Usage of photorefractive cristals in holographic associative correlators

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ABSTRACT

Photorefractive material have certain prospects for usage in coherent-optical schemes of the optical signal processing. Their values in this aspect are non-linear response to the intensity of signal and variety of temporal characteristics of record and erasure of images, including holographic ones.

In this presentation, questions connected with usage of photorefractive crystals in the holographic correlator with the associative response to fragments of recognised signal were investigated. Particularity of the correlator scheme consist in getting response in the manner of the signal under investigation itself. Due to it, the level of signal identification increases under its associative processing. Use of spatial modulator of signal wave front and photorefractive crystals in the scheme allows to vary a structure of angular spectrum of recorded images when writing the holograms. In certain limits, it gives a possibility to control sensitivity of image as to change of structure of fragments which restore a hologram, keeping stable associative response.

Keywords: photorefractive cristals, hologram, correlator

THEORETICAL BACKGROUND.

In this work particularities of using dynamic photorefractive material in the holographic correlation scheme with the associative response in the form of the full signal under investigation were studied. Main particularity of this scheme consists in eliminating functional differences between signal and reference beams [1]. So, two alike signal beams interfere on the hologram. Reconstruction of the hologram is produced by some fragments of such signal beam. Schemes of record and reconstruction of the hologram for such a correlator are shown on Fig.1A and Fig.1B.

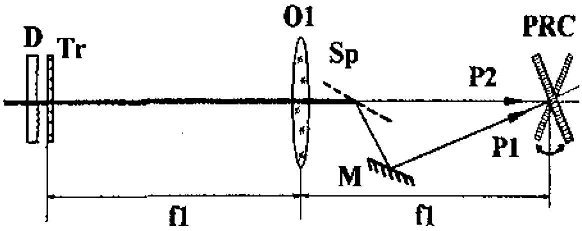

Fig.1A

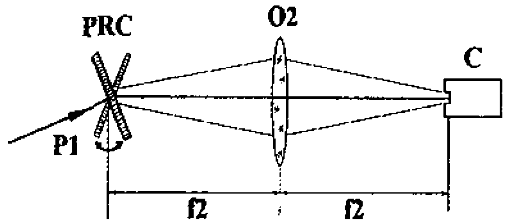

Fig.1B

Let us analyse an equation of hologram for such a scheme. An interference field of two alike, functionally equal signal beams is registered on the hologram. Distribution of their fields at the input of the correlator in plane (x_1,y_1) of location of transparency under investigation **Tr** is described by complex amplitudes $A'(x_1,y_1,t_1)=A''(x_1,y_1,t_1)$, and their angular spectra in focal plane (x_2,y_2) of objective $\mathbf{O_1}$ are presented by complex amplitudes $a'(x_2,y_2,t_1)=a''(x_2,y_2,t_1)$. When reconsructing a hologram by one of the beams, for instance by $A'(x_1,y_1,t_2)$, in focal plane (x_3,y_3) of objective $\mathbf{O_2}$, a holographic copy of other beam is formed:

$$A''(x_3, y_3, t_2) = \hat{F}^{-1}\{a'(x_2, y_2, t_2)\cdot a'^*(x_2, y_2, t_1)\cdot a''^*(x_2, y_2, t_1)\} =$$
$$[A'(x_3, y_3, t_2) * A'^*(x_3, y_3, t_1)] \otimes A''(x_3, y_3, t_1) \approx \delta(0, 0) \otimes A''(x_3, y_3, t_1) \quad (1)$$

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where, accordingly, $*$, $\otimes$, *, $\hat{F}^{-1}$ are operators of correlation, conyolution, complex conjugation and inverse Fourier-transformation; $\delta(0,0)$ is Dirac's function. It appears due to equality of complex amplitudes in square brackets of expression (1).

Let us consider, in what measure expression (1) will be true in the event of inequality of these amplitudes. It corresponds to the case of associative response of described correlation schemes, i.e. to recovery of the hologram by any fragment of signal beam only. We will write a distribution of complex amplitude of signal beam in the manner of sum of separate partial fragments:

$$A'(x_1,y_1,t_1)=\sum_{i=1}^{N}A'_i(x_1,y_1,t_1),$$

$$a'(x_2,y_2,t_1)=\sum_{i=1}^{N}a'_i(x_2,y_2,t_1) \qquad (2)$$

Thus (1) will be written as follows:

$$A''(x_3,y_3,t_2)=\hat{F}^{-1}\left\{\left[\sum^{N}a'_i(t_2)\cdot\sum^{N}a'^*_j(t_1)\right]\cdot\sum^{N}a''_k(t_1)\right\}=$$

$$\hat{F}^{-1}\left\{\begin{vmatrix} a'_1(t_2)a'^*_1(t_1) & a'_1(t_2)a'^*_2(t_1) & \dots & a'_1(t_2)a'^*_N(t_1) \\ a'_2(t_2)a'^*_1(t_1) & a'_2(t_2)a'^*_2(t_1) & \dots & a'_2(t_2)a'^*_N(t_1) \\ \dots & \dots & \dots & \dots \\ a'_N(t_2)a'^*_1(t_1) & a'_N(t_2)a'^*_2(t_1) & \dots & a'_N(t_2)a'^*_N(t_1) \end{vmatrix}_N \cdot a''(t_1)\right\}=$$

$$\left(\begin{Vmatrix} A'_1*A'^*_1 & A'_1*A'^*_2 & \dots & A'_1*A'^*_N \\ A'_2*A'^*_1 & A'_2*A'^*_2 & \dots & A'_2*A'^*_N \\ \dots & \dots & \dots & \dots \\ A'_N*A'^*_1 & A'_N*A'^*_2 & \dots & A'_N*A'^*_N \end{Vmatrix}\right)\otimes A''(t_2) \qquad (3)$$

