Two reference beam method for recording transmission or reflection holograms of two different objects with single exposure using three similar transmission gratings

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Abstract

A new technique of recording holograms of two objects at the same time with single exposure has been proposed. Two similar gratings have been utilized for both transmission and reflection holograms. This technique will increase the storage capacity of holograms by a factor of two. Another feature of this technique is in its simplicity.

Keywords: Holograms; Exposure; Grating; Transmission; Reflection

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1 Introduction

The general information regarding recording and reconstruction of transmission or reflection holograms is not needed to be discussed in depth as it has been presented excellently by many workers but a few are mentioned here [1-8]. Paper [9] describes a method of stabilizing the interference pattern when recording three dimensional transmission holograms in photochromic and photorefractive media. The method is based on using the dynamic interaction of the interference field with the recorded hologram.

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In this paper, a new technic of recording transmission or reflection holograms of two objects at the same time with single exposure using three similar gratings has been proposed. This technic does not use any beam splitters for producing object wave and reference wave. Gratings do the job of splitting laser beam into two object waves and two reference waves. If O_1 and O_2 represent the two object waves and R represents the references wave then at the holographic plate the amplitude transmittance will have the following terms:

$$T = [O_1^2 + O_2^2 + R^2 + O_1 O_2^* + O_2 O_1^*] + (O_1 + O_2)R^2 + (O_1^* + O_2^*)R^2$$

The first five terms in the square bracket will contribute nothing to the image formation. The next term $(O_1 + O_2)R^2$ will give two real images and the last two terms $(O_1^* + O_2^*)R^2$ will give two virtual images. Hence the storage capacity of the hologram is increased by a factor of two.

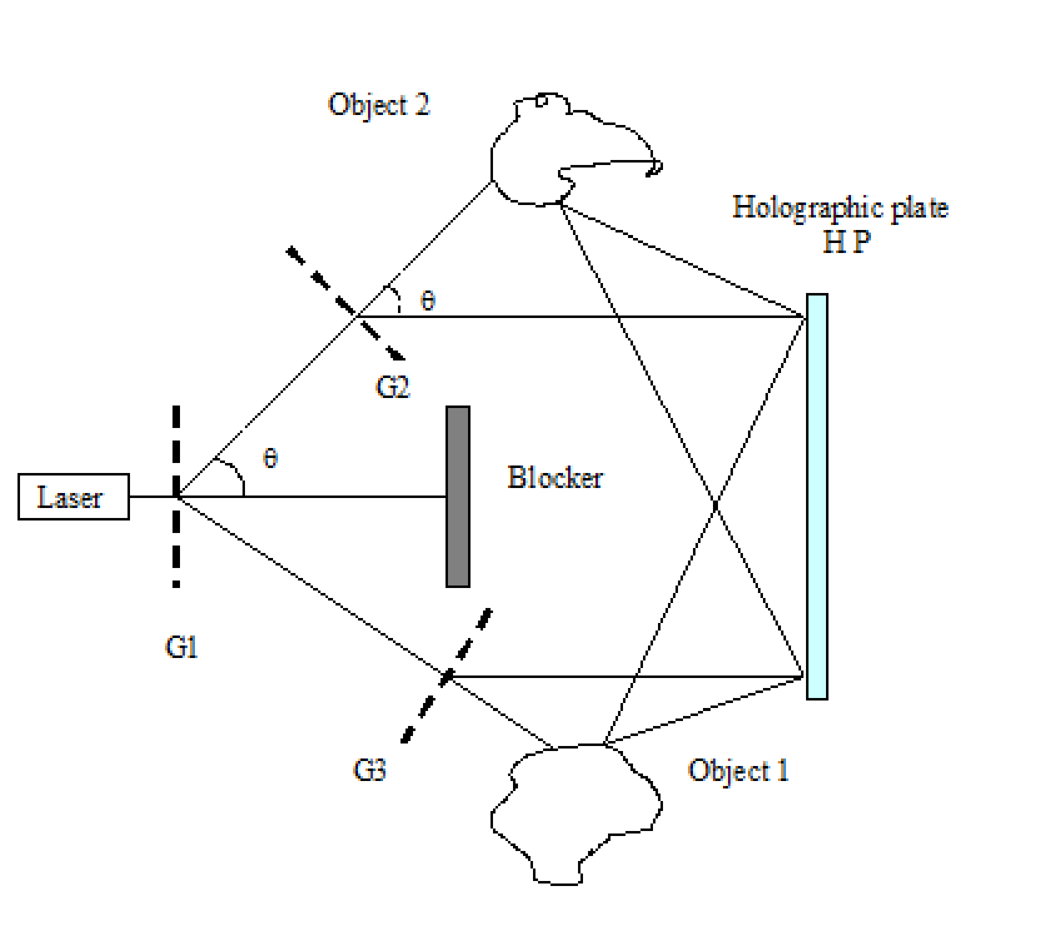

Figure 1: Recoding of a transmission hologram.

