Multicolour holography: a comparative study

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ABSTRACT

A multicolour holography study case will be presented with emphasis on colour control in different silver-halide materials. It has been systematized in order to compare the results obtained with Agfa 8E 75HD to those with Slavich PFG-01. Some experiments were made and the emulsion was manipulated before exposure to achieve high quality multicoloured white light reflection holograms. This work has therefore been developed in order to obtain the various colours in a very well controlled way.

Keywords: colour control; emulsion thickness; silver halide materials.

1. INTRODUCTION

As it is well known the final quality of a holographic image depends on a number of factors such as the set-up, the type of hologram, the recording material, the type of object, the emulsion, the processing technique, as well as the reconstruction conditions.

This study has been motivated by the need to find out an alternative material to Agfa (Holotest) 8E 75HD which had stopped being produced. Several silver halide materials were tested and the Slavich PFG-01 emulsion was found to have the best performance. After comparing preliminary results, it was decided to develop the present study using those two types of emulsion.

Most of multicolour reflection holograms are obtained by means of pseudocolour techniques, which require the preswelling and the appropriate manipulation of thickness of the emulsion before exposure, as well as the change of the reference beam for a correct record of different colours. The importance of this study to Creative Holography motivated a particular emphasis on (a) the behaviour of the emulsion in preswelling conditions, (b) the final quality of the holographic images and (c) the reconstructed wavelengths.

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Triethanolamine was the product selected for the preswelling because of the already known good results obtained on Agfa emulsion. After reaching the correct concentration of Triethanolamine in distilled water, that is needed to get the various colours on each type of emulsion, it was possible to produce creative multicoloured holograms made with creative purposes, where the colours are used in a controlled way.

2. CARACTERISTICS OF MATERIALS

Both studied materials are silver halide emulsions on glass and film. Based on the technical specifications given by the producers, the emulsions look very similar. However, when they are worked on, they show up significant differences which affect the final results. TABLE I shows the technical specifications of Agfa 8E 75 HD and Slavich PFG-01. (Red sensitivity materials)[1, 2].

TABLE I

Agfa (Holotest) 8E 75 HD (a)	**Slavich PFG-01 (b)**
Silver halide emulsion on glass and film	Silver halide emulsion on glass and film
Spectral Sensitivity: Red sensitive (633 nm)	Spectral Sensitivity: Red sensitive (633 nm and 647 nm)
Sensitivity (μ J/ cm2) 100	Sensitivity (μ J/ cm2) 100
Average grain size 35/ 44 nm	Average grain size 40 nm
Resolving power: 5000 lines/ mm	Resolving power: more than 3000 lines/ mm

3. THE EXPERIMENTAL STUDY

3.1. The set-up

Fig. 1 shows the set-up used for the research. For recording the holograms a very simple reflection geometry was used with the object beam focussed on a ground glass. The plane of polarisation had to be rotated, with a λ/2 retardation plate, in order to maximise diffraction efficiency and to avoid the presence of interference fringes that decrease the quality of final image.

