Holographic Optical Elements in Silver Halide for Outdoor Decoration

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Abstract

In this research work, ultra fine grain silver halide holographic recording plates used to record Holographic Optical Elements. Very high transparent and high diffraction efficiency is achieved by using the simple and inexpensive holographic dual beam multiple exposure technique for fabrication of symmetric periodic structures in holographic media. Long range periodicity is confirmed with laser light diffraction patterns, optical microscopic image and scanning electron microscopic images. Combination of DPSS laser source, bi-directional RPM controller and Holographic Optical Elements results proto type product called HOLO- SHOWER. Working principle and application of this proto type product described in detail. Our auspicious aim is to commercialize our product from our research.

Key words: Circular periodicity; Decoration; diffraction grating; Holography; Holographic optical elements; Light – shower.

1. Introduction

The projection of interference patterns is an interesting technique for recording periodic structures because the interference pattern is three dimensional. Thus, volumetric structures with dimensions of tenths of nanometre can be recorded, simultaneously in areas of several squared centimetres [1, 2]. Holography is one of a promising and inexpensive technique to fabricate large area and defect free periodicity [3]. Dual beam multiple exposure holographic technique is one of a simplest methods for periodicity fabrication compare to three beams, four beams interference and other methods [4]. Two beams interference technique possesses many advantages over the commonly used multiple beam interference technique, such as easy to fabricate different structures and high contrast between the minimal and maximal intensities of interference pattern due to the identical polarization of two laser beams interference area. Recently several groups have employed in this technique [5-7]. Recording and reconstruction of whole information of the objects play an important role in holography for beautification. The three – dimensional image recording in holographic photosensitive material paid great attention for the last few decades [8]. Our positive aim is to utilize the holographic optical elements for outdoor night time decoration by using three different wavelength lasers light and combination two symmetric periodic structures. For this, our research group developed a proto type product called HOLO – SHOWER. In this, we used circular and sqaure symmetric Holographic Optical Elements (HOEs) combine with bi-directional RPM controller and 100mW diode pumped solid state (DPSS) green wavelength laser source. HOLO – SHOWER is mainly used for beautifying front side of buildings, night parties, disco clubs, shopping malls, etc from its HOEs laser light diffraction. Experimental procedure for recording circular and square symmetric periodic structure of HOEs and their role in HOLO – SHOWER are explained in detail in next part.

2. Theory

When two beams of coherent equally polarised monochromatic optical plane waves of equal intensity intersect with each other, a standing wave pattern will be formed in the region of intersection. The combined intensity distribution forms a set of straight equally spaced bright and dark fringes. Thus holographic photosensitive plate would record a fringe patterns, a sinusoidal varying interference pattern is found at the surface of a substrate placed perpendicular to these planes. Dual beam interference pattern forms a series of straight parallel fringe planes, whose intensity maxima and minima are equally spaced throughout the region of interference. So the plane grating recorded. Multiple -

interference on the same plate with different angular rotation creates overlapping of plane gratings will result different symmetric patterns.

3. Experimental Arrangement

The experiment part is divided into two. One is recording of circular symmetric patterns and the other part deals with the recording of square symmetric patterns. For the fabrication of both symmetric patterns the same experimental set up is adopted.

3. 1. Circular and square symmetric HOEs

He – Ne continuous wave laser of 632.8nm wavelength with 35mW power laser source is used in our experiment to record periodic symmetric structures and name projecting HOEs. Ultimate holographic fine grain 04 emulsion is used in our experiment. The output narrow beam of our laser is divided into two beams by using variable density beam splitter (BS). The BS controls the required intensity ratio for the divided two beams for optimal beam ratio for HOE recording. The separated 0.8mm diameter narrow beams were directed from the front coated broad band Aluminium mirrors (M1 & M2) to the recording plate with desired angle (Θ). The separated beams are called object and reference beam. The object and reference beams were expanded and spatially cleaned by pin – hole with lens arrangement called spatial filter. The optically cleaned beams were collimated by using two collimating lenses (L1 & using two collimating lenses (L1 & L2). The collimated two beams are interfered at the recording plate (HP) at certain angle (θ) with equal intensity for circular symmetric periodic structure creation. Ultimate holographic ultra fine grain emulsion is used for recording. The grain size of the holographic silver halide emulsion is 4nm, has spectral resolution of 20000 lines / mm, and has wavelength sensitivity in 610nm – 660nm and exposure sensitivity of 200μJ/cm^2. Diffraction efficiency and transmission of these plates are very high compare to other commercially available silver halide holographic plates. Hence we used this plate for our experiment. We adopt two beams multiple interference technique for the creation of circular symmetric pattern and square symmetric patterns. The recording plate holder was fixed with rotational stage (RS), this electronic precision control rotational stage is used for multiple exposures recording of holograms. Uniblitz microsecond exposure controlling electronic shutter (ES) controls the exact exposure of the laser beam on recording plate. Circular and square symmetric patterns creation depends on the number of exposures on holographic plates with optimised angular rotation. The detail description of the patterns was explained in the next part. The whole experimental arrangement was placed on the top of vibration free isolation table and recording was done in dark room condition.

