Diffuse-object holograms in silver halide sensitized gelatin

A. FIMIA, I. PASCUAL, L. CARRETERO and A. BELÉNDEZ (†)

Laboratorio de Optica

Departamento Interuniversitario de Optica

Universidad de Alicante

Apdo. nº 99. Alicante E 03080. SPAIN

(†) Departamento de Ingeniería de Sistemas y Comunicaciones

Universidad de Alicante

Apdo. nº 99. Alicante E 03080. SPAIN

Phone: 34 - 6 - 590 35 09

FAX: 34 - 6 - 590 34 64

Journal of Modern Optics: Short contribution

ABSTRACT

This paper deals with diffuse-object holograms recorded in silver halide sensitized gelatin. Both the diffraction efficiency and the signal-to noise ratio when reconstruction is done with different wavelengths are measured. The experimental results we obtained show that new theoretical models for the functioning of this type of processing must be developed if we wish to justify the results we obtained.

Since the publication of Pennington, Harper and Laming's paper in 1971 [1], numerous papers have been published on the formation of phase holograms using the silver halide sensitized gelatin (SHSG) processing technique. SHSG is a processing technique which combines the energetic and spectral sensitivity of photographic emulsions with the high diffraction efficiency and the low level noise of dichromated gelatins. Once the photographic emulsion has been exposed, it is developed and then bleached. Due to the action of the bleacher, the developed silver is oxidized to Ag^+ , whereas the Cr^{+6} ion is reduced to Cr^{+3} during the same bleaching bath. This way the Cr^{+3} ion is linked to the gelatin chains in the vicinity of the oxidized silver grains achieving a variation of hardening between the exposed and nonexposed zones of the emulsion. The emulsion is then fixed to remove all the excess silver halides. The processing is completed with the washing of the emulsion and its dehydration through successive baths in iso-propanol, following a processing similar to that of a dichromated gelatin.

Previous papers [2, 3] have proven that SHSG is a good alternative to dichromated gelatin (DCG) in the production of holographic optical elements with results similar to those obtained in DCG. A recent paper [4] shows that it is possible to use the SHSG technique for making free-space holographic optical interconnects with high diffraction efficiency and high signal-to noise ratio (SNR).

The aim of this paper is to describe and discuss some experimental results obtained with diffuse-object holograms made using the SHSG processing technique by analyzing the optimization procedure in order to obtain high diffraction efficiencies and good SNR.

From the different sources of noise in phase diffuse-object holograms recorded in SHSG, noise gratings do not exist due to the fact that this processing technique introduces considerable emulsion thickness changes [5]. Due to this, the principal sources of noise that we must consider are scattering and the intermodulation noise caused by the self-interference of light from the extended object.

The object consisted of a uniformly transilluminated square glass diffuser ($2 \times 2 \text{ cm}^2$) with an opaque square in the center ($1 \times 1 \text{ cm}^2$). The distance of the object from the

recording medium was 30 cm and the angle between the object and the reference beam was 40° , and the reference-to-object beam ratio was 5. In all experiments analyzed in this letter Agfa 8E75 HD plates were used and the exposures were made with 633 nm radiation from a He-Ne laser. The SNR was measured as the ratio of the average light intensity in the reconstructed square ring object to the average intensity of the scattered light in the center. After recording and processing, measurements were taken of the diffraction efficiency and the SNR of these holograms for two replay wavelengths: 633 and 488 nm. Special attention is given to the bleaching step in which we have analyzed the influence of the bleach bath temperature on diffraction efficiency and SNR. The process used in our experiments is shown in Table I.

Figures 1a and 1b show the plots of diffraction efficiency and SNR, respectively, as a function of the density before bleaching for 633 and 488 nm readout wavelengths used in the experiments. As can be seen from these figures, diffraction efficiency is better for a readout wavelength of 488 nm, while the SNR is better for 633 nm. Moreover, from these figures we can see that this process leads to efficiencies of $\sim 40\%$ for a SNR of ~ 50 when a wavelength of 633 nm is used during measurement.

Figures 2a and 2b show the variation in diffraction efficiency and SNR, respectively, when the temperature in the bleaching bath is increased. As can be seen from these figures, when the bleaching temperature increases there is an increase in diffraction efficiency while SNR decreases.