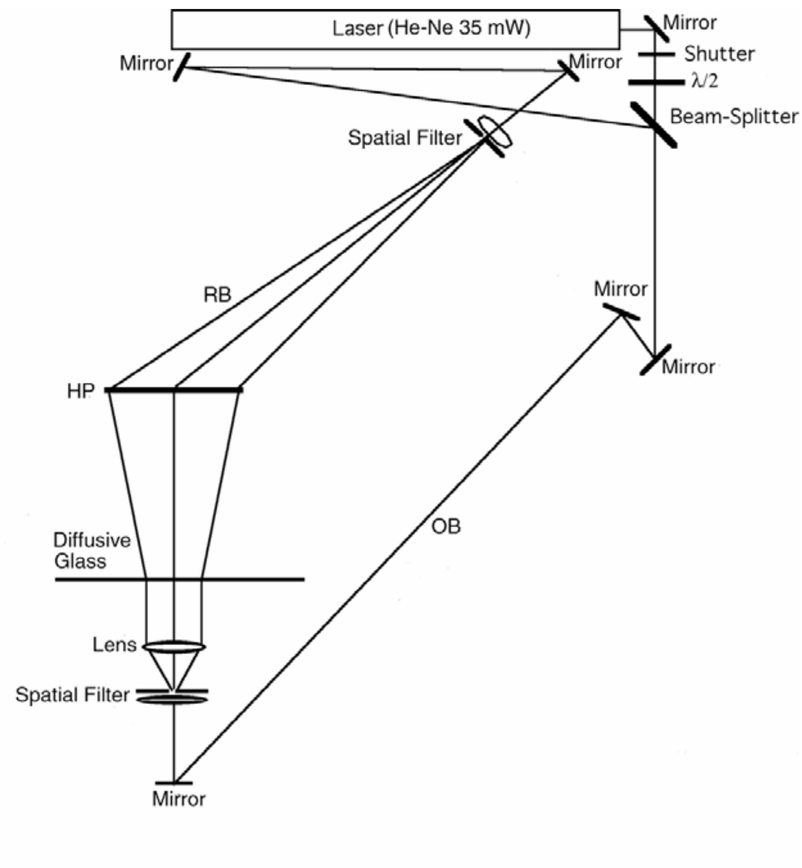


Fig. 1. Set-up used for recording the holograms

3.2. Preswelling

As it was said before, the technique generally used for changing the wavelength and obtaining multicolour holograms implies the preswelling of the emulsion[3,4]. It is necessary to soak the plate into a defined concentration of chemical products, the most well known of which is Triethanolamine (TEA), squeegee the plate, let it dry and clean the glass very well before exposing the plate to the light.

Kaufman’s, concentrations of Triethanolamine have been used on Agfa emulsion, as indicated in TABLE II.[5]:

TABLE II

Agfa (Holotest 8E 75 HD)			
Time of Soak /(min)	**Concentration of TEA /(%)**	**Wavelength**	**Colour**
5	Water and wetting agent	(for increasing the sensitivity)	Red
5	3.5	570-580 nm	Yellow
5	10	487- 510 nm	Green
5	13.5	430- 487 nm	Blue
5	17	400- 430 nm	Violet

In spite of the fact that the processing baths used by Kaufman (D 19+PBQ or EDTA bleach) were different to those that have been used in this research (PicAAC+ EDTA+R-9) the wavelength of reconstruction remained as expected.

However, it was verified that the concentrations used on Agfa plates to get the different colours were not suitable for Slavich plates. It was necessary to find out why. Some differences in the type of emulsion were clearly found. The Slavich emulsion is softer than Agfa emulsion. So the preswelling must be carefully handled in order to prevent the emulsion from swelling too much or even separating from the plate. It was found that 2-2.5 minutes of soak in the solution were enough to change the thickness of this emulsion. First low concentrations of TEA and little time of preswelling have been used. Then, gradually, higher concentrations of TEA and longer preswelling time have been tested. However, it could be observed that longer time did not mean a better performance of the emulsion. The results obtained are presented in TABLE III.

TABLE III

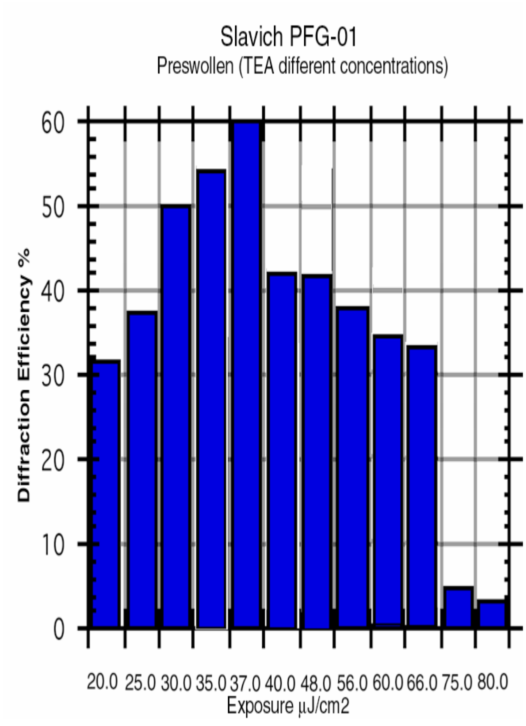
Slavich PFG-01			
Time of Soak /(min)	**Concentration of TEA /(%)**	**Wavelength**	**Colour**
2.5	Water and wetting agent	635- 625 nm	Red
2.5	1.5	610- 605 nm	Orange
2.5	2	595- 580 nm	Yellow
2.5	3.5	555- 550 nm	Green Yellowish
2.5	5	540- 535 nm	Green
2.5	9	520- 490 nm	Cyan
2.5	10	460- 455nm	Blue
2.5	13.5	430- 420 nm	Violet

