A Study on Advances in Creating 3D Holographic Images and Optical Applications of Holography

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Abstract *-Nowadays, the most beautiful 3D pictures and movies are created by means of holograms. The most advantage of this technique is the possibility to observe 3D images without using glasses. The quality of created images by this method has surprised everyone. In this paper, the experimental steps of making a transmission hologram have been mentioned. In what follows, current advances of this science–art will be discussed. In another section of this paper the optical application of holography has been reviewed. Finally, the predictions for the future of holography have also been studied.*
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Keywords: *Holography, 3D Images, Optical Applications.*

1. INTRODUCTION

Dennis Gabor found basic principles of holography while trying to improve the efficiency of transmission electron microscope in 1948 [1]. He performed his first experiments using mercury vapor lamp. After 23 years of experiments, Gabor won the Nobble Price in 1971. Digital holography was invented in 1900. The improvement of computer science led to delivering the recording and reconstructing processes to the computers and hence the creation of computer generated holograms (CGHs) in which artificial holograms are made by means of numerical methods [2]. Nowadays, holography has a broad range of applications in various sciences. No matter how much one is familiar with holography, a scientist or an ordinary person, he would soon engage with holography spontaneously. Increasing applications of holography will soon find their way through everyday life. This paper has done a theoretical and experimental study on creating 3D images by means of holography. Also, a much more universal future is predicted for this technique and the optical application of holography has been reviewed.

2. BASIC PRINCIPLES OF HOLOGRAPHY

There are two waves in holography, the reference wave and the object wave, which the object wave is the light that illuminates the object and after reflecting reaches to the holographic plate, and the reference wave directly hits the holographic emulsion. The image is recorded on the holographic plate and then it is possible to reconstruct the image without the presence of the main object. Therefore, holography technology consists of two phases, recording and reconstructing. The coherence and monochromatic light of laser is used for holographic recording. What is formed on recording media (sensitive emulsion) is an interference pattern made from the interference of two waves. This recording is named hologram; the reconstructing process is done using the same recording laser light in transmission holograms, and using white light in reflection holograms.

3. EXPERIMENTAL WORKS

In this section, the experiments done for making transmission holograms are demonstrated. In these experiments, two kinds of transmission setups, off-axis single beam and split-beam setup, have been used, which have been respectively shown in figures 1 and 2.

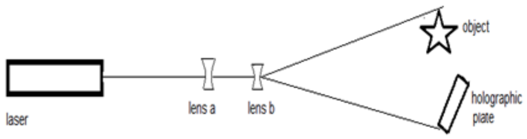

Fig. 1. Off-axis single beam setup

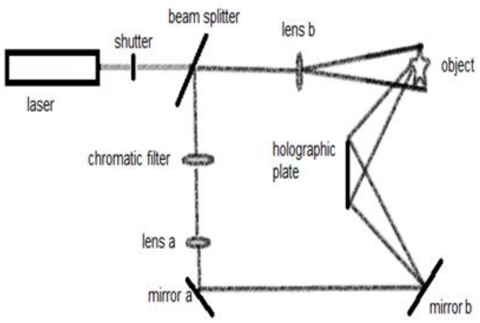

Fig. 2. Split-beam setup

The intensity of the reference wave must be higher than the object wave, and this is an important factor in the diffraction efficiency. For a desired result 4:1 relation was selected. The difference path between the reference wave and the object wave must be less than the coherence length of the applied laser, i.e. about 15-30 cm in the case. The applied holographic plate is Slavich PFG-01, silver halide emulsion, made in Lithuania. This plate is fine-grained red sensitive, 600-660 nm, and is illuminated by CW lasers. Average grain size is 40 nm, resolving power more than 3000 line/mm and the emulsion thickness 7 µm. The index of refraction is 1.61 and the mass per unit surface of silver halide is 2.7 g/cm^2. These types of plates have been designed for both transmission and reflection hologram recording. The PFG-01 light sensitivity is maximized at approximately 80 $microJ/cm^2$. The maximum diffraction efficiency is more than 45%. These plates are 63×63 mm. The applied laser is 1.5 mW He-Ne laser, and the objects used are plastic white pawns, chess game pieces. The exposure process is done in mere darkness, and the exposure time is calculated 6 seconds. After recording, the plate is removed from its set place to perform the exposure procedure done in green safe light. In order to develop the plates the JD-2 developer, the most commonly used developer and processing chemical, is used. This process includes two steps, developing and bleaching, despite the old processes which had three steps, developing, bleaching and fixing. Before the experiment all three solutions must be provided, but the two parts of developing solution have to be combined with 1:1 relation just before using. There are two real and virtual images in holographic reconstruction. Fig 3 and 4 represents the reconstructed virtual and real images respectively.