From analysis of expression (3) follows that the greater contribution of diagonal factors of the matrix is in contrast with contribution of factors with mismatched indexes, the closer a holographic copy of beam $A''(x_1,y1,t_2)$ turns out to be to the source original. Herewith it is necessary to point to the fact that diagonal factors are summed up in coherent way, unlike the others. Consequently, conducting artificial fragmentation of input beam with the help of the spatial modulator - a diffuser **D**, it is possible, to the certain extend, to control correlation of useful and background components in the resulting image. This allows to use smaller and smaller fragment of restoring signal for getting good associative response in the manner of the full signal.

EXPERIMENTAL RESULTS

Using photorefractive crystals in the correlator scheme ensures prerequisites for check of made conclusions. At the expense of record and reconstruction of a hologram in the real scale of time an influence of uncontrolled factors changing the field of the signal beam decreases. Moreover, it is easy to realise its simultaneous registration with the different level of «fragmentation». In our experiments special spatial modulator **D** was used, which consists of ensemble ($\sim10^3$) of round phase scatterers. Optical length of scatterer ensures a field fluctuation delay as to the phase by the value close to π. As a result of modulation, angular spectrum of signal beam gained two components. First component, diffuse one, depends on number and sizes of scatterers. Second component is just the non-diffracted radiation. Herewith, both components are equally subjected to possible change and distortion. Reconstruction of holograms was conducted by fragments of transparency under its partial stopping.

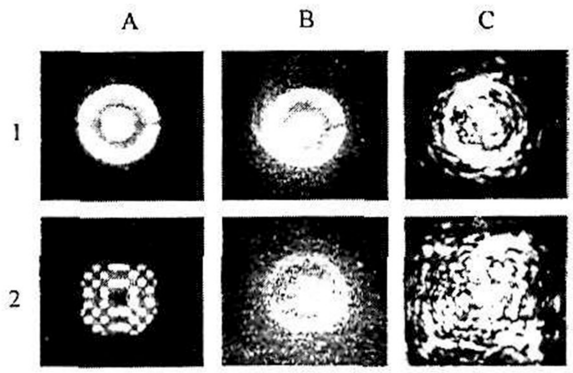

Fig. 2

Results of conducted experiments are illustrated by photographs on Fig.2. In the row A, structures of restoring transparencies are shown with circular and rectangular symmetry. In B and C rows present photographs of restored images which were received for diffuse and non-diffracted components. One can see that complicating the signal beam angular spectrum allows to stabilise associative response in an essential way. In this case fragments of signal field being common for both transparency and modulated by scatterers (~150) participate in the image reconstruction. Reconstruction by such common areas of the field without modulation forms complex cross-correlation field distribution (See Fig.2.2C.). Its structure depends on both transparencies and has nothing in common with the written ring-shaped transparency.

On Figs. 3 and 4 photographs are brought, illustrating associative response of scheme when the sizes of restoring fragment are reduced. A are the images at the readout transparency, B are reconstructed images. One can see that image is certainly identified, up to 90÷97% of stopped-down beam section area.

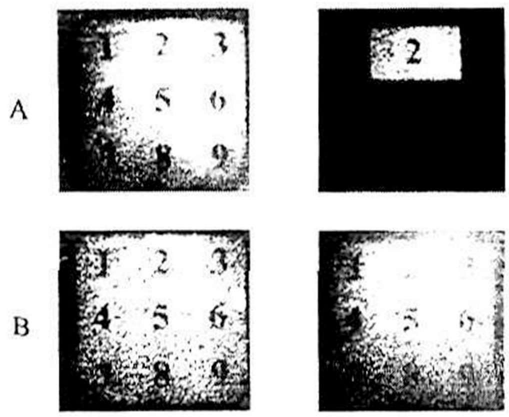

Fig. 3

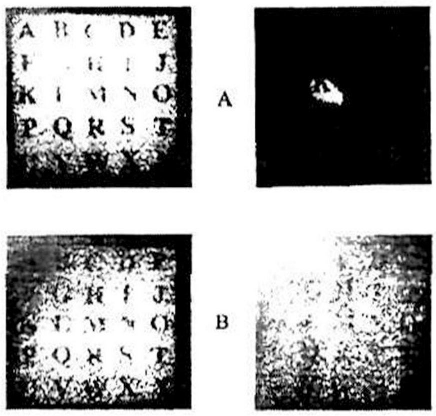

Fig. 4

In our experiments for recording the holograms crystals of lithium niobates were used. Conditions of record do not differ practically from described in previous work [2].

DISCUSSION AND CONCLUSION

Results of this work confirm a good perspective of using the dynamic photorefractive materials in the new type of correlator. A conclusion on possibility of improvement of such schemes as to accuracy is confirmed with their help.

Associative response for complex signal beams is received when using the fragments of sufficiently small sizes.

In this work we did not pay attention to the influence of temporal and energy characteristics of photorefractive crystals on associative response. But we expect that such sort of investigation will be useful when studying the physical processes in photorefractive crystals.

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