In both emulsions-Agfa and Slavich- the preswelling in water and wetting agent (Agepon) was used to increase the sensitivity of the emulsion. In this way the diffraction efficiency of the red wavelength could be increased when compared to the efficiency of the other wavelengths.

3.3. Time of Exposure

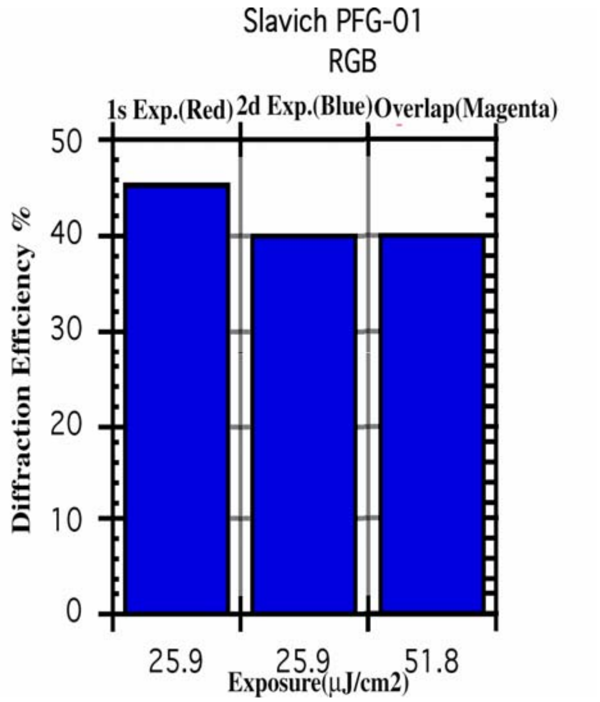
As preswelling increases the sensitivity of the emulsion, it was necessary to find out the correct value of exposure time. Several values have been tried. The results are shown in the plots of fig 2 and 3.

It is possible to verify that the best diffraction efficiency is reached at 37 μJ/cm2. When more than one exposure is required it is necessary to reduce a little the time of each exposure in order to avoid too much energy on the part of the plate where more than one exposure took place. The value of exposure time that is necessary to get equivalent results on both Agfa and Slavich plates is different. It is about twice in Agfa plates.



Exposure (μJ/cm2)

Fig. 2 Diffraction efficiency as a function exposure energy density (plates with one exposure).



Exposure (μJ/cm2)

Fig. 3 Diffraction efficiency as a function exposure energy density (plates with more than one exposure).

3.4. Chemical Processing

The chemical formulae used for processing holograms on Agfa emulsion are quite different to the ones used for the processing on Slavich emulsion[6, 7, 8, 9].

They were selected because their results were the best with the respective emulsions. For Agfa plates processing the (Pic)AAC developer and EDTA bleach were selected because their diffraction efficiency was higher [10,11]. However, with this bleach the hologram shows a milky aspect. But after a bath for just a few seconds in R-9 bleach, the hologram turns completely transparent and the wavelength is not changed. The products for Agfa emulsion processing are indicated in TABLE IV.