Fig 3. The reconstructed virtual image

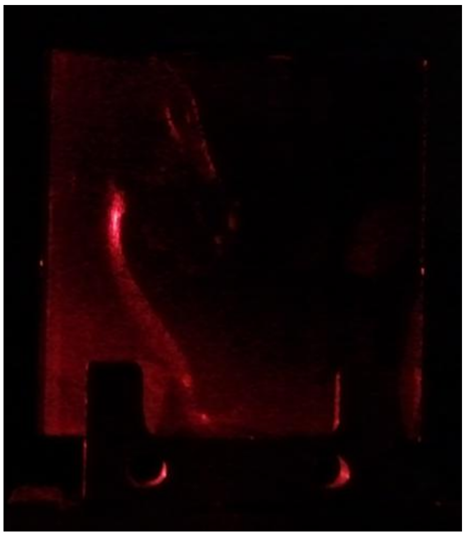

Fig 4. The reconstructed real image

The images are seen in the same red color of the He-Ne laser. The virtual image is orthoscopic and reconstructed in the back of the plate and the real image is pseudoscopic and reconstructed in front of the plate. In order to reconstruct the real image, the hologram has to be illuminated with the conjugated reference wave. To do so the hologram must be turned by 180°.

4. REVIEWING OPTICAL APPLICATIONS OF HOLOGRAPHY

Holography has many growing applications in different sciences such as: biology, medicine, IT, communication, architecture, security and packing. There are optical applications existing for holography, and some of them are still developing. Here, it has been tried to review optical ones, which include Holographic Interferometry and Holographic Optical Elements (HOEs).

4.1 Holographic Interferometry

Combining conventional interferometry with holography one can produce three-dimensional interferograms, images of diffusely- reflecting, three-dimensional objects that are overlaid with interference fringes indicating areas of deformation or displacement in the object [3]. The advantage of this technique compared to method of Photo-elasticity is that small deformation (<1 μm) of diffuse reflecting objects can be measured. This way the holographic interferometry plays an important role in the nondestructive testing (NDT) [4]. There are several flavors of holographic interferometry, but most rely on a similar basic principle: the combination of a reference hologram recorded while the object is in neutral equilibrium, with no stress applied, and a second holographic image created while the captured is being subjected to some form of stress: mechanical, thermal, vibrational, etc. In some cases, even a single hologram may be sufficient for the purposes of holographically interferometry [3]. Three main techniques are used for this purpose: double-exposure, real-time and time-average techniques [5]. Through the double-exposure technique, one can detect flaws in a structure while under constant stress. With the real-time technique, one can perform a rapid sweep of vibrational excitation and look for resonant frequencies. Finally, using the time-average technique, one can create high-visibility interferograms of an object under vibrational stress for detailed study [4]. The last technique has been used in the study of musical instruments [6].

4.2 Holographic Optical Elements

Another interesting optical application of holography is to make optical elements holographically. This is because a transmission hologram behaves like a lens in many ways, and a reflection hologram behaves like an optical mirror [7]. The advantages compared to the conventional optical elements are small thickness of the elements and the possibility to develop optical elements that cannot be created in a conventional way [8]. In this case, holographic diffraction gratings, lenses, mirrors, beam splitters and collimating mirrors can be made [7]. The production of holographic optical elements does not require additional knowledge of holography and its application areas [8].

5. ADVANCES IN CREATING 3D IMAGES USING HOLOGRAPHY AND THE FUTURE OF THIS TECHNOLOGY

Nowadays, 5000 lines/mm for a holographic plate seems to be a normal amount. Previously, holographic plates were sensitive to a very limited spectral range of wavelengths; hence they were classified into red-sensitive and green-sensitive holographic plates and films. Nowadays, the holographic plates which are sensitive to the whole visible range of lights are easily manufactured, e.g. PFG-03C (silver halide) and TCC-2 (photo-thermoplastic). Though these full-colored plates expire sooner, they produce high-quality images. Using some of photorefractive crystals has enabled scientists to use the recording media to record a new holographic image again, after recording and reconstructing the previous image. Nowadays, most curators produce holographic 3D images from their valuables. It is possible to copy these holographic plates without having access to the main object. In many parts of the world, exhibitions are held for the public to see the beautiful holographic images. These images are mostly reflective, because as already stated reflective holograms are easily reconstructed by means of the white light of small projectors, and it is not necessary to use laser beam which is likely to damage human eyes. Lance Winslow has written a comprehensive book beautifully predicting the future of holographic projection technologies [9]. Reading this book is recommended to all interested people. These predictions include the application of this technology in cellphones, television sets, computer games, billboards, simulation and education. Some other sections of this book discusses about the potential of this technology in different fields, for instance this technology can greatly help traffic police to show the traffic signs. It can also help people to have a virtual trip. In another section of this book, which is far beyond our imagination, the author predicts that holographic images will be used as clothing and even make-up in the future. Although, nowadays holographic 3D movies and pictures are produced in a way that the observer is surprised, it is predicted that the quality of this science-art will be improved to an extent that it will be impossible to distinguish holographic images from real objects.

6. CONCLUSIONS

Nowadays, holography has so many various applications in different sciences. Due to the improvement of light sources, optical elements, holographic plates and the other holographic recording media, the quality of holographic images has been significantly improved. A report on creating and reconstructing of transmission red-sensitive holograms has been provided. Reviewing optical applications of holography shows that this technology can greatly help scientists. In what follows, this paper discusses the holographic projection technologies of the future. Scientist predicts a very bright future for this technology, and it is predicted that this science-art will find its way from exhibitions and laboratories to the everyday life of the ordinary people.

Acknowledgement - Hereby, the authors would like to thank Prof. Habib Majidi Zolbanin, Ms. Homa Hosseini and Mr. Naser Partovi Shabestari for their helps.

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