Low–Cost Holographic Concentrator for Photovoltaic Cells Application

Adnan Salih Al-Ithawi*, Asmaa Jawad Kadhim Al-Kinani

Department of Physics/College of Science for Women/Baghdad University, Iraq

Article history:
Received: 29 April, 2014
Accepted: 07 May, 2014
Available online: 01 December, 2016

Keywords:
Holography, concentrator, Holographic solar concentrator

Corresponding Author:
Prof. Dr. Al-ithawi. A.S.*, Email: dradnan_salih (at) yahoo (dot) com
Dr. Al-Kinani. A.J.K.
Lecturer

Abstract
To reduce the cost of solar photovoltaic power generation used 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. In present work a holographic optical element 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 concentrator is light–weight, low-cost with diffraction efficiency 63%. The hologram was used with dye sensitized solar cell (DSSC), the efficiency of the solar cell increased by 2X.

Citation:

All Rights Reserved with Photon.

1. Introduction

Photovoltaic cells are one of the most potential alternative sources of energy. Photovoltaic cells can directly convert solar energy into electrical energy. The overall efficiency of conversion is obviously connected with the efficiency of photovoltaic cells, but first of all with the optical system which ensures the transfer of sunlight on the cell array. Different kind of solar cells are sensitive to different region of the solar spectrum. Such solar cells do not make full use of the incident solar energy. The part of radiation not used by the solar cells causes deterioration in the performance characteristics, particularly as a result of overheating and degradation of collector material (solar cells).

One of the main problems confronting photovoltaic energy systems is the cost. To emphasize this issue the National Academy of Engineers has made reducing the cost of photovoltaic systems its number 1 grand challenge in engineering. Two of the main approaches to reducing the cost of Photovoltaic are: 1) implementing large centralized concentrator systems that replace costly photovoltaic materials with less expensive solar collectors; and 2) fabricating low cost thin film materials for distributed energy collection systems. Both approaches are viable techniques however another approach is also possible that uses low concentration (2-10X) optical collectors in combination with moderately priced photovoltaic devices. This approach reduces the required volume of photovoltaic material to produce a fixed amount of power and energy at a lower overall system cost (Kostuk et al., 2009).

The dispersing and focusing properties of holographic optics can be exploited for producing concentrators which can make photovoltaic cell systems relatively cheaper. The attempt to increase the effectiveness of solar cells of different band-gaps led to the development of wavelength selective concentrators which can concentrate different region of the solar spectrum at different location on the collector plane. These concentrators are used with solar cells having the corresponding spectral sensitivity. The selective concentration for photovoltaic cell array of different band gaps is usually accomplished by a dispersing element or dielectric filters. The use of concentrator photovoltaic solar cells reduces the cost of solar cells by replacing costly solar cell area with relatively cheap concentrator area. However, as the concentration goes on increasing the tracking of the daily movement of the sun becomes more involved.
Therefore, for designing efficient photovoltaic solar panels, the three factors, e.g., solar concentration, splitting of solar spectrum, and tracking of daily movement of the sun should be taken into account simultaneously. Holographic optics can provide a solution to these problems (Ludman et al., 1982; Kubitzek et al., 1987; Ranjan et al., 2009).

Holographic optical elements have long been considered for use as solar concentrators (Ludman et al., 1982; Zhang et al., 1988). Some of the advantages of holographic optical elements include high diffraction efficiency in a single diffraction order, broadband angular and wavelength response with thin layers, and the ability to multiplex different holograms in the same recording material. One of the issues with respect to holographic concentrators requiring additional study is how to evaluate their benefit relative to standard flat panel and concentrating solar energy systems. This can be achieved by combining hologram properties into a model that in turn predicts total energy production from specific photovoltaic system configurations. In this work, a holographic optical element is generated by recording interference pattern of a plane wave and a spherical wave derived from the same laser source on a high resolution film (Dichromate gelatin film fabricated in this work).

2. Experimental part

The collection of light from a moving source (such as sun) which exhibits a broad spectral range of wavelengths is a complex process. Holographic optical elements have the capability to perform a range of functions in one element thus providing a potential solution to this problem without the need for tracking or mechanical movement. There are materials that are capable of appropriate recording of holographic solar concentrators. They include dichromated gelatin, photo-resist and photopolymers. Dichromated gelatin is a good photosensitive material for recording a holographic solar concentrator as it can provide high diffraction efficiency over quite large bandwidths apart from being quite cheap.

2.1 Dichromate gelatin film fabrication

There are many materials that may be used to fabricate holograms. Dichromated gelatin is typically used in solar holography because this material can have high efficiency in thin layers. Dichromated gelatin is totally grainless and fully transparent, can produce diffraction efficiencies of around 90% with negligible scatter, and can be made to play back at any desired wavelength with either a broad or a narrow bandwidth. The medium requires careful control of humidity, temperature, as well as clean room conditions.

One can produce these plates in the laboratory. The emulsion consists of gelatin powder (7g), and water (100ml). The mixture was heated and pipette out on leveled optical glass slide. The gelatin film then soaked in a solution of 6% (NH\textsubscript{4})\textsubscript{2}Cr\textsubscript{2}O\textsubscript{7} in water.

2.2 Recording and reconstruction of holographic concentrator

Holographic concentrators are off-axis Gabor zone plate (Gabor., 1948; Horman et al., 1967; Schwar et al., 1967) recorded optically. Many recording and reconstruction geometries for recording holographic concentrators have been suggested. In this work, a holographic optical element is generated by recording interference pattern of a plane wave and a spherical wave derived from the same laser source on a high resolution film (Dichromate gelatin film fabricated in this work).

2.3 Measuring HSC efficiency

The purpose of the holographic element is to diffract sunlight with a broad range of incident angles and wavelengths to the PV cell regions. The hologram should also efficiently diffract scattered and diffuse light to the PV cell regions. The diffraction efficiency is defined as light diffracted by the hologram relative to light incident on the hologram. After developing process, the hologram was reconstructed, and the diffraction efficiency was calculated by measured the intensity of zero and first orders in reconstruction step. For this particular hologram, the diffraction efficiency at 532 nm was found to be 63%.

3. Results

The recorded holographic optical element was also played back using white light lamp and sun light to show effectiveness of spectrum splitting and its concentration.

3.1 Reconstruction with white light

The parallel radiation from the white light lamp is diffracted by the hologram resulting in a figure (1), shows that diffraction is stronger for longer wavelength and a spectrum is formed. This has the advantage that appropriate photovoltaic cells can be installed for different spectral regions.
Figure 1: spectrum of whit light lamp diffracted through a holographic element

3.2 I-V characteristic of DSSC under HSC
I-V characteristics of solar cells in a concentrator are highly dependent on the concentrator. It is influenced both by the total irradiation on the cells and on how the light is distributed over the cells. If the concentrator is to be used for photovoltaic applications it is important to measure these characteristics in the concentrator to be able to estimate the efficiency of the complete system. The hologram was used in the field with dye sensitized solar cell, the efficiency of the solar cell increased by 2X as shown in fig (2).

Figure 2: I-V characteristic for solar cell

Conclusion

The present work shows that such light weight, low cost holographic optical element can advantageously used with solar cell to increase the efficiency of solar photovoltaic power generation.

Acknowledgment

We are grateful to college of science for women, department of physics for providing characterization facility for our experiment work.

References


For publications/ Enquiries/ Copyrights:
Email: photonjournal@yahoo.com