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# Recording of Holographic Solar Concentrator in Ultra Fine Grain Visible Wavelength Sensitive Silver Halide Emulsion

## Recording of Visible wavelenght Concentrating Hologram

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***Abstract*—Holography is an optical technique which is involved in the solar applications specifically solar concentration. Visible spectrum of solar light concentration on wavelength depended solar cells is effective way to enhance the diffraction efficiency of the solar cells, this is prime aim of this work. Initial step of successful recording of high diffraction efficiency phase holographic optical element were recorded. For this, we used ultra fine grain visible wavelength spectral sensitive silver halide holographic emulsion from Ultimate holography. The novelty of this work is three different laser sources of 442nm, 532nm and 633nm were used for multiplex holographic transmission lens in a same emulsion and applied for solar concentration. We optimize exposure sensitivity for each laser wavelengths and combined wavelengths in order to obtain the multiple band response of the material. The detail study of holographic optical elements recording is explained.**

***Keywords*—Holographic Optical elements, Holography, Solar Energy, Holographic Lens, Wavelength Multiplexing, Diffraction Efficiency, Holographic Lens, Solar Cells.***

## I. INTRODUCTION

Precise knowledge of solar irradiance components at the earth surface is leads to many solar energy applications. India is endowed with rich solar energy resource since it is located in the equatorial sun belt of the earth. The daily average solar energy incident over India varies from 4 to 7 kWh/m$^2$ with about 2,300–3,200 sunshine hours per year, depending upon location. This is far more than current total energy consumption. The annual global radiation varies from 1600 to 2200 kWh/m$^2$, which is comparable with radiation received in the tropical and sub-tropical regions. Thus it is clear that solar power projects are commercially viable in most parts of India. Specifically conversion of solar energy into electric energy is highly important to meet at current energy crises, it is one of the most important and promising application of solar energy for the current world. One of an approach to increase the conversion efficiency of the solar cell is concentration of solar light on the solar cells. Many conventional solar concentrators are involved to concentrate the solar light to enhance the conversion efficiency of the solar cells [1]. Current trends demand that the photovoltaic (PV) concentrators must achieve various goals of lowering costs at all levels and/or increasing the energy yield [2]. Conventional concentrators are complicated and some of it needs cooling and tracking system. Alternative technique of holography is an optical method that can provide a variety of improvements to existing solar energy conversion devices and systems. Holographic Optical Elements (HOEs) are very good example of optical concentrators and have been suggested for use as solar concentrators. The diffraction and the dispersion properties of HOEs are examined for use as solar concentrators for photovoltaic systems [3,4]. Advantage of holographic optical elements are light weight, durable, economical, less expensive, easy reproduction, low cost in terms of mass production and multifunctional, thus holography offers an ideal spectrum splitting for photovoltaic conversion [5]. Holographic Solar Concentrator (HSC) in different holographic emulsion are mentioned here, recently HSC recorded in photopolymer is reported by Sam et al [6] but self life, material availability and stability should be reconsider. HSC in surface relief material has been reported [7]. Stojenoff works related with HSC in Dichromated Gelatin has been reported [8,9]. Almost all the HSC has been recorded by using single wavelength and the holographic emulsion is also sensitive to particular wavelength only. In this work, we used visible color sensitive ultra fine grain holographic emulsion from Ultimate Holography and from our knowledge; this is first time three visible laser sources are used for the fabrication of HSC. We successfully recorded the HSC and its characteristics are discussed in details. HSC capability of concentrating the wanted wavelength of solar spectrum into the desired direction can concentrate light on the wavelengths dependable solar cells and it will help to enhance the system efficiency 30-40%. One of a main advantage of a holographic solar concentrator as compared to a conventional one is seen in the overall reduction of investment cost and in the possibility to generate inexpensive solar electric power [9,10].

## II. Experimental Arrangement

Three laser sources of 442 nm, 532nm and 633nm are used to record the HSC, here we recorded holographic transmission lens as HSC. The detail of the experimental layout is follows. The laser beam is divided into two beams by using variable density beam splitter (BS) and the two divided beams named as reference and object beams. The object beam is redirected from Aluminum front coated mirror (M1) to the recording plate (HP) with the desired angle, in between it was spatially cleaned by spatial filter (SF1) and the distance between HP and SF1 decides the focal length of the Holographic Optical Element. Another beam called reference beam is expanded and specially cleaned by using spatial filter arrangement (SF2) and collimated by lens (L1). The spatially filtered collimated beam and diverging beams are interfered at the ultra fine grain silver halide holographic emulsion at HP. The schematic of the experimental arrangement is shown in figure 1 red wavelength He-Ne laser.

