PROCEEDINGS REPRINT

SPIE—The International Society for Optical Engineering

Reprinted from

Holographic Optics III: Principles and Applications

12-15 March 1991
The Hague, The Netherlands

Volume 1507

HOLOGRAPHIC OPTICAL SYSTEM TO COPY HOLOGRAPHIC OPTICAL ELEMENTS

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ABSTRACT

We present, in this paper, a holographic system formed by two holographic lenses that, when working with white light, allow us to select a particular wavelength. If we obtain adequate spatial and temporal coherence conditions it is possible to copy holographic optical elements (HOEs) with partially coherent light by using optical systems formed by holographic optical elements.

1. INTRODUCTION

Recording materials play an important role in the design of holographic optical elements as the efficiency in maximum diffraction that must be obtained in holographic optical elements is basically a function of the photochemical characteristics of recording media as well as of the processing method they need. Each material shows its own energetic and spectral response, which sometimes makes it impossible to obtain HOEs in a certain region of the spectrum due to the fact that there are no coherent sources emitting in that region of the spectrum.

We present, in this paper an afocal two-element transmission holographic system. This system can be used to work in white light¹ and so it is possible to work in the region in which the recording media present maximum energetic and spectral sensitivity. Moreover as a consequence of this it is possible to work in the infrared region or in other regions.

2. HOLOGRAPHIC SYSTEM

The holographic system is formed by two transmission holographic lenses with the same focal length, separated by a distance which corresponds to twice the focal length of each one of them, so that working with white light we can select a particular wavelength, filtering the image from the first lens on the focal plane by means of an appropriately sized diaphragm.

Let us consider the scheme of the holographic system using two thick-phase transmission lenses as shown in figure 1. The holographic lenses used in this system were constructed in the arrangement shown in figure 2 (a) and reconstructed in the configuration shown in figure 2 (b). As usual, we will denote by R, O, C and I the sources which illuminate the object and reference light beams, and the light beams which reconstruct and form the image, respectively.

Fig. 1.- Basic scheme for the system of two holographic optical elements reconstructed with white light to copy holographic optical elements.

Fig. 2.- (a) Holographic lenses construction and (b) reconstruction geometries.

The recording material used was silver halide sensitized gelatin (SHSG)² in Agfa-Gevaert emulsion 8E75 HD, using the radiation of 633 nm of a He-Ne laser. With this processing it is possible to obtain HOEs with a high transmittance on the whole visible spectrum, presenting at the same time an optimum signal-to-noise ratio (SNR). The HOEs present maximum diffraction efficiency near the theoretical value for the Bragg angle at this wavelength. The parameters corresponding for two holographic lenses are shown in table I.

Table I: Parameters for two holographic lenses at 633 nm wavelength.

Exit pupil diameter (D)	100 mm
Focal length (f)	200 mm
Aperture (f/D)	f/2
Carrying frequency	1000 lines/mm

The optical system presented here can work at any of the emission wavelengths of the source used. In this study, the source used was a high pressure mercury lamp. Table II shows the spectral response of the holographic system as regards its efficiency.

Table II: Spectral response of the holographic system.

λ (nm)	Maximum diffraction efficiency for each lens (%)	Maximum diffraction efficiency for the holographic system doublet (%)
405	61	38
436	61	38
488	60	37
514	60	37
546	47	22
578	48	23
633	45	20

The photosensitive materials used in this study to obtain the holographic optical elements register high sensitivity to short wavelengths within a visible spectrum; therefore, we have selected a wavelength of 405 nm for the study. This wavelength, as well as its corresponding bandwidth, was selected using an appropriately sized and positioned D_2 diaphragm (see figure 1).

In order to choose the 405 nm wavelength, we placed the D_2 diaphragm on the focal plane of the first HOE; this plane corresponded to 405 nm.

The holographic system has been analyzed by ray tracing³, which give us information about the shape and size of the spectrum. From this point on, the radiation bandwidth used was determined according to the size of the diaphragm that was selected. If the diameter of the D_2 diaphragm is 2 mm, the bandwidth of the working wavelength is 10 nm.

By knowing the size of the source and its corresponding bandwidth, it is possible to find the coherence conditions of our system. These coherence conditions will in some way indicate the quality of the elements that will later be obtained using the holographic optical system. From the point of view of theoretical calculus, the spatial coherence factor comes from the Van-Cittert Zernike Theorem⁴ and the temporal coherence factor is calculated assuming that the thermal source of emission possesses a Gaussian profile. From these calculations we can deduce that the spatial and temporal coherence factors are > 0.9 and this basically indicates that it is possible to obtain good holographic optical elements with this holographic system.

3. EXPERIMENTATION

A process for copying HOEs using partially coherent sources of light can be developed by using the holographic system described above. The copying process⁵ consists of storing the interference pattern of the two wave fronts generated in the master HOE in a recording material that has sufficient spatial resolution. Making copies is complicated and the difficulty lies precisely in the recording of the spacing of the interference fringes that constitute the HOE, as they are usually the size of micrometers. In order to copy high frequency HOEs, the master HOE must be reconstructed and the resulting holographic image used as the object when recording the copy. In addition, the master HOE must be placed in direct contact with the recording material we want to use to make the copy. This produces a confrontation of the photosensitive layers. The masters used are diffraction gratings and volume holographic lenses obtained in silver halide sensitized gelatin with a wavelength of 633 nm using an He-Ne laser. The characteristics of the master HOEs are shown in table III.

Copies of diffraction gratings and holographic lenses using dichromated gelatin (DCG) recording material obtained from 649 F Kodak plates and Shipley AZ-1350 J and B photoresists have been made.

Figure 1 includes a scheme of the copying arrangement. This arrangement works with a high-pressure mercury lamp and a wavelength of 405 nm. The D_1 and D_2 diaphragm are 2 mm in diameter.

Table III: Parameters for masters at 405 nm wavelength.

GRATING	
Frequency	1000 lines/mm
Diffraction efficiency	38%
Transmission efficiency	42%
LENS	
Exit pupil diameter (D)	55 mm
Focal length (f)	165 mm
Aperture (f/D)	f/3
Carrying frequency	1000 lines/mm
Diffraction efficiency	38%
Transmission efficiency	42%

The results that have been obtained when copying diffraction gratings are shown in figure 3. Figure 3 (a) shows diffraction efficiency in relation to exposure when using dichromated gelatin. A good level of efficiency is observed - around 85% - and energy sensitivities are around 80 mJ/cm². Figure 3 (b) shows diffraction efficiency in relation to exposure when using photoresists. This efficiency level reaches 40% which indicates that the profile recorded when using this type of material should not be sinusoidal, which is when the process is being carried out in non-linear conditions.

As regards the copied holographic lenses, these were made for the exposure values that would produce the highest diffraction efficiency in the central zone. The copied lenses were made using dichromated gelatin and photoresist and in both cases, good quality optical lenses were obtained.

4. CONCLUSIONS

We could say that the design and construction of this holographic optical system represents the incorporation of holographic optics into the field of conventional optics. By using a copying process, HOEs have been obtained with both DCG and photoresist. These copies are of good optically quality, which is to say that they present high diffraction efficiency. Therefore it is possible to obtain HOEs with partially coherent light using an optical system formed by HOEs.

Fig. 3.- Diffraction efficiency in relation to exposure using (a) dichromated gelatin and (b) photoresist.

5. REFERENCES

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