Pseudocolor reflection hologram properties recorded using monochrome photographic materials

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Geometry analysis of pseudocolor holograms was carried out. Color shift of reconstructed light emission and relative image brightness dependance on emulsion expander content was defined.

1. INTRODUCTION

At present the problems of design and technology to obtain multicolor holograms are thoroughly investigated. In result high quality holograms are being made[1]. However to record a multicolor hologram is still a complicated technological problem. The main reason is the lack of commercially available photographic materials and multicolor lasers used in multicolor holography. The possibility to obtain a multicolor holographic image could be provided by a reflection hologram property to change the reconstructed image color together with hologram layer thickness change in the process of photo chemical development[2]. This way is of primary practical value for art holography, because various attractive color compositions could be made. The color of a hologram recorded in such a way is artificial. It differs from a real color of a real object. That is why such holograms are called "pseudocolor" ones.

They could be made both by means of rainbow holograms and reflection holograms. One can use one-stage and multi-stage techniques as well.

The present paper describes the three-stage production technique of pseudocolor reflection holograms

For photomaterial commercially produced PFG-03 plates were used. The idea to obtain a pseudocolor hologram is realised in superimposing of several multicolor holograms reconstructed by one and the same light source. These sub-holograms could be recorded either on one hologram or on two holograms sticked together afterwards. Before being recorded each subhologram is subjected to processing in plastificator solution to make emulsion layer thickness change. As an emulsion expander triethanolamine and glycerol are commonly used. After the processing the photographic plate is dried, exposed and developed as a typical monochrome hologram.

Reconstruction wavelength change of each subhologram as referred to record wavelength takes place because of emulsion layer shrinkage. That is one of the reasons of reconstructed image shift as to recorded object. The images reconstructed by separate subholograms will be also shifted in relation to each other. The total image will have washed-out spectrum outlines.

2. GEOMETRY ANALYSIS OF PSEUDOCOLOR HOLOGRAMS

On the basis of measurement method[3] we could define image positions reconstructed by subholograms. The record and reconstruction diagram is shown in Fig. 1. The object has a form of parallelepiped protruding by a half in front of a hologram plane. Fig. 2 shows two images calculated at conjugated reconstruction of pseudocolor hologram. Image I was obtained at $\mu = 1$ and is a precise copy of an object. Image II was obtained at $\mu = 0{,}79$ ($\mu = \lambda_C/\lambda_R$ = 514 nm /647 nm/. Although reconstruction source position conforms to reference source position the image obtained is rather distorted by shrinkage. The distortions could be diminished while changing the reconstruction source position. In this example the image is reconstructed with a good precision at x, y coordinates when reconstruction source position is C : R_C = 120 cm, α_C = = -40° (reference source position R:R_R = 162 cm, $\alpha_R \cong -56°$, see Fig.1). However at z - coordinate the image looks extended, Fig. 3.

As a result one can monitor the positions of reconstruction and reference beams. Doing that one can compensate image distortions reconstructed by pseudocolor hologram at x, y coordinates. In this case the matching of images could be rather satisfactory for visual attraction. There are some difficulties in the parasite interference elimination. This caused by Brewster angle deflection in reference beam while "red" subhologram recording. Image distortions at z - coordinate have to be compensated in some other way; e.g. special preparation of the object.

Using both two-stage and three-stage production technique of pseudocolor holograms one has to keep in mind their specific feature. This being a viewing angle defined by a master-hologram position. Wavelength difference during subhologram reconstruction process influences these certain viewing angles position also.

Fig.4 shows viewing zones of composite holograms at reconstruction source position R = 1 m, α_C = 56°. Dotted line shows master-hologram position. The measurements prove that limited viewing zone of pseudocolor hologram is caused by incomplete matching of composite zones. Hence it is recommended to use either large square master-holograms or to find the most advantageous position for a hologram to look at.

3. EXPERIMENT

The above pseudocolor hologram features have to be investigated in detail. That should help to find a reasonable compromise between the color effects and distortions of the restored image. Quality analysis shows the advantages of three-stage production technique while using master-holograms of transmissive and reflective types.

For the purpose to make this technique perfect some test experiments were made. The method[4] used was to record test mirror holograms and to measure DE and spectrum of the reconstructed image. Test holograms of two groups, four in each one were investigated. The first group was processed before the exposure in water-alcoholglycerol mixture of various concentration (3, 6, 9, 12%). Every type of mixture was used to process one test photoplate. The second test group was first subjected to exposure 1 then processed in the same way as the first group and then subjected to exposure 2. The exposure was made by He-Ne laser at 633 nm wavelength, the development solution was GP-2 and fixing solution was of an acid type.

