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Recording of the pseudo- and orthoscopic images of the same resolution in one hologram by using the rainbow holography technique

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1. Introduction

The rainbow holography has been proposed by BENTON [1] as a two-step method of holographic image recording. This technique renders the possibility of obtaining the high quality reconstruction also when the monochromatic radiation is used. The method due to Benton involves the recording of a real image reconstructed from the so-called primary hologram, while the plane of the recording medium should coincide with the plane of the recorded image. Here, the presence of a long narrow slit restricting the object beam during the reconstruction of the primary hologram and simultaneous recording of the rainbow hologram constitutes the main idea of the method since this slit is also recorded on the rainbow hologram and during the reconstruction its image plays the role of the entrance pupil of the optical system used to the observation of the reconstructed optical wave field. Therefore, a sharp and monochromatic image may be obtained also when white light is used. Obviously, the width of the slit influences the image quality. The suitably chosen slit allows to reconstruct the image without spectral washout and for the minimized speckling effect [2].

2. Critical remarks on the restriction of the single-step technique of rainbow hologram production

The recording of the object field by using the method suggested by Benton is rather laborous since it requires making two separate holograms. A simpler method is to record optical image obtained with the help of an optical system, for instance, a single lens or objective [3]. In this case the slit should be placed in front of the system. Depending on its position either orthoscopic or pseudoscopic recording geometry may be realized (Figs. 1 and 2, respectively).

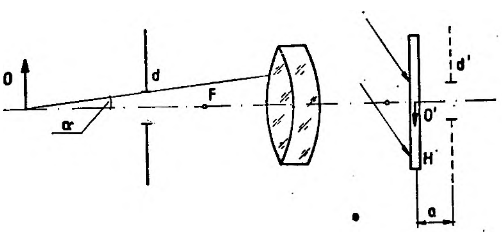

Fig. 1. A single-objective system to record the rainbow holograms in orthoscopic geometry. O – object, O' – image, d – slit, d' – its image, a – distance from the slit image to the object image, α – object aperture angle, F – focus, H – hologram

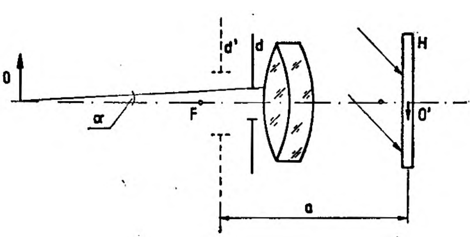

Fig. 2. Recording of the rainbow hologram in the single-objective system of pseudoscopic geometry. Notation is analogous to that in Fig. 1

If $\Delta O'$ denotes the minimum distance resolved by the optical system with a slit it is easy to show that

$$\Delta O' = \frac{1}{2}\frac{\lambda}{\alpha}, \ \sin\alpha \cong \alpha \tag{1}$$

where λ is the wavelength, and α is the aperture angle in the object space. Obviously, the greater is the angle the higher the resolving power of the system. By expressing the angle α by the system's parameters such as the distance s of the object from the lens, the distance a of the exit pupil from the image plane and the focal length f, the formula (1) may be written in the following form

$$\Delta O' = \frac{a(s-f)\lambda}{d'f}. \tag{2}$$

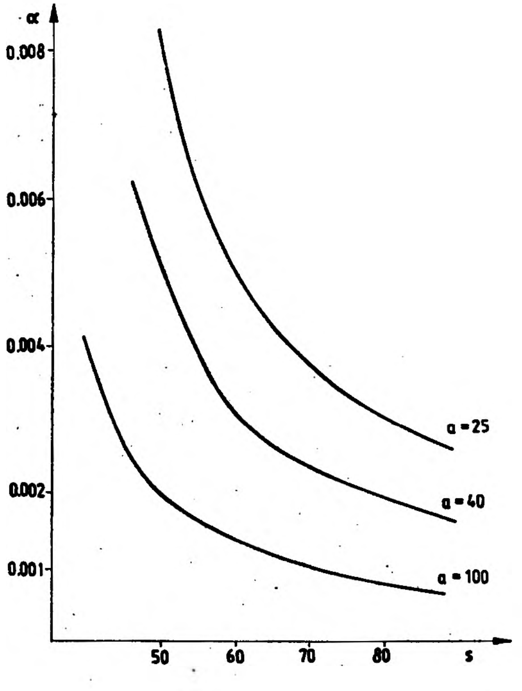

Fig. 3. Dependence of the object aperture angle on the distance of the object from the lens for different distance of the exit pupil plane from the object plane

