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Imperfections of Photographic Plates and Influence on Storage Capacity of Holographic Memories***

Significant variation in plate thickness, leading to widening and shift of point spread function, was found by measuring transfer properties of normal (A-glass) and special (U-glass) photoemulsion substrates of Scientia 10E75 8E75 plates. It has been shown that by proper choice of page size no significant loss occurs in the storage capacity of a holographic memory.

When reconstructing a hologram the object beam passes through the glass holder of the developed photoemulsion and the substrate becomes a part of the optical imaging system. Science this glass plate is not optically flat its thickness varies, the plate becomes the weakest part of the system and the resolution of the image is mainly determined by aberrations caused by the plate.

We examined the well known holographic materials Gaevert-Agfa types 8E75 and 10E75. The normal A-glass photoplates are produced without any guarantee for flatness, while the special U-glass photoplates are produced with a maximum deviation from flatness of 5 μm/inch, which seems to be a very good tolerance for a mass-produced plate, 1.2-1.4 mm in thickness.

A small part of the plate can be considered as a wedge of angle δ, and a ray passing through this area is defected by an angle

$$\theta = (n-1)\delta,$$

where n stands for the refractive index of the glass. Due to the variation in thickness, the rays passing through different parts of the plate are scattered and a spread effect occurs.

The scattering was measured by using the arrangement shown in Fig. 1. The intensity distribution on the image of a pinhole was scanned without introducing a glass plate into the optical path (dashed marginal rays); thereupon a plate, from which the emulsion has been removed, was introduced behind the lens (solid lines). Figures 2 and 3 represent the measured intensity distributions for 8E75, 10E75, respectively. The circles around the origin correspond to the equiintensity curves in the unperturbed image of the pinhole, being illuminated by a Gaussian beam of diameter less than that of the pinhole. The irregular curves show typical intensity distributions for both types of plate measured for a surface

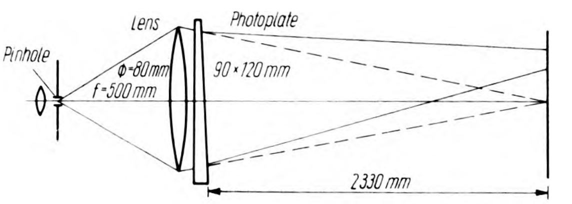

Fig. 1

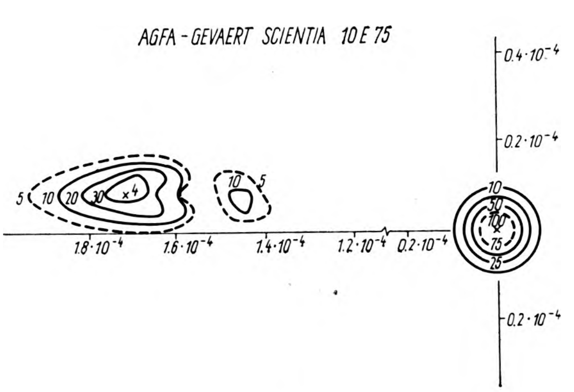

Fig. 2

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80 mm in diameter. The values outside the curves are proportional to the intensity.

It can be seen that a plate causes an average shift of the image, and, moreover, a relatively wide angular spread around the average. However, one should not be mistaken by the first impression, i.e. that the spread is considerably smaller than the average shift. This average varies from plate to plate and it is impossible to make predictions on the average wedge-angle. (The measured angle for U-glass plate was found to be that guaranteed by the manufacturer.)

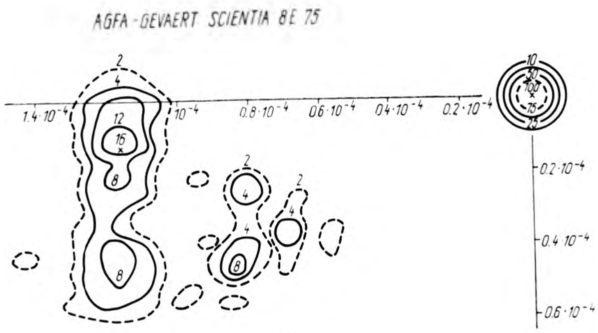

Fig. 3

Generally, the resolution of the holographic image is significantly reduced by the plate imperfections, as the angular resolution of an 80 mm aperture, being 10^{-5} radians, is less by an order of magnitude than the distortion introduced by the plate. When simultaneously exploiting the whole surface of the hologram the transmission of the reconstructed object beam via the plate is to be avoided; thus, either reflection holography should be used or the geometry applied such that both the reference and reconstruction beam impinqe on the rear side of the plate.

