International Journal of Physics and Applications.
ISSN 0974-3103 Volume 5, Number 2 (2013), pp. 115-120

http://www.irphouse.com

Compound Holographic Optical Element System for Splitting and Concentrating Solar Spectrum on Laterally- Arranged Multiple Band Gap Solar Cells

Asghar Khan, N.R.Chakraborty and H.L.Yadav

Assistant Professor, Department of Physics
Karim City College, Jamshedpur
khanasghar047@gmail.com
Associate Professor, Department of Physics
Kolhan University, Chaibasa
nil_c53@yahoo.co.in
Associate Professor, Department of Physics, NIT Jamshedpur
Corresponding author: hly_physics@rediffmail.com

Abstract

In present work a compound holographic system consisting of a diffraction grating and a holographic lens has been fabricated to disperse and focus different portion of solar spectrum on laterally arranged solar cells of different band gaps to achieve maximum efficiency operation. Such concentrators are light–weight, low-cost and do not require tedious processing for their mass production.

Key words: Dispersive concentrating system, Compound holographic optical Element, Holographic concentrator, Diffractive optical system

Introduction

To reduce the cost of solar photovoltaic power generation use of concentrators is an attractive proposition. This scheme replaces costly solar cell area with relatively low-cost smaller concentrator area still achieving same out-put power. However, such concentrators concentrate the entire solar spectrum on cells. The portion of solar radiation which does not match the band gap of solar cells degrades the absorber material by overheating. This also leads to fall in efficiency of performance of solar cells. To get rid of absorption of unwanted portion of solar spectrum, spectral splitting and their concentration on laterally arranged multiple band gap solar cells has been proposed and are being extensively investigated both using conventional optical elements and holographic optical elements [1-9].

In present work a compound holographic optical element system consisting of holographic grating and a holographic lens has been fabricated on a single high resolution holographic plate (PFG01). Spectrum of white light diffracted through recorded compound system has been presented. To show the effectiveness of such system in laterally arranged solar cells of different band gap a laboratory test was carried out by concentrating different portion of solar spectrum on a photocell. Stopping potential was measured for spectrum of different wavelengths (frequencies) so as to determine Planks constant (h).

2. Recording and play back geometry of compound holographic optical element system

Recording of interference pattern generated due to coherent superposition of a spherical wave coming out of a point source and a plane wave front gives rise to an off axis zone plate which is regarded as a holographic lens(10-11). Whereas, holographic grating is recording of interference pattern of two coherent plane waves in a high resolution recording medium. (12-13)

For recording compact dispersing concentrating holographic system a high resolution silver halide film was exposed to resulting interference pattern of coherent superposition of two plane wave fronts to record a grating in first exposure using experimental setup as shown in figure 1.Second exposure was made on the same film at the same location where plane wave front remained the same as before but collimating lens from one of the path was removed from object beam to make object beam a spherical wave front as shown in Figure-2.The doubly exposed recording plate was processed using reversal bleach method [14] to get the compound system.

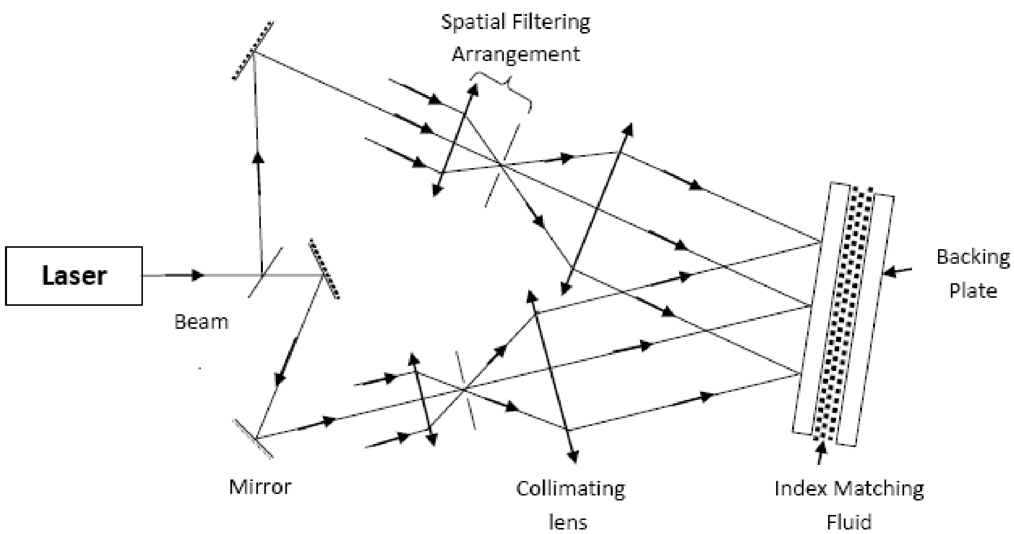

Fig.1- Schematic of the geometry for recording Holographic grating during first exposure