In Figure 3a graph describing the dependence of the angle α on the distance of the object from the lens is given for different values of the exit pupil distance from the image plane. From the graph it follows univocally that for a given distance s the resolving power is greater for less values of a. It should be noticed that the parameter a is essential since it determines not only the distance between the exit pupil and the image planes at the recording stage but also the distance between the plane of the reconstructed image and the exit pupil of the observation system during the reconstruction. From the geometry of the systems presented in Figs. 1 and 2 it follows that this parameter may not be chosen arbitrarily small in a pseudoscopic system and therefore the pseudoscopic images are characterized by lower resolution when compared to the orthoscopic ones. In particular in a single-objective system we are not able to record the pseudoscopic and orthoscopic images of the same magnification and the same resolution [4].

3. A modification of the single-step method allowing the recording of ortho- and pseudoscopic images of the same magnification and resolution on one hologram

Since, for recording the pseudoscopic rainbow holograms in a single objective system it is possible to achieve such resolution as it would be the case for orthoscopic version of the system we suggest a modification of the single-objective system. The model of the optical system presented below consists of two equal objectives forming an afocal optical system. Thus, the system considered offers magnification 1:1 all along the optical axis. The slit may be moved between those objectives. If it happens to be placed behind the first objective but in front of its image focus the recorded image will be of orthoscopic nature. By shifting the slit outside the focal plane closer to the other objective the geometry will be changed to the pseudoscopic one.

It may be seen that it is easy to record the pseudoscopic and orthoscopic images of the same resolution by using the new optical system. It suffices to locate the object in the focus and the slit immediately behind the first objective (Fig. 4), then an orthoscopic image will

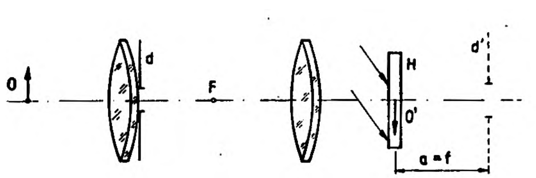

Fig. 4. Recording of the orthoscopic rainbow hologram in an afocal optical system

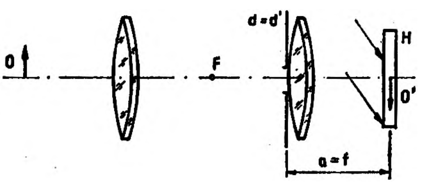

Fig. 5. Recording of the pseudoscopic rainbow hologram in an afocal optical system

be recorded in the plane of the hologram positioned at the image plane of our system. By leaving the position of the object unchanged but shifting the slit to the position immediately in front of the second objective an image of pseudoscopic geometry will be recorded on the same hologram (Fig. 5). In both the case a plane reference wave is used, its incidence angle being changed between the exposures in order to separate spatially the images of the slits.

Let us notice, however, that in both the cases the distance of the image plane from the exit pupil plane of the system is the same and equal to the focal length f. The value of the object aperture angle depends only upon the distance between the exit pupil and the image plane as well as upon the width of the exit pupil

$$\alpha = \frac{1}{2}\frac{d'}{a}. \tag{3}$$

Thus, in our case it is expressed by the formula

$$\alpha = \frac{1}{2}\frac{d'}{f}, \tag{4}$$

which is valid for both the orthoscopic and pseudoscopic versions.

4. Conclusions

The suggested two-objective afocal system of 1:1 magnification enables to record in a simple way both ortho- and pseudoscopic holograms. Both the images recorded are characterized by the same resolution. In particular, two object fields may be recorded on one hologram. When the white light beam of incidence identical with that of the reference beam applied