2 Experimental set up and discussions

2.1 Transmission hologram

A lot of literature is available on the subject such as a few is listed in the references. Therefore, in this article, a brief description of the technic is presented. As can be seen in Fig. 1, laser light from grating $G1$ is diffracted and the diffracted beams in the first order go towards other two similar gratings $G2$ and $G3$. The direct beams from $G2$ and $G3$ illuminate object 1 and object 2 respectively and the reflected light from objects reach the holographic plate. The diffracted beams in first order by gratings $G2$ and $G3$ go directly to the holographic plate and serve as reference beams. Thus at the holographic plate, there two object waves and two reference waves, interfering together. The direct beam from grating $G1$ may be required to be blocked because of intensity proportion. The plate is developed as usual following the standard method described in the literature. Upon reconstruction, two virtual and two real images will be observed and in each image both objects will be seen.

2.2 Reflection hologram

In a similar way as shown in Fig. 2, the reflection hologram of two transparent objects like negatives of an object with single exposure can be constructed. The main difference in this case is that the reference wave and the object wave meet the holographic plate from opposite side.

3 Theory and discussion

Let us consider that two object waves are represented by $O_1 = O_{o1}e^{i\Phi_1}$ and $O_2 = O_{o2}e^{i\Phi_2}$,where Φ_1 and Φ_2 are the associated phase with the respective object waves. At the holographic plate they interfere with the reference wave $R = R_o e^{i\delta_1}$. The resultant amplitude at the plate will be