Color measurements of reconstructed luminance for the first group of test holograms are shown in Fig.5. The resulting experimental dependance could be approximated by an empiric formula which puts reconstruction wavelength λ_I together with the glycerol consentration Γ in %

$$\lambda_I = 613 - 6{,}65\Gamma$$

Using color zones at Fig.5 one could choose in advance a glycerol consentration necessary for the desired color effect.

The second test group measurements are given in Table I. The table describes holographic image features obtained by mixing two colors. The latter were superimposed on a layer of two exposures. It should be said that the number of exposures diminisches DE. DE of the first record is considerably higher than the second one, etc. However as referred to measurement precision tolerance total DE remains constant.

The user is interested mainly in the brightness of a reconstructed image. It is influenced both by hologram DE and wavelength λ_I of reconstructed image.

Table II gives the measurements of brightness perception ratios of various reconstructed components. They were taken with respect to an eye curvature for exposure (3+2) mJ/cm^2 with a higher DE. The table shows relative brightness degradation for short wavelength component when glycerol content increases. The degradation is slower of the DE fall.

Shortening the time of the first exposure one can make brightness ratio for short and long wavelength components better. This ratio could be considered as being near to the optimum for pseudocolor holograms processing technique at glycerol content 6+9%.

4. CONCLUSION

The development prospects of pseudocolor holography, in our opinion, depend on the solution of complete matching of reconstructed color-image components. It would be recommended to use for pseudocolor holograms highly effective processing materials including dichromated gelatin.

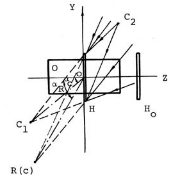


Fig.1. Record and reconstruction diagram of pseudocolor holograms

R - reference source, O - object(or a real image reconstructed by a master-hologram), H_o - master-hologram, C, C_1, C_2 - reconstruction sources

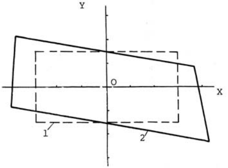


Fig.2. Image distortion at emulsion layer thickness variation between hologram record and reconstruction stages

$1 - \mu = 1;\ 2 - \mu = 0.79$

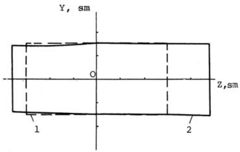


Fig.3. Image correction at reconstructing source shift

1 - object position, 2 - image position

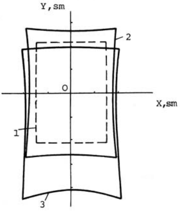
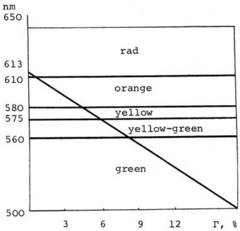


Fig.4. Viewing zones separation of pseudocolor hologram

1 - master-hologram position
2 - viewing zone of red image
3 - viewing zone of green image



;.5. Reconstructed light flow wavelength and reconstructed image color dependence on glycerol concentration

Table 1

Two-stage recording technique of test holograms

glycerol concentration, %	$E_1 + E_2$ mJ/sm	λ_1 nm	λ_2 nm	η_1, %	η_2, %	η_Σ, %
6	3+2	617	584	22	10	32
	3+4	609	597	18	5	23
9	3+2	611	555	22	7	29
	3+4	606	550	17	2	19
12	3+2	617	544	26	4	30
	3+4	616	537	18	6	24

Table 2

Component brightness ratio of reconstructed image at two-stage recording technique

glycerol concentration, %	λ_1, nm	λ_2, nm	V_1	V_2	$V_1:V_2$	$\eta_1:\eta_2$	$B_1:B_2$
6	617	584	0,42	0,82	1:2	2:1	1:1
9	611	555	0,49	1,0	1:2	3:1	1,5:1
12	617	544	0,42	0,98	1:2,3	1:6,5	3:1

V_1; V_2 - visibility factors for λ_1; λ_2 wave lengths, respectively

B_1; B_2 - relative brightness values of reconstructed light flow: $B_1=V_1\cdot\eta_1$ $b_2=V_2\cdot\eta_2$

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