TABLE IV

Products for Agfa emulsion processing					
Developer (Pic)AAC		**EDTA Bleach (Rehalogenant)**		**R-9 Bleach (Solvent)**	
Pyrocatechol	10 gr.	Distilled Water	700 cc.	Potassium Dichromate	2 gr.
Sodium Sulphite Anhydrous	5 gr.	Disodium Salt EDTA	30 gr.	Sulphuric Acid	10 c.c.
Ascorbic Acid	18 gr	Potassium Bromide	30 gr.	Distilled Water	up to a litre
Urea	50 gr	Ferric Sulphate	30 gr		
Sodium Carbonate	60 gr.	Hydrogen Sodium Sulphite	30 gr.		
Distilled Water	up to a litre	Distilled Water	up to a litre		

The different steps for processing Agfa emulsion are the following:

a) develop in PicAAC for 2 minutes; b) wash intermediately in distilled water for 2-3 minutes; c) bleach in EDTA bleach until clear, for about 2 minutes; d) wash again in distilled water for 2-3 minutes; e) soak in R-9 bleach until the emulsion becomes transparent, for about 10-15 seconds; f) wash in running water for 10 minutes; g) wash finally in water with wetting agent for 1 minute; h) leave it dry slowly.

The products for Slavich emulsion processing are indicated in TABLE V.

TABLE V

Products for Slavich emulsion processing			
Developer SM-6		**PBU-amidol Bleach**	
Ascorbic Acid	18 gr.	Potassium Persulphate	10 gr.
Phenidone	6 gr.	Citric Acid	50 gr.
Sodium Hydroxide	12 gr.	Cupric Bromide	1 gr.
Sodium Phosphate Dibasic	28.4 gr.	Potassium Bromide	20 gr.
Distilled Water	up to a litre	Amidol	1 gr.
		Distilled Water	up to a litre

The different steps for processing Slavich emulsion are the following:
a) develop in SM-6 for 2-3 minutes; b) wash intermediately in distilled water for 2-3 minutes; c) bleach in PBU-amidol until the emulsion becomes transparent, for about 2 minutes; d) wash in running water for 10 minutes; e) wash finally in water with wetting agent for 1 minute; f) leave it dry slowly.

In the case of Slavich emulsion two developers give satisfactory results: modified Pyrochrome and SM-6. After some experiments the first one was put away for two main reasons: a) the brownish colour produced by Pyrogallol which changed the wavelength and b) lower diffraction efficiency. In fig. 4 and 5 it is possible to see the differences for an exposure of 37 μJ/cm2.

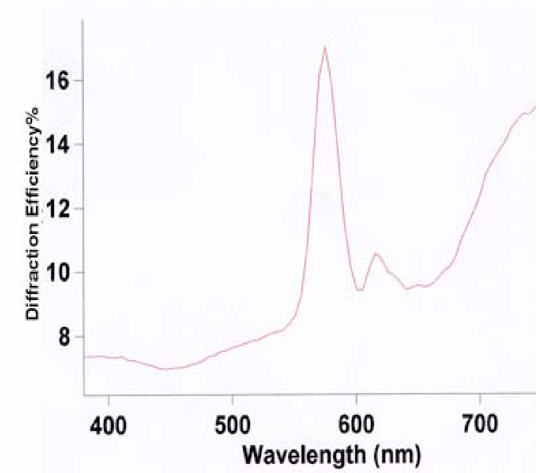


Fig. 4 Diffraction efficiency as a function of wavelength for a plate developed with modified Pyrogallol (575 nm).