For a holographic memory the difficulties can be overcome by the page organization. When recording the content of the data mask containing N_1 bits, we use only a small area (i.e. a subhologram) of linear size defined by the resolution demands [1]:

$$\frac{d_1 d_2}{\lambda f} \geqslant 2,$$

where d_1 is the line ear size of a bit and d_2 is the same for the subhologram, λ is the wavelength and f the focal length of the Fourier transform lens (see Fig. 4). The plate is then covered by subholograms lying side by side, produced by the proper choice of the direction of the light wave illuminating the data mask. Denoting the number of subholograms by N_2, the total capacity being $Q_{id} = (N_1 N_2)^2$ can be expressed as a function of the linear aperture A and focal length of the Fourier transforming lens [1]. For the ideal case

$$Q_{id} = \frac{1}{64} \cdot \frac{A^4}{\lambda^2 f^2}.$$

In the absence of aberration the hologram could record the same amount of information in the following two cases:

1. when the data mask contains all the information simoultaneously (i.e. when $N_1^2 = Q_{id}$ and the number of subholograms is $N_2 = 1$) or

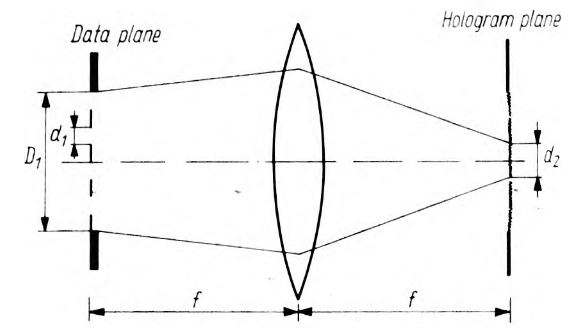

Fig. 4

2. when the data mask contains only one bit of information (covering, of course, the whole surface of the mask) and the bits are registered succesively (i.e. $N_1 = 1$ and $N_2 = Q_{id}$).

In reality there are limitations restricting the freedom of choice of the number of bits on the data mask, furthermore, there is also a need for introducing safety strips between bits on the data mask and subholograms [2]. For the case of the aberrations introduced by the photoplate it should be borne in mind that the retrieved data page may be randomly shiften in the detector plane by a distance up to $\pm \theta_{\max} f$.

To avoid crosstalk between the detectors a safety strip of width

$$\Delta_1 = 2\theta_{\max} f$$

is introduced between bits and the capacity decreases to

$$Q = Q_{id}\left(\frac{d_1}{d_1 + \Delta_1}\right)^2.$$

Taking into account, that the number of bits on the data mask of linear size D_1 is now

$$N_1 = \frac{D_1}{d_1 + \Delta_1}$$

we get for the capacity

$$Q = Q_{id}(1 - 2\theta_{\max}\frac{f}{D_1}N_1)^2.$$

The capacity does not depend symmetrically on N_1, and N_2; the optimal case would be one bit/page. However, the loss due to the plate aberrations for $\theta_{\max} = 10^{-4}$ and $f/D_1 = 4$ does not exceed 10%, unless $N_1 \geq 10^2$.

A page content of $N_1^2 = 10^4$ seems to be satisfactory from the practical point of view.

Taking into account the distortion of the plate the question arises as to whether the requirements for the transforming lenses of the optical system could not be made less exacting.

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Thanks are due to Mr. F. Király for his valuable help in carrying out the experiments.

Imperfections des plaques photographiques et leurs effets sur la capacité des mémoires holographiques

Lors des mesures des propriétés du transfert normal (verre A) et spécial (verre U) du support des plaques Scientia 10E75,8E75 on a constaté les effets des changements d'épaisseur de la plaque provoquant un élargissement et un déplacement de fonction d'affouillement locale. On a prouvé qu'il n'y a aucunes pertes de capacité de mémoire holographique si le format de la plaque est bien choisi.

Несовершенство фотопластинок и их влияние на ёмкость голографических помятей

Влияние изменений толщины пластинки, приводящее к расширению и смещению точечной функции размытия, было выявлено во время измерений свойств нормального (стекло A) и специального (стекло U) основы пластинок Scientia 10E75,8E75. Доказано, что при соответствующем подборе формата пластинки не происходят никакие существенные потери ёмкости голографической памяти.

References

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