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Letters to the Editor

On a possible application of one-step pseudoscopic rainbow holography to interferometric examination of phase objects

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In a double-exposure holographic interferometry two wavefronts, corresponding to the object states during the first and the second exposure time, are simultaneously reconstructed. Then the localization of the interference fringes becomes an essential problem since they need not be positioned at the image plane. Then, the fundamental role being played by the entrance pupil of the optical system used for the observation. In the case of a large pupil it may happen that the reconstructed image will be seen sharply, while the system of interference fringes carrying the information about the changes in the object under test occurring between the exposures may be weakly seen [1]. In particular, if the observing pupil is infinite no interference fringes may be observed [2].

Therefore, it is important to restrict the angular extention of the beams forming the images of particular points of the object. This problem is solved in a somehow natural way in a rainbow holography [3]. The rainbow holography is a technique of the wavefront recording and reconstruction in a way similar to that used in the image-plane-holography [4]. The basic feature distinguishing it from the image-plane-holography is the presence of a long narrow slit in the optical system used to produce the image of an object examined.

A single-objective system to produce pseudoscopic rainbow holograms is shown in Fig. 1.

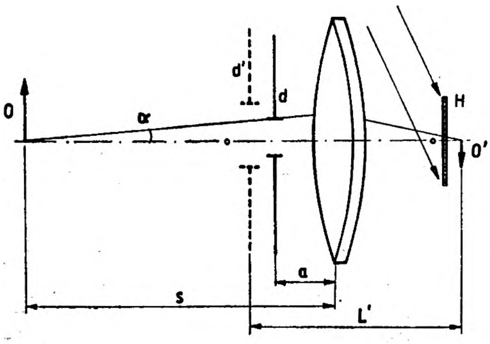

Fig. 1. Single objective system to produce the pseudoscopic rainbow holograms: O – object, O' – image, d – width of the slit, d' – width of the slit image, s – distance from the object to the system, a – distance from the slit to the system, L' – distance from the exit pupil of the system to the image plane, α – object aperture angle, H – hologram

If the plane of the recording medium overlaps the image plane of the optical system then, during the reconstruction performed with a beam conjugate with respect to the reference beam, both the image of the object in the hologram plane and the real image of the slit are obtained. The distance between the hologram and the real image of the slit during the reconstruction is identical with the distance between the image plane and the virtual image of the slit during the recording. If in the optical system (Fig. 1) a double exposure hologram is recorded, then the localization of the interference fringes becomes very easy, due to the presence of the slit image which constitutes the pupil of the observation system and also due to the fact that these fringes are located at the plane of the reconstructed image of the object under test. Another advantage offered by the rainbow holography, as applied to the interferometric examinations, is the possibility of obtaining the white light reconstruction in which the image is free of speckling effects confusing usually the analysis of the results obtained at coherent light reconstruction. For instance, if the movement of a body in one direction is recorded in one colour, its movement in another direction may be recorded in another colour on the same hologram [5, 6].

The rainbow holography may be also applied to the interferometric examinations of phase objects. The images reconstructed with a white light beam are of the highest brightness, while the interference fringes localized in the image plane are of good contrast.

It is easy to show [7] that the aperture angle in the system from Fig. 1 is given by the following formula

$$a = \frac{d'}{2}\,\frac{f}{L'(s-f)}$$

where f is the focal length of the objective, s is the distance of the object from the system, d' is the width of the slit image which occurs at the distance L' from the image of the object. Thus, it may be seen that the aperture angle is inversely proportional to the distance L' The greater the distance, the lower the resolution of the reconstructed images. When completing the single objective system by adding another objective, so that they both create an afocal system, it is possible to obtain the images of higher resolution [7]. The new system offers the advantage that it produces a constant magnification for all the points of the spatial object, in contrast to the single objective version of the system for which each cross-section of the examined three-dimensional object is imaged with another magnification depending on its position along the optical axis. The scheme of such a system working at the 1 : 1 magnification is shown in Fig. 2. The object is placed at the distance s from the additional objective, while this distance must fulfil the following condition:

$$s \leqslant 2f.$$

The image occurs then at a distance s' from the second objective and the following dependence is satisfied

$$s' = 2f - s.$$

The afocal system considered above may be used with success to visualize the refractive