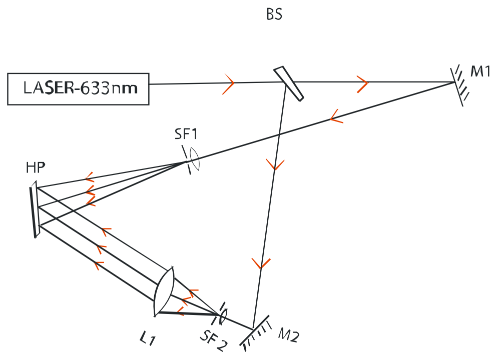


Fig. 1. Schematic of holographic lens recording

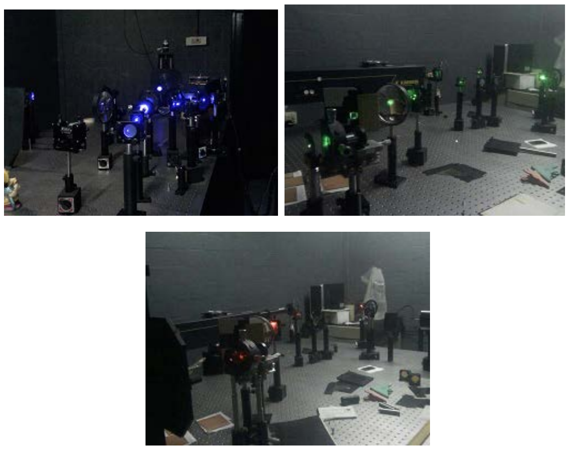

Fig. 2. Experimental Arrangement for Holographic Lens recording in Blue, Green and Red Wavelengths

The Uniblitz electronic shutter allows the interference of the two beams as per their exposure sensitive, it is not shown in the schematic. Again the same procedure followed for other two laser sources of wavelengths 442nm and 532nm by replacing the laser sources without disturbing the optical layout. Initially experiments were carried out to optimize the exposure sensitivity for each laser source by trial and error methods, once it was optimized for all the three wavelengths, then calculated the right exposure sensitivity for all the three wavelengths. The exposure sensitivity is optimized by trial and error method for all the laser sources separately as well as combined. The whole experimental set up is arranged on the top of vibration isolation table and it is shown in figure 2. The recorded wavelength dual – beam multiplex transmission holographic lens is processed by developer - bleach combination as phase hologram. The obtained results are discussed in result and discussion section. The same experiment is followed for other two lasers too and the beams are interfered at the same area of the plate. The recorded interference patterns under the safe light condition with optimized laser exposures is processed by developer - bleach combination.

## III. Result and Discussion

High diffraction efficiency of over 50% was recorded and also high visible transmission was achieved by using Ultimate developer and modified rehalogenating bleach combination. High diffraction efficiency of hologram is achieved by using Silver Halide as a phase modulation material that is bleached holograms. We modification R10 bleach from the standard bleach by only chemical concentration, we used Pottasium Dichromate (1g), Pottasium Bromide (35g) and Sulphuric Acid (1ml). The recording of holographic solar concentrator in three laser wavelengths multiplexed on a single element is first time reported as per our knowledge. The advantage of holographic solar concentrator is spectrum splitting and concentration but here we have split the spectrum and paid attention for concentration of specific wavelengths on visible

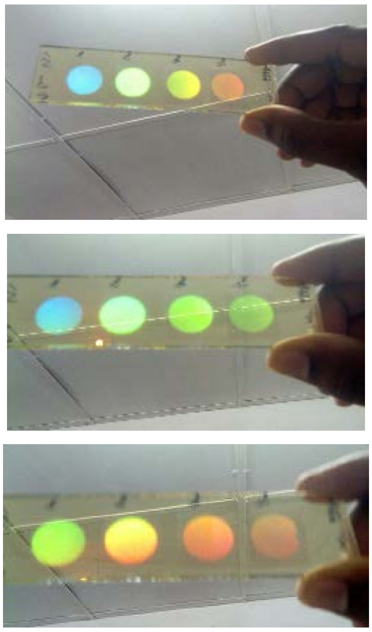

Fig. 3. Transmission Holographic Lens Recorded by Three Visible Laser Wavelengths.

wavelength dependable solar cells. Exposure sensitivity of the plate for all three wavelengths was inspected by exposed the plate separately ranging from 100µJ/Cm$^2$ to 2000µJ/Cm$^2$. Also exposure of the HSC was performed sequentially, starting with the blue wavelength of 442nm, followed by the green wavelength of 532nm and ending with the red wavelength of 633nm. A set of HSC with different exposure energy combinations for each wavelength was obtained, ranging from 120 through 225µJ/Cm$^2$ for the He-Cd laser, 150 through 225µJ/Cm$^2$ for green wavelength DPSS laser and 500 through 1000µJ/Cm$^2$ for the He-Ne laser. The recorded HSC is shown in figure 3. These HSC is applied to concentrate the specific wavelength on the wavelength dependable solar cells is continuous in further development of this. This will without doubt enhance the conversion system efficiency to 30-40%. We proposed this wavelength multiplexed holographic optical element with high efficiency as well as its spectrum splitting and focusing property can be applied for HSC. Spectrum splitting of HSC is shown in Fig. 4.

Fig. 4. Spectrum splitting of Holographic Solar Concentrator

## IV. Conclusion

A Panchromatic silver halide holographic emulsion used for the fabrication of wavelength multiplexed holographic solar concentrator. We optimized the exposure sensitivity of the material separately for blue, green as well as red and also for combined wavelengths. Here we proposed the multiplexed element applied for concentrating the solar radiation to enhance the conversion efficiency of the cascade wavelength dependable solar cells. Also this material can be used to manufacture cost effective holographic beam combiner as well as color display holograms and photonic crystals. Further progressing research is going on for the device engineering.

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