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S. N. Koreshev, Yu. A. Cherkasov, I. L. Kislovskiy

The diffraction efficiency of η holograms recorded on photo- /213*
thermoplastic (FTP) layers reaches 20-30% [1]. In a number of actual holographic devices, however, holographic recording is done in digital form, which leads to substantial reduction of η [2]. This article deals with a theoretical and experimental study of η for actual FTP [1] and typical digital holograms.

We shall examine the dependence of the η of a digital phase Fourier hologram of a point object on the amount of deformation Δ and the discrete-structure parameters representing the hologram. Let N be the number of discrete elements representing the hologram (Fig. 1), let d be the digitization time of the hologram, let a be the size of a digital element, and let k be the ratio of the hologram's period to its digitization period.

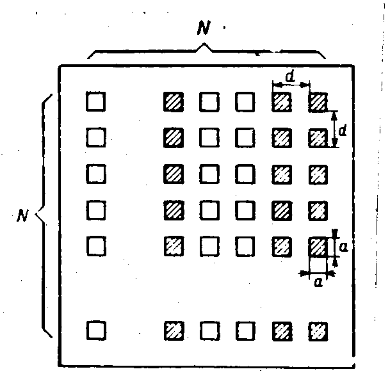

Fig. 1. Structure of digital hologram.

As opposed to the usual outline for calculating η [3], when deriving the transmission function of phase holograms we accounted for transmission of an optical mask, which was used to perform digitization.

In the assumption that the law of phase change for the light passing through the hologram when it is regenerated is identical to the distribution law of illumination intensity in the interference pattern when recording the hologram, η can be described by expression /214

*Numbers in the margin indicate pagination in the foreign text.

$$\eta=\frac{1}{(Nd)^4}\left|\frac{Nkd}{\pi}\left\{d\sin\left(\frac{\pi}{k}\right)-a\sin\left(\frac{\pi a}{kd}\right)\right\}\frac{\sin\left(\frac{\pi N}{k}\right)}{\sin\left(\frac{\pi}{k}\right)}e^{-j\frac{\pi}{k}(N+1)}-\right.$$
$$\left.-N^2a^2I_1\left(\frac{m}{2}\right)\right|^2, \qquad (1)$$

where I_1 is a Bessel function of the first kind to the first power; m is the phase difference of the light perpendicularly striking the hologram and passing through segments of the hologram with maximum and minimum depth of deformation.

Expression (1) describes the η of digital holograms with square digitization elements. Note that if N/k is a whole number, then, considering that $m = 2\pi(n_0 - 1)\Delta/\lambda$, expression (1) can be rewritten as

$$\eta=(a/d)^4 I_1^2[\pi(n_0-1)\Delta/\lambda], \qquad (2)$$

where n_0 is the index of refraction of the FTP; Δ is the amount of deformation; λ is the wavelength of the radiation regenerating the hologram.

Experiments were performed for FTP based on polyvinyl carbazole and trinitrofluorenone charge transfer complexes [1]. For them, $n_0 = 1.496$, the transmission coefficient at $\lambda = 0.488$ μm, at which the hologram was regenerated, was 60%, ratio $a/d = 0.5$, $N = 70\times70$, and $k = 2.5$.

The experimental and theoretical $\eta(\Delta)$ relations are shown in Fig. 2. As the figure implies, both curves are qualitatively the same and described by a curve with a maximum. The maximum value of η, equal to 2% considering transmission, is achieved at $\Delta = 0.56$ μm, η diminishing both upon reduction and increase of Δ. The discrepancy in curve shapes cannot be caused, as estimates revealed, by non-sinusoidal (trapezoidal) profile of deformation on the FTP, and the causes of its appearance remain unclear. It should be /215

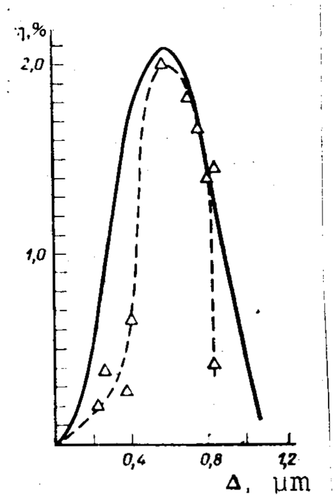

Fig. 2. Dependence of diffraction efficiency η of digital phase holograms on the amount of deformation Δ of FTP: solid line -- theoretical data, broken line -- experimental results.

noted that the obtained value of η is 5 times higher than that for amplitude silver-halide photographic materials [2], which equals 0.2% when recording digital holograms.

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16. Abstract

This article deals with an experimental and theoretical study of the dependence of η of a digital phase Fourier hologram of a point object on the amount of deformation Δ and the discrete-structure parameters representing the hologram. An expression is given for η. Experiments were performed on photothermoplastic layers based on polyvinyl carbazole and trinitrofluorenone charge transfer complexes. The maximum η, 2%, is found at $\Delta = 0.56$ μm.

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