/f_1,\ \kappa y_3/f_1] \otimes$$

$$\otimes P_1(x_3, y_3)\} + \exp[-i\kappa(x_3^2 + y_3^2) l/2\,f_1^2]\,\{F\,[\kappa x_3/f_1,\ \kappa y_3/f_1] \otimes$$

$$\otimes \Phi(x_3, y_3) \otimes \exp(i\,k\,a\,x_3\,l/f_1^2)\,P_1(x_3, y_3)\}\}\,. \tag{10}$$

We represent the light field in the back focal plane of the lens L_2 (Fig. 1*b*) in the form of the Fourier integral of the light field in the spatial filtering plane

$$u(x_4, y_4) \sim P_2'(x_4, y_4) \otimes \exp[-i\,\kappa\,(x_4^2 + y_4^2)\,\mu^2/2\,l] \otimes$$

$$\otimes \{\{\exp[i\,\kappa\,(x_4^2 + y_4^2)\,\mu^2/2\,l] \otimes t\,(-\mu\,x_4, -\mu\,y_4) \times$$

$$\times \exp i\varphi_1(-\mu x_4, -\mu y_4)\}\, p_1(-\mu x_4, -\mu y_4) \exp i\varphi_2(-\mu x_4, -\mu y_4) +$$

$$+ \{\exp[i\,\kappa\,(x_4^2 + y_4^2)\,\mu^2/2\,l] \otimes t\,(-\mu\,x_4, -\mu\,y_4) \times$$

$$\times \exp i\,\varphi_1(-\mu\,x_4 + b, -\mu\,y_4)\}\, p_1(-\mu\,x_4 + a\,l/f_1, -\mu\,y_4) \times$$

$$\times \exp i\,\varphi_2(-\mu\,x_4 + a\,l/f_1, -\mu\,y_4)\}, \qquad (11)$$

where

$$P_2'(x_4, y_4) = \int\limits_{-\infty}^{\infty}\!\!\int p_2(x_3 + x_0, y_3) \exp[-\,i\kappa(x_3x_4 + y_3y_4)/f_2]\, dx_3 dy_3$$

is the Fourier transform of the transmission function of the screen with circular aperture whose coordinates are x_0, 0.

It follows from expression (11) that speckle fields of two exposures coincide. They are identical within the region of overlap of the functions of the pupil of the lens L_1. Let us assume that the period of the function characterizing the phase distortions of illuminating wavefront and the on–axis wave aberrations due to the lens L_1 exceeds the speckle size in the Fourier plane and for small amount of displacement $p_1(-\mu\,x_4, -\mu\,y_4) \mid p_1(-\mu\,x_4 + al/f_1, -\mu\,y_4)$. Then the illumination distribution in the plane (x_4, y_4) (Fig. 1*b*) can be written down in the form

$$I(x_4, y_4) \sim \{1 + \cos[\varphi_1(-\mu\,x_4, -\mu\,y_4) + \varphi_2(-\mu\,x_4, -\mu\,y_4) -$$

$$- \varphi_1(-\mu\,x_4 + b, -\mu\,y_4) - \varphi_2(-\mu\,x_4 + a\,l/f_1, -\mu\,y_4)]\}\, |P_2'(x_4, y_4) \otimes$$

$$\otimes \exp[-i\,k\,(x_4^2 + y_4^2)\,\mu^2/2\,l]\,\{t\,(-\mu\,x_4, -\mu\,y_4) \times$$

$$\times \exp[-i\,k\,(x_4^2 + y_4^2)\mu^2/2\,l] \otimes P(x_4, y_4)\}|^2, \qquad (12)$$

where

$$P(x_4, y_4) = \int\limits_{-\infty}^{\infty}\!\!\int p_1(-\mu\xi, -\mu\eta) \exp[i\kappa(\xi x_4 + \eta y_4)\,\mu^2/l]\, d\xi\, d\eta,$$

$\xi\,\mu^2/\lambda\,l$ and $\eta\,\mu^2/\lambda\,l$ are the spatial frequencies.

Consequently, the interference pattern characterizing the wave aberrations due to the lens L_1 is also localized in the far diffraction zone for the above–considered case of spatial filtering of the diffraction field in the hologram plane. In this case wave aberrations due to the lens L_1 are caused by diffraction of diverging spherical wave with radius of curvature L_1 propagating at an angle to the optical axis, for which $\tan\gamma = x_0/f_1$.

In the experiment the double–exposure lens Fourier holograms were recorded on Micrat–VRL photographic plates with the use of a He–Ne laser at a wavelength of 0.63 μm. As an example, the interference pattern obtained when performing spatial filtering by reconstructing a hologram with a small–aperture laser beam ~2 mm in diameter is shown in Fig. 2.