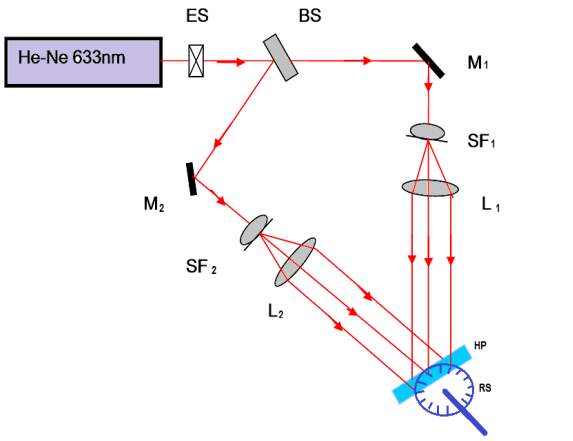

Fig .1: Experimental design

The whole experimental arrangement in schematic is shown in Figure 1. After optimised laser light exposure in the dark room condition, the plates were chemically developed by Ultimate developer for 4minutes, rinse in distilled water for 3minutes and by using ultimate bleach for turn the hologram into phase holograms. After bleach the plates were placed in distilled water for 5 minutes with continuous rinse. Once the chemical process was over, then the plates were kept for one day for natural drying. The result is very clear transparent and high diffraction efficiency holograms. The photograph of the HOEs is shown in Figure .2.

4. Result and Discussion

The circular and square symmetric patterns were recorded in silver halide holographic plate and is shown below

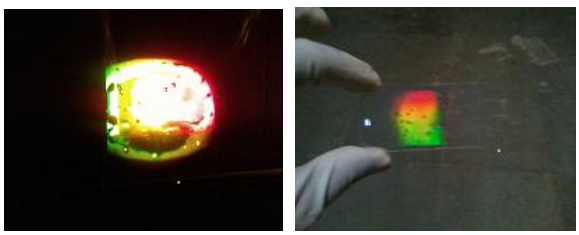

Fig .2: Symmetric pattern holograms after wet chemical processing

4.1. Square symmetric periodic structures

The square periodicity of the recorded holograms were confirmed with the laser light diffraction pattern, Optical microscopic image and Scanning electron microscopic image are shown in Figure .3, Figure .4 and Figure .5 respectively.

Fig .3: Blue laser Light Diffraction

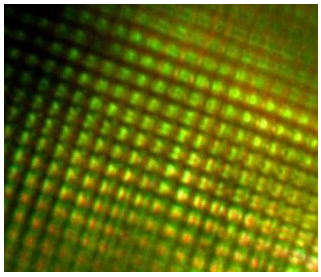

Fig .4: Optical Microscopic Image

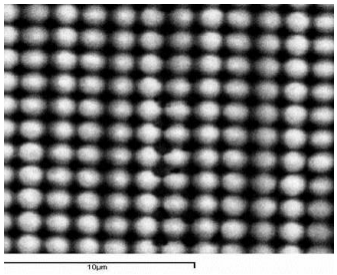

Fig .5: Scanning Electron Microscopic Image

4.2. Circular symmetric periodic structures

The circular symmetric periodic structures were confirmed with laser diffraction pattern, Optical microscopic image and scanning electron microscopic images are shown in Figure .6, Figure .7 and Figure .8 respectively.