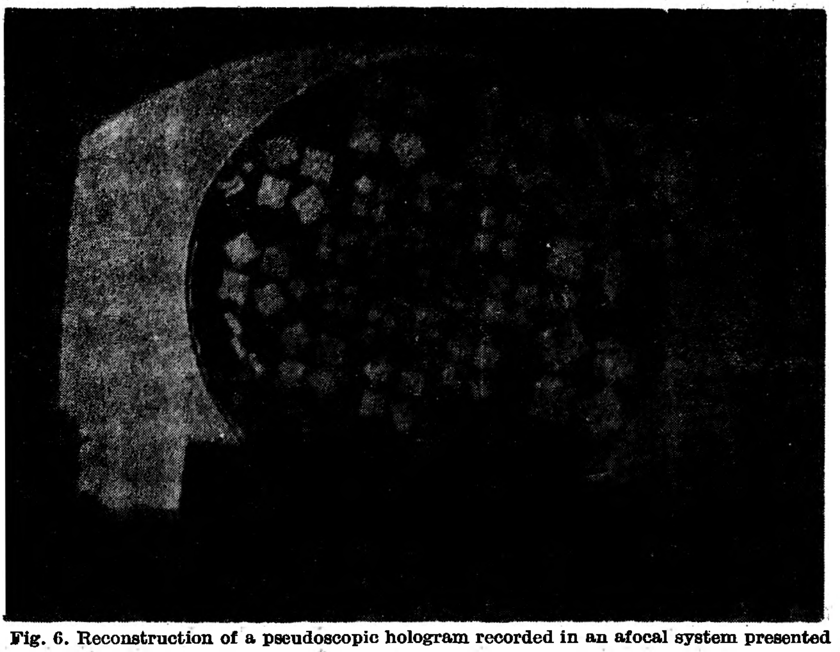

Fig. 6. Reconstruction of a pseudoscopic hologram recorded in an afocal system presented in Fig. 5 by using a white light beam. The object was a linear resolving-power test of geometric progress. On the same hologram a Siemens test was recorded in orthoscopic geometry, which may be observed when changing the angle of observation

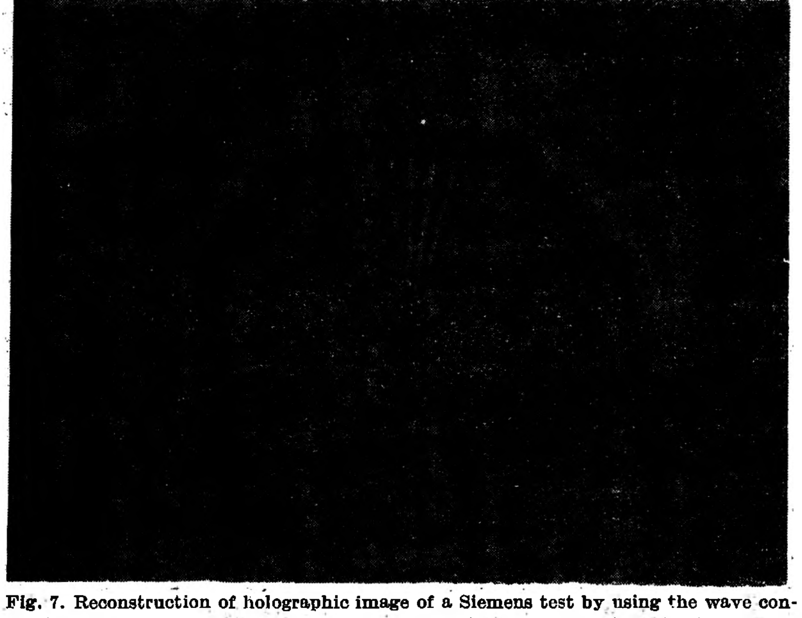

Fig. 7. Reconstruction of holographic image of a Siemens test by using the wave conjugate with respect to the beam recording the pseudoscopic image. Since the test was recorded in orthoscopic geometry (Fig. 4) no real image of the slit corresponding to the exit pupil in this geometry will appear during the reconstruction with the beam described above. Hence, the reconstructed image is spectrally washedout. Obviously, by changing the reconstructing wave to that identical with the reference wave applied during the reconstruction of the orthoscopic image the situation is opposite, i.e., the orthoscopic image becomes monochromatic, while the pseudoscopic one is spectrally washedout

during recording of the orthoscopic image is used for the reconstruction an image of good quality is obtained with no spectral washout. By rotating the hologram by 180° or by applying the wave being conjugate with respect to the reference wave a pseudoscopic image is also of good quality and undisturbed by the spectrally washedout orthoscopic image which is reconstructed simultaneously. This means, that for a given reconstructing beam two images are obtained of which one is monochromatic, while the other spectrally washed out. Obviously, the first is orthoscopic and the other pseudoscopic, while they do not perturb each other (see photos – Figs. 6 and 7).

References

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