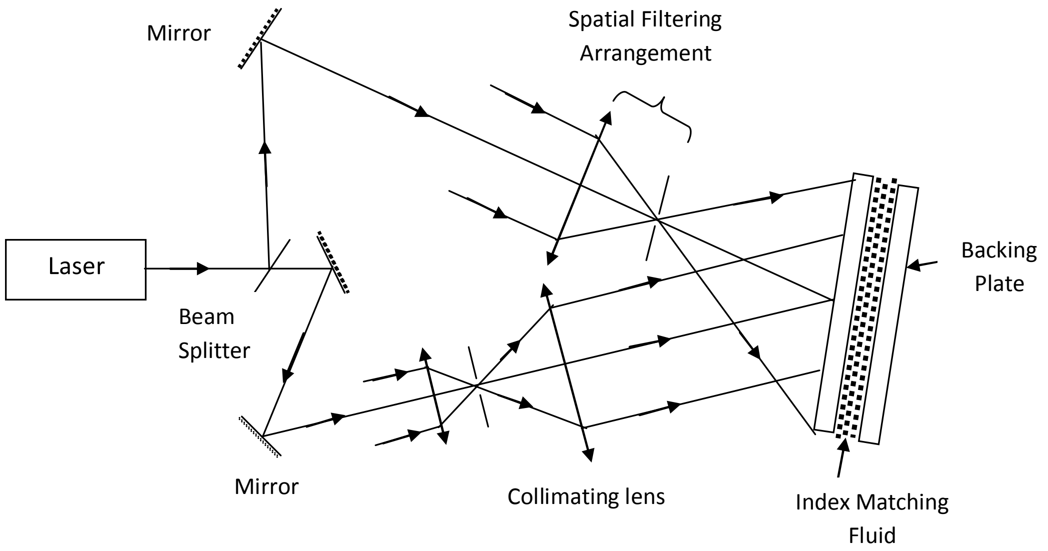

Fig.2- Schematic of the recording geometry for Holographic lens during second Exposure

Experimental:

The recorded compound system was played back using mercury vapor lamp to show effectiveness of spectrum splitting and its concentration (fig3). Figure 4 shows spectrum of mercury vapor lamp diffracted through a holographic lens. Figure 5 shows spatially separated focused line spectrum when mercury light passes through the compound holographic system consisting of a grating and a lens.