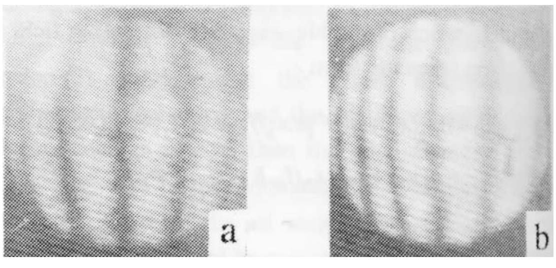

FIG. 2. Shear interferograms recorded when performing spatial filtering in the hologram plane: a) on the optical axis, b) off the optical axis.

The hologram was formed with the help of the lens with a focal length of 180 mm and a pupil diameter of 27 mm. The diameter of quasiplanar radiation beam, used for illumination of the mat screen, was 50 mm. The distance from the mat screen to the lens was equal to 100 mm, and the curvature radius of a diverging quasispherical wavefront of a reference beam in the plane of photographic plate was 405 mm. Prior to the second exposure the photographic plate was displaced by (0.4±0.002) mm and the tilt angle of the illuminating wavefront was changed by 7′40″±10″.

The interference pattern shown in Fig. 2*b* corresponds to the case of reconstruction of the double–exposure hologram at the point located on the axis of displacement of the photographic plate at a distance of 15 mm from the optical axis. In this case the image of the mark in the form of the letter *T* drawn on the mat screen remains at the same position, and illumination is produced by the plane wave bounded by the aperture of the lens L_1 (Fig. 1*a*) and propagating at the angle to the optical axis, for which $\tan\gamma = x_0/f_1$. As a result, in the case of illumination of the mat screen by radiation with quasiplanar wavefront the displacement of the hologram from the laser beam at the stage of its reconstruction leads to the formation of the shear interference pattern characterizing on–axis and off–axis aberrations due to the lens L_1, which are summed with the phase distortions of the illuminating wavefront introduced by the corresponding periphery of the mat screen and its part bounded by the aperture of the lens L_1. It should be noted, for example, that with the use of a negative lens for the double–exposure recording of the Fourier hologram[10] different scales of the Fourier transmission functions of the mat screen and impulse response of the lens due to vignetting of spatial spectrum of waves scattered by the mat screen results in recording of the larger extent of the illuminating wavefront in the Fourier plane in comparison with aperture size of the lens. That gives rise to the constant illumination within larger field–of–view angle.

Figure 3*a* shows the interference pattern when performing spatial filtering in the hologram plane characterizing primarily the spherical aberration in the paraxial focus of the illuminating wavefront within the aperture of the pupil of the lens L_1 (see Fig. 1*a*). In this case the double–exposure hologram was recorded when the mat screen was placed adjacent to the plano–convex lens with a focal length of 250 mm and a pupil diameter of 47 mm, and the radius of curvature of the reference wavefront in the plane of photographic plate was equal to the focal distance of the lens. The displacement of the photographic plate prior to the second exposure was equal to (0.4±0.002) mm, and the tilt angle of the illuminating wavefront was changed by 5'30"±10".

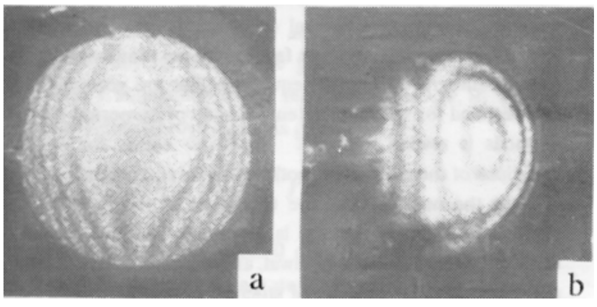

FIG. 3. Shear interferograms characterizing: a) phase distortions of the illuminating wavefront and b) phase distortions of the reference beam.

A characteristic feature of this interference pattern is that it does not alter with displacement of the hologram from the reconstructing laser beam, except that transition from the interference fringe, corresponding to the maximum of the interference pattern localized in the hologram plane and shown in Fig. 3 *a*, to the interference fringe, corresponding to its minimum, results in the change of phase in the filtered interferogram by π, as revealed in the case of formation of the shear interferograms for control of the wavefront based on the double–exposure recording of the lensless Fourier hologram.

Thus, the given theoretical and experimental results demonstrate the formation of the shear interferograms in fringes of infinite width using diffusely scattered fields based on the coincidence of speckle fields from two exposures during recording of the lens Fourier hologram of the mat screen illuminated by the radiation with quasiplanar wavefront. In this case the interference pattern characterizing the wave aberrations due to the lens and phase distortions of the illuminating wavefront, is localized in the far diffraction zone and the spatial filtering is necessary for its recording, while the sensitivity of the holographic interferometer to the wave aberrations is the higher, the longer is the distance between the mat screen and lens.

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