Two important conclusions can be drawn from the experimental results obtained. The first is that existing theoretical models can not be used to explain the experimental results we obtained in the analysis of signals which correspond to diffuse-object holograms [6], and the second is that it is likewise impossible to use existing models to justify the increase in diffraction efficiency when using a wavelength of 488 nm for reconstruction. We know that in processes corresponding to bleached silver halide emulsions, when using rehalogenating bleaches, diffraction efficiency in long wavelength zones is greater than that in short wavelength zones (see Figure 3), and as we shown in this paper, when SHSG is

used, the results are just the opposite. In Figure 3, we have plotted the diffraction efficiency and the SNR for diffuse-object holograms processing with rehalogenating bleaches (see Table II). As can be seen in this figure the maximum diffraction efficiency obtained when we reconstructed with a 633 nm wavelength was ~38%, while only a maximum diffraction efficiency of ~26% was achieved when a 488 nm wavelength was used during the reconstruction of the holograms. We think that this decrease of the diffraction efficiency at short wavelengths is due to the photochemical composition of the system recorded in the exposed area of the recording material. According to this, it would be a method for analyzing the photochemical composition of the exposed and unexposed areas in this type of processing techniques. Resolving all these interesting and unexpected results obtained with SHSG will require additional research, but we hope to be able to find the answer in the near future.

In summary, we have carried out experiments on both diffraction efficiency and SNR for diffuse-object holograms and the results we have obtained show that current theoretical models on the formation of latent images cannot completely account for the storage of information in SHSG holograms. In fact, some recent papers [7, 8] have already pointed out the need to modify existing models in order to be able to justify all of the experimental results obtained with this type of processing.

REFERENCES

- [1] PENNINGTON, K. S., HARPER, J. S., and LAMING, F. P., 1971, *Appl. Phys. Lett.*, **18**, 80.
- [2] FIMIA, A., BELÉNDEZ, A., and PASCUAL, I., 1991, *J. mod. Optics*, **38**, 2043.
- [3] FIMIA, A., BELÉNDEZ, A., and PASCUAL, I., 1992, *Appl. Optics*, **31**, 3203.
- [4] FUENTES, R., PASCUAL, I., BELÉNDEZ, A., FIMIA, A., EGOZCUE, J.J., NAVARRO, 1993, *Proc. EOS Annual Meeting Digest*, **3**, 129.
- [5] BELÉNDEZ, A., PASCUAL, I., and FIMIA, A., 1993, *Opt. Quantum Electron.*, **25**, 139.
- [6] UPATNIEKS, J., and LEONARD, C., 1970, *J. opt. Soc. Am. A*, **60**, 297.
- [7] PHILLIPS, N. J., ROLLISON, R. D., BARNETT, C. A., and SCHICKER, S. R., 1993, *Proc. SPIE* (to be published).
- [8] USANOV, Y. E., SHEVTSOV, M. K., KOSOBOKOVA, N. L., and KIRIENKO, E. A., 1991, *Opt. Spectrosc.*, **74**, 375.

FIGURE CAPTIONS

Figure 1: (a) Diffraction efficiency and (b) signal-to noise ratio as functions of the density before bleaching for SHSG diffuse-object holograms. Readout measurements were made at 488 nm (■) and 633 nm (□).

Figure 2: (a) Diffraction efficiency and (b) signal-to noise ratio as functions of the bleaching temperature for SHSG diffuse-object holograms. Exposure is 100 $\mu\text{J}/\text{cm}^2$ and readout measurements were made at 488 nm (■) and 633 nm (□).

Figure 3: (a) Diffraction efficiency and (b) signal-to noise ratio as functions of the density before bleaching for rehalogenating bleached emulsion diffuse-object holograms. Readout measurements were made at 488 nm (■) and 633 nm (□).

TABLE I

Step

1. Develop with Kodak D-8 for 3 min at 20°C
2. Rinse in running water for 30 s
3. Bleach in modified Kodak R-10 with K Br (1 part A, 30 parts B, and 10 parts water) until the plate turns white at X°C
4. Rinse in running water for 30 s
5. Fix in Kodak nonhardening bath F-24 for 2 min at 20°C
6. Wash in running water for 10 min
7. Dehydrated in 50% isopropanol for 3 min
8. Dehydrated in 90% isopropanol for 3 min
9. Dehydrate in 100% isopropanol for 3 min
10. Dry in a vacuum chamber

TABLE II

Step

1. Develop with Kodak D-8 for 3 min at 20°C
2. Rinse in running water for 30 s
3. Fix in Kodak bath F-5 for 5 min at 20°C
4. Wash in running water for 5 min
5. Bleach for 1 min after the plate has cleared at 20°C
5. Wash in running water for 5 min
6. Dry in air

Bleach formula

Potassium bromide (K Br)	7 g
Ptassium Ferricyanide ($K_3Fe(CN)_6$)	8 g
Distilled water to make	1 litre

(a)

(b)

FIGURE 1
A. Fimia et al

(a)

(b)

FIGURE 2
A.Fimia et al.

(a)

(b)

FIGURE 3
A. Fimia et al.