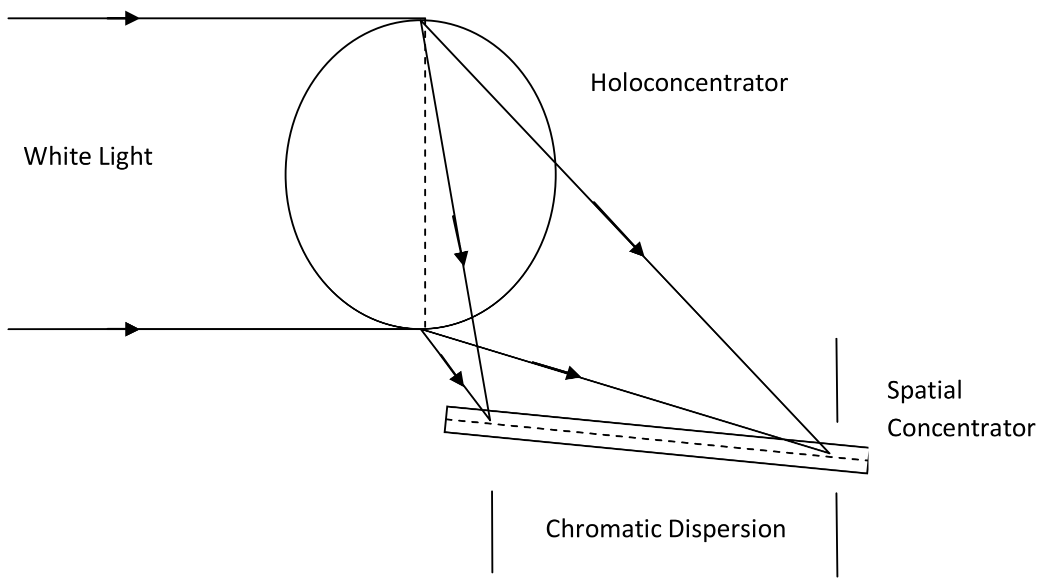

Fig.3- Schematic of reconstruction setup of holographic concentrator in white light

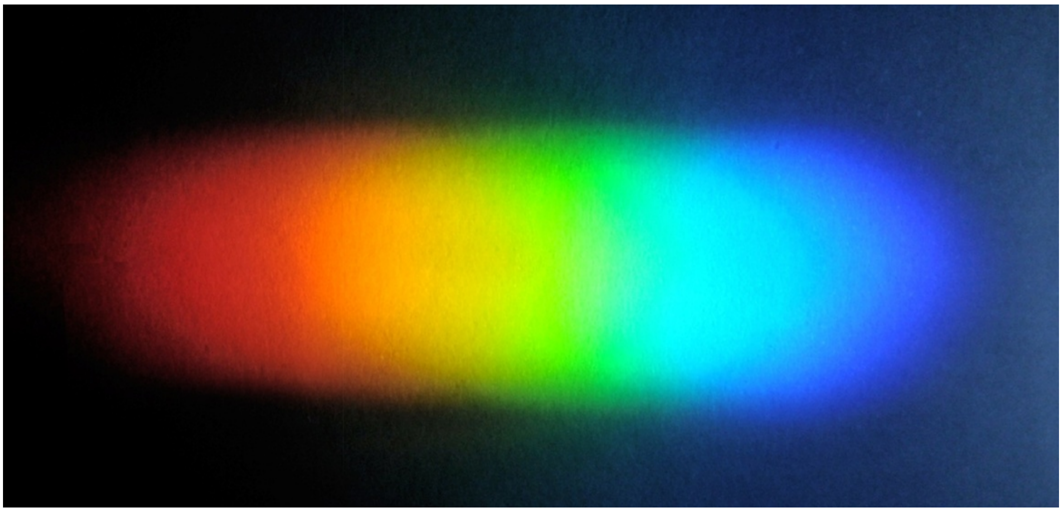

Figure 4 spectrum of mercury vapor lamp diffracted through a holographic lens.

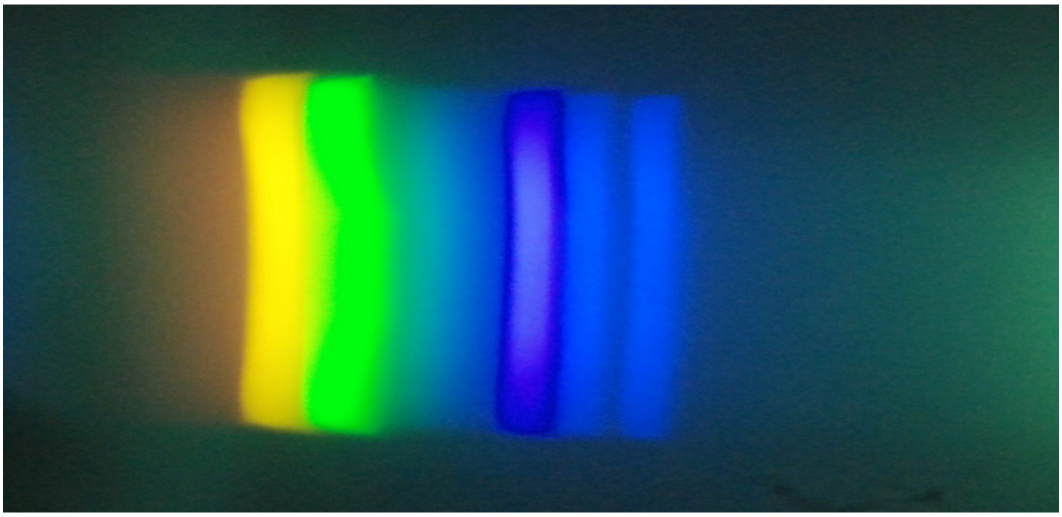

Figure 5 spatially separated focused line spectrum obtained from a stacking of conventional grating and a conventional conversing lens

Result and Discussions

Focused spatially separated line spectrum was further used in photoelectric effect experiment to obtain stopping potentials of target material (cesium) of the photocell at different optical frequency. Values of stopping potentials at different wavelengths were used to find value of Plank's constant. Table 1.Presents stopping potential of target material at different frequencies.