$$A = O_{o1}e^{i\Phi_1} + O_{o2}e^{i\Phi_2} + R_o e^{i\delta_1} \quad (1)$$

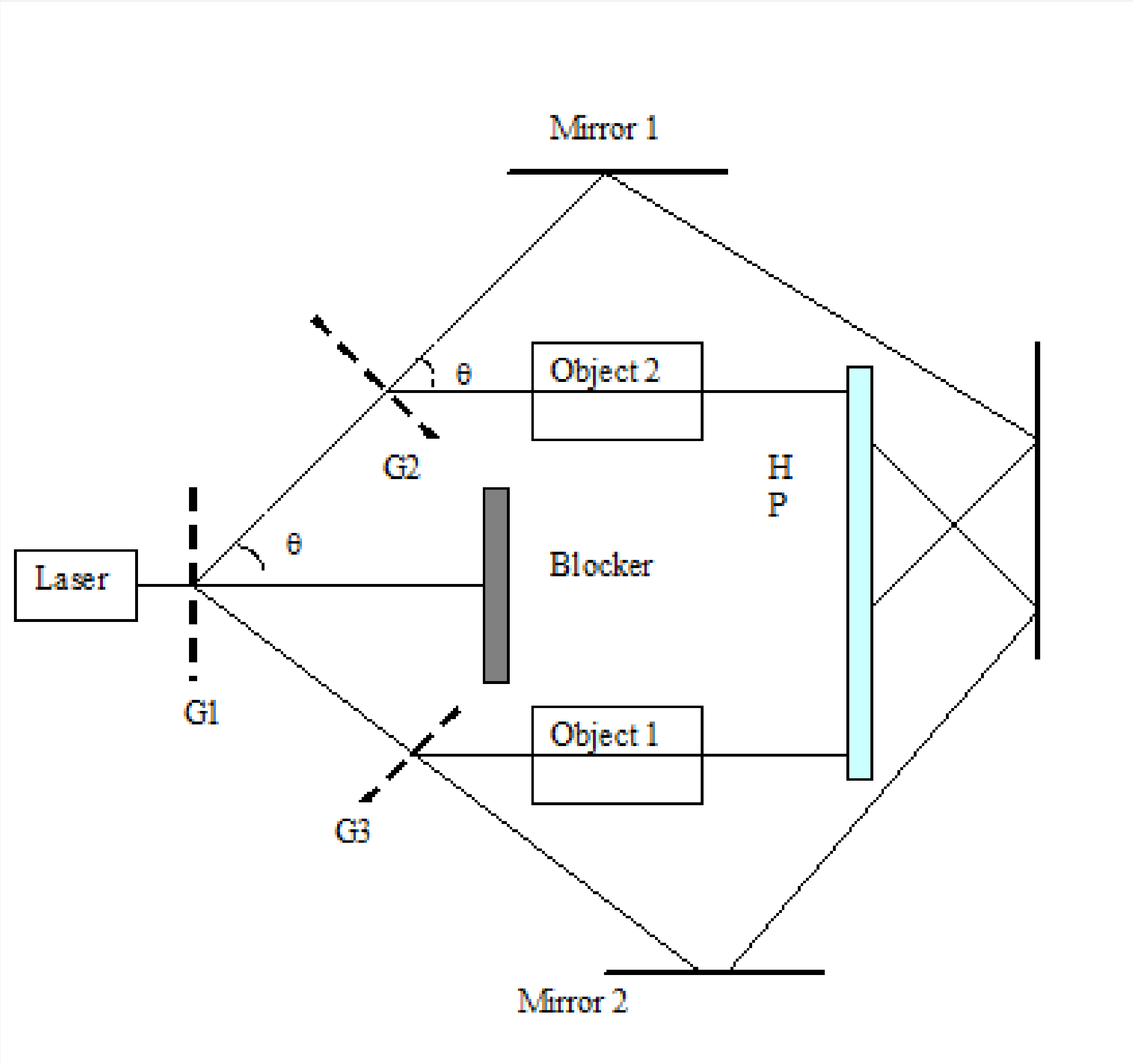

Figure 2: Recoding of a reflection hologram.

The average intensity at the plate will be

$$\begin{aligned} I &= (O_{o1}e^{i\Phi_1} + O_{o2}e^{i\Phi_2} + R_o e^{i\delta_1})(O_{o1}e^{i\Phi_1} + O_{o2}e^{i\Phi_2} + R_o e^{i\delta_1}) \\ &= O_{o1}^2 + O_{o1}O_{o2}e^{i(\Phi_1-\Phi_2)} + O_{o2}^2 + O_{o1}O_{o2}e^{-i(\Phi_1-\Phi_2)} + R_o^2 \\ &\quad + O_{o1}R_o[e^{i(\delta_1-\Phi_1)} + e^{i(\Phi_1-\delta_1)}] + O_{o2}R_o[e^{i(\delta_1-\Phi_2)} + e^{i(\Phi_2-\delta_1)}] \end{aligned} \tag{2}$$

The irradiance at the plate when the developed holographic plate is illuminated by the reference wave is

$$\begin{aligned} \beta_r = \; & R_o O_{o1}^2 e^{i\delta_1} + R_o O_{o1}O_{o2}e^{i(\Phi_1-\Phi_2)}e^{i\delta_1} + R_o O_{o2}^2 e^{i\delta_1} + R_o O_{o1}O_{o2}e^{-i(\Phi_1-\Phi_2)}e^{i\delta_1} \\ & + R_o^3 e^{i\delta_1} + O_{o1}R_o^2[e^{i(2\delta_1-\Phi_1)} + e^{i\Phi_1}] + O_{o2}R_o^2[e^{i(2\delta_1-\Phi_2)} + e^{i\Phi_2}] \end{aligned} \tag{3}$$

Rearranging the terms, we have

$$\begin{aligned} \beta_r = \; & R_o e^{i\delta_1}(O_{o1}^2 + O_{o2}^2 + R_o^2) + R_o O_{o1}O_{o2}e^{i(\Phi_1-\Phi_2)}e^{i\delta_1} + R_o O_{o1}O_{o2}e^{-i(\Phi_1-\Phi_2)}e^{i\delta_1} \\ & + O_{o1}R_{o2}[e^{i(2\delta_1-\Phi_1)} + e^{i\Phi_1}] + O_{o2}R_o^2[e^{i(2\delta_1-\Phi_2)} + e^{i\Phi_2}] \end{aligned} \tag{4}$$

The last two terms of equation 4 will give two real images and two virtual images. The first term is just the reference wave with some amplitude modulation. The third and the fourth terms are the ghost images and will have no value in this context. The two images are overlapping with each other. However from the expression it looks like that there will be two virtual and real images of both objects lying side by side.

4 Conclusion

In this article, a simple elegant technic of making transmission and reflection holograms of two objects at the same time with single exposure has been proposed. This technique will enhance the storage capacity of holograms by a factor of 2.

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