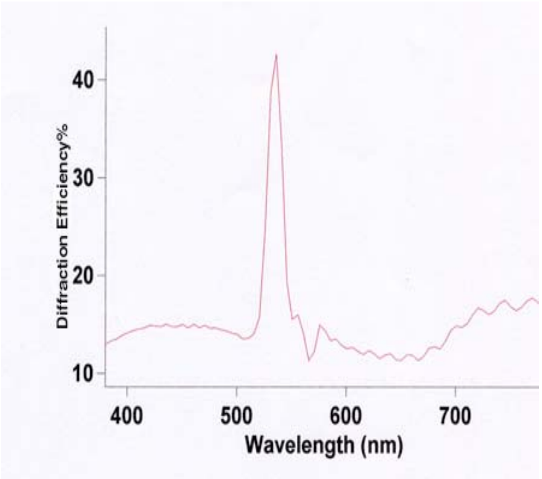


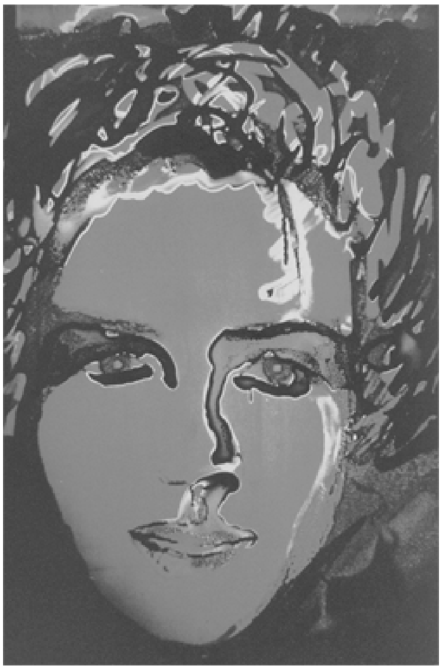
Fig. 5 Diffraction efficiency as a function of wavelength for a plate developed with SM-6 (535 nm).

3.5. Temperature of baths

The temperature of the baths mostly during preswelling is also an important factor for the results obtained in different colours. This conclusion could be drawn after a sequence of steps taken during the research. When working at the temperature of 25°C it was possible to obtain all wavelengths of reconstruction including blue and violet. But when the temperature was changed to 15°C, it was not possible to find the same colours, mostly the shorter wavelengths. In order to check which conditions were affecting the results, further experiments were made: a) putting the processed plate in an oven at 25°C, 30°C and 35°C; b) raising the processing baths to 25°C and c) raising the preswelling baths to 25°C. It was verified that only the temperature of variation of the preswelling affect the colours.

4. RESULTS

After studying the conditions affecting the reconstructed colours of a reflection hologram it was possible to define a kind of "palette" that helps the painter to select the colours applied on each part of the hologram. The emulsion can be "painted" in an expressive way with different colours not at random, but having the pre-conception of the final result. Using the described technique it was possible to produce multicolour holograms such those represented in Fig. 6 and 7.



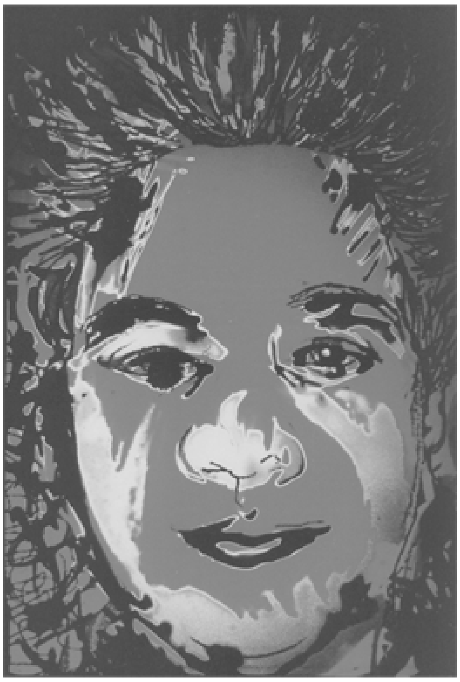


Fig. 6 and 7. Multicolour holograms of the Series "Faces", using the technique described in the text.

5. CONCLUSIONS

This study leads to the conclusion that it is possible to achieve multicolour holograms by using Triethanolamine to change the thickness of emulsion both in Agfa and Slavich materials. However, the percentage of TEA in preswelling solutions used for a specific wavelength of reconstruction is not equal in both emulsions.

Any spectral colour can be obtained during just one exposure, but for obtaining non-spectral colours like magenta or pink it is necessary to do more than one exposure.

This study shows that Slavich emulsion shows higher sensitivity in the preswelling with TEA solutions, thus a high diffraction efficiency is reached with a shorter exposure time. For more than one exposure it is necessary to adjust the energy needed to get a high diffraction efficiency without overexposing the emulsion.

The effect of the temperature of the preswelling baths is also a determinant factor in the reconstructed colour.

6. AKNOWLEDGEMENTS

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