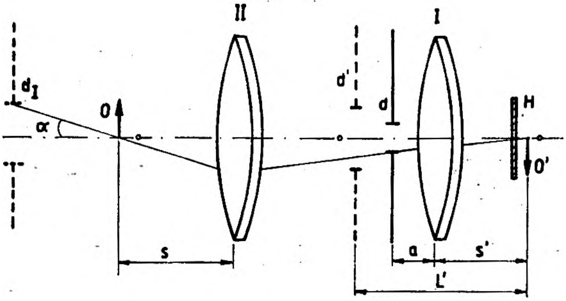

Fig. 2. Scheme of an afocal two-objective system to record pseudoscopic rainbow holograms working at 1 : 1 magnification: O – object, O' – image of the object, s – distance of the object from the additional objective II, s' – distance of the image from the objective I, a – distance of the slit from the objective I, d – width of the slit, d' – width of the exit pupil, d_I – width of the entrance pupil, L' – distance of the exit pupil from the image plane, a – object aperture angle, H – hologram

index distribution in transparent media. The optical system shown in Fig. 3 produces the 1 : 1 magnification. The slit is located immediately behind the objective and the hologram is recorded in a pseudoscopic geometry. The object is placed in the focal plane of one objective while the image appears in the focal plane of the other one. It is worth noting that the distance L' is equal to the focal length f, while in the case of a single objective it is always greater than f. The aperture angle in the system from Fig. 3, presented as a function of magnitudes being of our interest, is defined as follows:

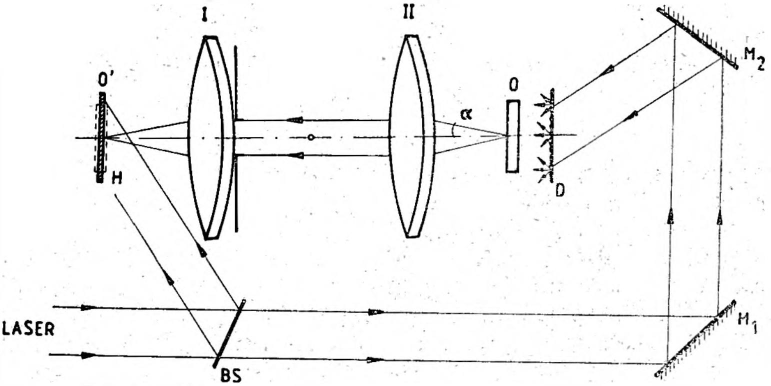

Fig. 3. Application of the system from Fig. 2: O – object examined (located at the object focal plane of the additional lens II), O' – its image. Slit located immediately before the objective I. BS – beam splitter, M_1, M_2 – mirrors, D – diffusing plate, α – object aperture angle ($\alpha = d/2f$)

$$\alpha = d'/2L'.$$

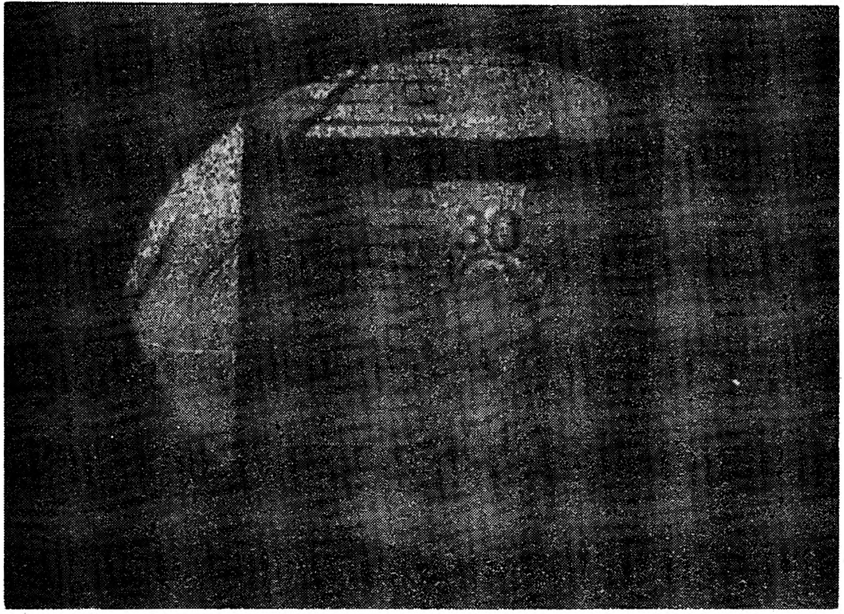

Fig. 4. Visualization of the turbulence in the pot with water of room temperature after throwing a piece of ice into water. A pseudoscopic double-exposure hologram was produced at 10 s time interval between the exposures. The reference wave was plane, while the reconstructing white light beam was divergent

Since in this case L' may be less than that in the single objective version, the recorded image is of much higher resolution.

The photograph (Fig. 4) presents the results of an experiment made in a system analogical to that shown in Fig. 3. This is the reconstruction in white light of pot filed with water of room temperature, into which a piece of ice was thrown and which was recorded on a double exposure rainbow hologram. The exposures were taken at 10 s time interval. As it may be seen the afocal system may be successfully used to visualize the turbulence in fluids.

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