Sl.No.	Colour of spectrum	Frequency in Hz	Stopping potential in Volts
1	Violet (ν_1)	7.14 X10^{14}	1.164
3	Blue (ν_2)	6.88 X10^{14}	0.950
4	Green (ν_3)	5.49 X10^{14}	0.373
5	Yellow (ν_4)	5.19 X10^{14}	0.248

From Einstein Photoelectric equation

$$h\nu_1 = h\nu_0 + eV_1 \quad (1)$$
$$h\nu_2 = h\nu_0 + eV_2 \quad (2)$$
$$h\nu_3 = h\nu_0 + eV_3 \quad (3)$$
$$h\nu_4 = h\nu_0 + eV_4 \quad (4)$$

From equation(1) and equation(2)

$$h(\nu_1 - \nu_2) = e(V_1\text{-}V_2)$$

therefore,

$$h = e(V_1\text{-}V_2) / (\nu_1 - \nu_2)$$

Also,

$$h = e(V_3\text{-}V_4) / (\nu_3 - \nu_4)$$

Calculated value of h was found to be 6.46X10^{-34} J-Sec.

Conclusion

The present investigation shows that such light weight, low cost holographic system can advantageously used for laterally arranged solar cells of matched band gap to get appreciable efficiency of solar photovoltaic power generation.

References:

[1] Jackson ED. Areas for improvement of the semiconductor solar energy converter. In Transactions of the conference on the use of solar energy. University of Arizona Press. Tucson, Arizona, 1955;122.
[2] Jackson ED. Solar energy Converter.US Patent 2, 949, 498, August 16.1960.
[3] Moon RL, James LW, Vander Plas HA, Yep To, Antypas GA, Chai Y. Multigap solar cell requirements and the performance of AlGaAs and Si cells in concentrated sunlight. Conference record of the 13th IEEE photovoltaic specialists conference. Washington, 1978;859-867.
[4] Ludman JE. “Holographic solar concentrators “ Appl. Opt.21, 1982, pp-3057.

[5] Hull, J.L., Lauer J.P., Broadband, D.C, “Holographic solar concentrators “, Proc.SPIE, , 1987, 692, pp-68.
[6] Bloss, W.H., Griesinger, M., Reinhardt, E.R, “ Dispersive concentrating systems based on transmission phase holograms for solar applications”, Appl.Opt, 21, 1982, pp-3739.
[7] Shakher C., Yadav HL, “ Dependence of diffraction efficiency of holographic concentrators on angle of illumination, hologram-thickness and wavelength of illuminating light” J.Opt(Paris).21, 1990, pp-267.
[8] Martin A. Green and Anita Ho-Baillie, “ Forty three percent composit split spectrum concentrator solar cell efficiency” Prog. Photovolt: Res. Appl2010, 18:42-47.
[9] D.A.Caselli and C.Z. Ning, “High- performance laterally arranged multiple-bandgap solar cells using spatially composition graded CdxPb1-x S nanowires on a single substrate:a design study, Optic Express, vol 19, noS4, A686, 4July 2011.
[10] M.H. Horman and M.H.M Chau, “ zone plate theory based on holography”, appl. Opt. 6, 317(1967).
[11] A.K. Richter and F.P. Carlson, “ holographic generated lens”, Appl.opt 13 2924, (1974).
[12] G schmal and D. Rudolph, ” Holographic diffraction gratings.” In progress in optics. 14, 197 (1976).
[13] D. Peri, and A.A. Friesam, “ image resolution using volume diffraction gratings. Opt. let. 3 124 (1978).
[14] H.T. Buschmann, “ The production of low noise, bright phase holograms by bleaching”, optic, 34240 (1971).