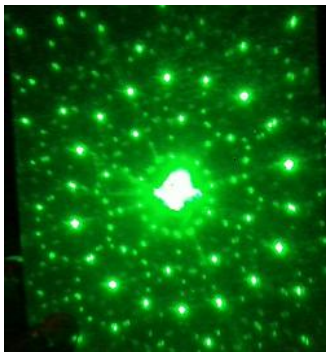

Fig 6: Laser Light Diffraction

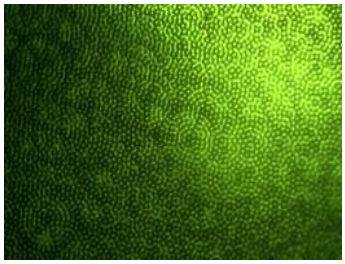

Fig .7: Optical Microscopic Image

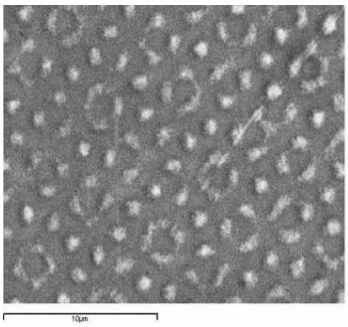

Fig .8: Scanning Electron Microscopic Image

4.3. Combination of symmetric structures

We illuminate one circular structure HOE with three visible wavelengths of Blue (445nm), Green (532nm) and Red (650nm) with the laser power of 200mW, for this illumination we used Diode Pumped Solid State (DPSS) Laser source. The light shower from our proto type product HOLO – SHOWER is shown in Figure .9. The combination of square symmetric HOE with circular symmetric HOE illuminating with two different wavelengths is shown in Figure .10.

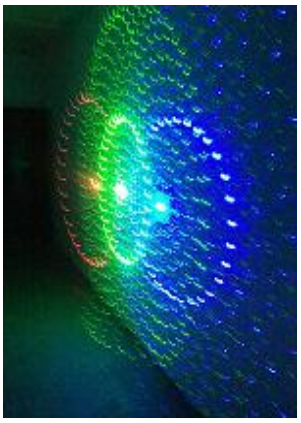

Fig .9: Three visible wavelength laser diffraction circular patterns from single HOE

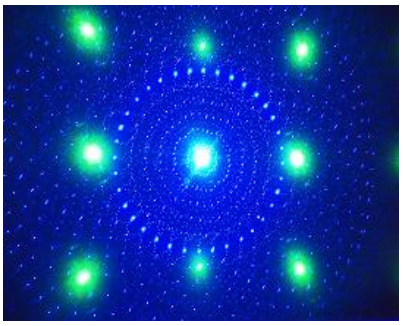

Fig .10: Combination of Square and Circular symmetric HOEs

4.4. Specification of HOLO – SHOWER

The HOLO – SHOWER proto type product is combination of symmetric pattern HOEs, Bi-directional RPM controller and 100mW DPSS laser source is shown in Figure .11 and other specifications are explained in detail.

Fig .11: Proto type HOLO - SHOWER

Dimension: 110 X 65 X 55 mm^3 (Subject to change) **Laser Type:** DPSS laser. **Laser Power:** 100 – 200 mW. **Laser Wavelength**: 532nm, 445nm and 650nm, **Holographic Elements:** 2 different periodic symmetric structures **Power Input:** 12 V AC **Operation:** Indoor and Outdoor decoration by means of symmetric laser light patterns. **Advantage:** Cost effective long range illumination. **Effective illumination range:** 5 X 6 m^2 when HOLO – SHOWER placed at 2metre away from the illuminating surface.

The illumination and the rotation of the HOLO – SHOWER are controlled by means of a Bi- directional RPM controller, made of a Dc motor integrated with a programmable VFD circuit which can be operated in both manual and auto modes.

5. Conclusion

The two different square and circular long range periodic structures created by holographic dual beam multiple interference technique and these HOEs successfully combined with bi-directional controller and laser source to fabricate proto type product for night time illumination for beautification. The proto type product won the commended award for best HOE application in the International Hologram Manufacturer Association (IHMA) holography award 2013. In future research we would like to commercialise our product with cost effective and high withstand of HOE for outdoor application.

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