SECTION B

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The Duplicating of Holograms

Further technical development of the holography requires a simple and efficient method of hologram duplicating. The problem is practically difficult in the case of holograms with high spatial frequences registered. On the other hand the duplicating of the holograms with spatial frequencies ranging up to 1000 pair lines may be reduced to elaborating a corresponding technology.

In our paper we have restricted our attention to two basic methods of duplicating a) copying holograms with the help of the contact printing method, b) making replics of the phase holograms in the thermoplastic materials [1].

The photographic contact printing as it was applied by us consisted in making photographic contact copies of an amplitude hologram, the latter being obtained with the use of any well-known holographic method. The light sensitive material used for copying was bromo-silver photographic plate or a photopolymer layer. A condition for achieving a sufficient fidelity was to assure a minimum distance between the hologram surface and the light sensitive material. When applying a vacuum contact the distance obtained was of order of one wavelength. As an illuminator conventional point light sources were used. In this way the copies of both the two-dimentional objects and spatial objects with the reference spatial frequencies being of order of 700 pair lines/mm. An essential point here is the manner of the photochemical of the master hologram, which has to be characterized by great photographic contrast of the holographic microstructure.

The method of the contact printing offers a possibility of processing the holographic information in order to increase the diffraction efficiency of the copy

with respect to the original. If the energetic transmittance of the master hologram is described by

$$T_{e0} = C|R+P|^{-2\gamma} = C(RR^*+PP^*+2R_0P_0 \cos\Psi)^{-\gamma} \qquad (1)$$

where $R(x) = R_0 e^{iax}$ denotes a complex amplitude of the reference beam, $P(x, y) = P_0 e^{iq(x, y)}$ is a complex amplitude of the object beam, Ψ denotes the phase difference between the waves R and P at the given point of the hologram plane, and C and γ are some characteristic constants for a photochemical process taking place at the time of the hologram recording. During the contact printing the transmittance T_{c0} is transformed into the transmittance of the copy T_{ek} by means of a chemical process determined by the constantas C and γ:

$$T_{ek} = C'(T_{eo}I)^{-\gamma'}. \qquad (2)$$

Here, 1 denotes the intensity of the light used for copying.

Assuming as a first approximation that a distance between the master hologram and the light sensitive material is arbitrarily small the diffraction effects occurring during the copying may be neglected and the consideration may be restricted to the energetic transmittance of the copy as determined in [2].

As a result the amplitude transmittance of the amplitude hologram copy may be expressed in the form

$$T_{ak} = [CC'I^{-\gamma'}(PP^*+RR^*+2P_0R_0 \cos\Psi)^{\gamma\gamma'}]^{-1/2}. \qquad (3)$$

During the reconstruction process, when illuminating with the help of a reference beam of complex amplitude S, the light field diffracted on the hologram copy is

$$U = ST_{ak}. \qquad (4)$$

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Fig. 1

Exploiting the linearity condition typical of the holography, i. e. the fact that $|R|^2 > |P|^2$, and expending [3] into series we obtain for the diffracted image beam of the first order

$$U_1 = K\gamma\gamma' SPe^{i\varphi}, \qquad (5)$$

where $K = CC'I^{-\gamma'}$.

As can be seen the intensity of the reconstructed waves may be increased by copying on a material with great γ.

Even greater changes may be introduced to the hologram by contact printing on photopolimeric films resulting in producing phase holograms. In this case

$$T_{ak} = \exp[K(RR^* + PP^* + RP\cos\Psi)^{\gamma\gamma'}]^{1/2}(n-1)k \qquad (6)$$

where n is a index of refraction of the polymer and $k = 2\pi/\lambda$.

The resulting intensity of the reconstructed image wave

$$(U_1)^2 = K^2\gamma^2\gamma'^2(n-1)^2k^2|SPe^{i\varphi}|^2 \qquad (7)$$

may be additionally amplified by using a photopolymer of great n [3].

In the experiments carried out on this occasion also an influence of the nonlinearity of the photosensitive material has been observed resulting in appearance of higher order diffraction in the copy of the master hologram, while the original produced first order diffraction, only.

Duplicating the holograms by making replicas in thermoplastic polymers was realized by thermoplastic treatment. The original hologram was a relief phase hologram. The surface of the hologram was metallised by depositing a gold, silver or aluminium layer in the vacuum. The matrix obtained in this way was used for manifold reproduction of the hologram in the thermoplastic materials. The replicas were phase holograms of relief type. Depending on the thermoplastic material used the phase transmitting holograms may be achieved, which by deposing a thin metal layer may be transformed into reflecting holograms or reflecting-transmitting ones. In Fig. 1 a relief hologram made out of polystyrene has been presented, while in Fig. 2 the reconstructed image received from this hologram is shown.

The method of the matrix reliefing may be difficult to apply when performing holograms with the high spatial frequencies (1000 pair lines/ mm) to be recorded. The quality of the metal layer deposited on the master hologram is also of considerable importance as far as the relief fidelity is concerned. In the case of too thin and nonuniform layers the informa-
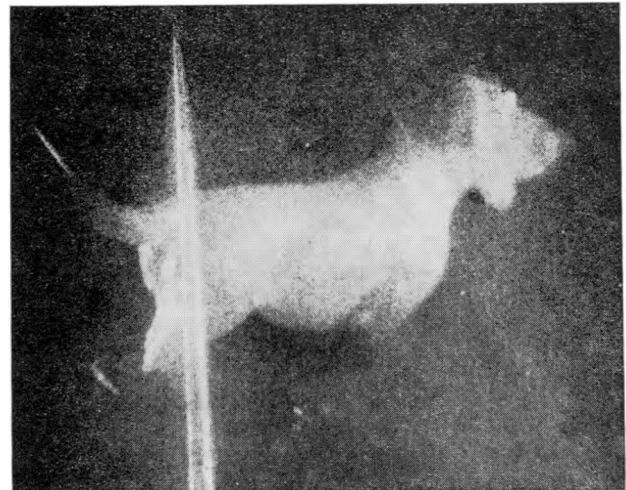

Fig. 2

tion contained in the holograms becomes distorted or destroyed. Next, an important part is also played by the sort of polymer used for reliefing. Its fine-graineness is here essential. The experiments carried out have to be considered as initial phase of the study. The work will be continued.

References

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Reflection Relief Holography

In the paper the results of the examination of the reflecting relief holograms of great diffraction efficiency (when compared with the transmission holograms of both the amplitude and phase type) have been presented. The first mentions about the application of the reflecting holograms [1] concerned the holograms performed in a conventional way, using the bromo-silver materials. To increase the diffraction efficiency on the diffracted light beams travelling backwards, the surface of the holograms was metallized.

In the present paper the relief holograms were obtained with the help of photopolymers. The obtained phase relief holograms were coated with the metal films of different reflection and absorption coefficients and of different thickness. The wave-front reconstruction by reflecting relief holograms takes place when illuminating its surface with a wave $Q = Q_0 \exp(i\varphi)$ and the reconstructed waves U_r propagate in the direction of the light source [2]. The light field reconstructed with the help of hologram may be described by introducing the concept of the amplitude reflectance R

$$U_r = QR \qquad (1)$$

which, when reducing the notation to one dimentional case for the sake of simplicity may be put into the form

$$R(x) = r_a \exp(i\Phi(x)) \qquad (2)$$

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where x denotes a coordinate in the hologram plane and r_a is an amplitude coefficient characterizing the material of which the relief hologram was made. For conductors [3, 4] we have

$$r_a = K^2 \exp i\delta = \frac{n - i\varkappa - 1}{n - i\varkappa + 1} \qquad (3)$$

where K^2 denotes the intensity coefficient of reflection,

δ is a change in the wave phase during reflection on a conductor surface,

$\varkappa$ is the coefficient of the conductor absorption,

n — is the reflection index of the conductor.

The magnitude Φ in formula (2) denotes a change in phase of the incident wave determined by the relief shape containing the holographic information. The relief shape may be described by specifying the relief deepness $d(x)$, which depends on the production technology, the light intensity distribution of the interference field in the hologram plane and the kind of photochemical process applied to registration (Fig. 1).
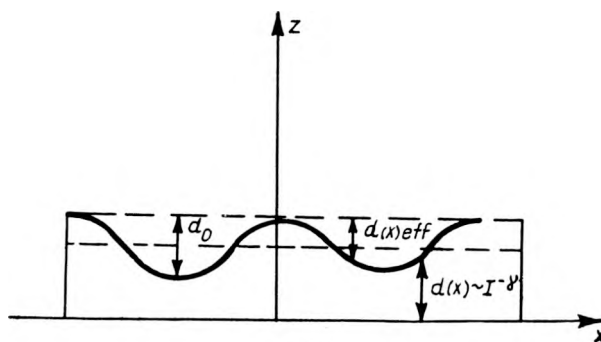

Fig. 1