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Design of Hexagonal Micro Lenses Array Solar Concentrator

Alaa Bader Hassan , Sabah Ali Hussein

Department of Physics , College of Education Ibn Al-Haitham for Pure Sciences , University of Baghdad,Iraq

ABSTRACT: Hexagonal micro lenses array have been designed by using Zemax Optical design software to increase the efficiency of solar cell by technique of light trapping of concentrated solar radiation. Light focused by lenses at focal plane that slits are placed, to allow light passing through it into solar cell. The mirror slices make light reflected many times at cell edges, and the chance to light escape outside the cell very small, because of the slits making long optical path into the cell, and then increasing absorption of photons.
The results show superior detector measurements of solar system that have slit of (0.1 mm) , and acceptance angle of (25^o) that give acceptable efficiency of solar system .

KEYWORDS : micro lenses array, trapping system , solar concentrator, zemax

I. INTRODUCTION

The most important solar system is solar concentrators which deal with solar radiation to increase the efficiency of solar cell [1]. The benefit of solar concentrator is to reduce the effective area of receiving surface. The system of light trapping uses slits to passing through it to solar cell and mirrors to increase the internal reflection of solar radiation [2].
In this work; Trapping light concentrator system has been designed, including Hexagonal micro lenses array (10x10 lenses) of area (10 cm^2) that has packing factor (100%) concentrate light at focal plane where slits are placed for light passing through it into the solar cell, and reaching the lower part of the system (detector) which made of mirror to achieving internal reflections and increasing optical path , consequently increasing photons absorption . Figure (1) shows the parts of solar concentrator system and the technique of light trapping.
Light concentrator system has been interested by researchers and designers, which is .nimportant to improve solar systems. H. K. Jason and E. J. Tremblay present an orthogonal concentration method to further confine sunlight within planar solar collectors [3]. J H. Karp and J. E. Ford used conventional concentrator photovoltaic (CPV) systems focus sunlight directly onto a PV cell micro-optic waveguide concentrator's sunlight is coupled directly into the waveguide without absorption or wavelength conversion [4]. K. Tvingsted et al, demonstrate a novel light trapping configuration based on an array of micro lenses in conjunction with a self aligned array of micro apertures located in a highly reflecting mirror [5].

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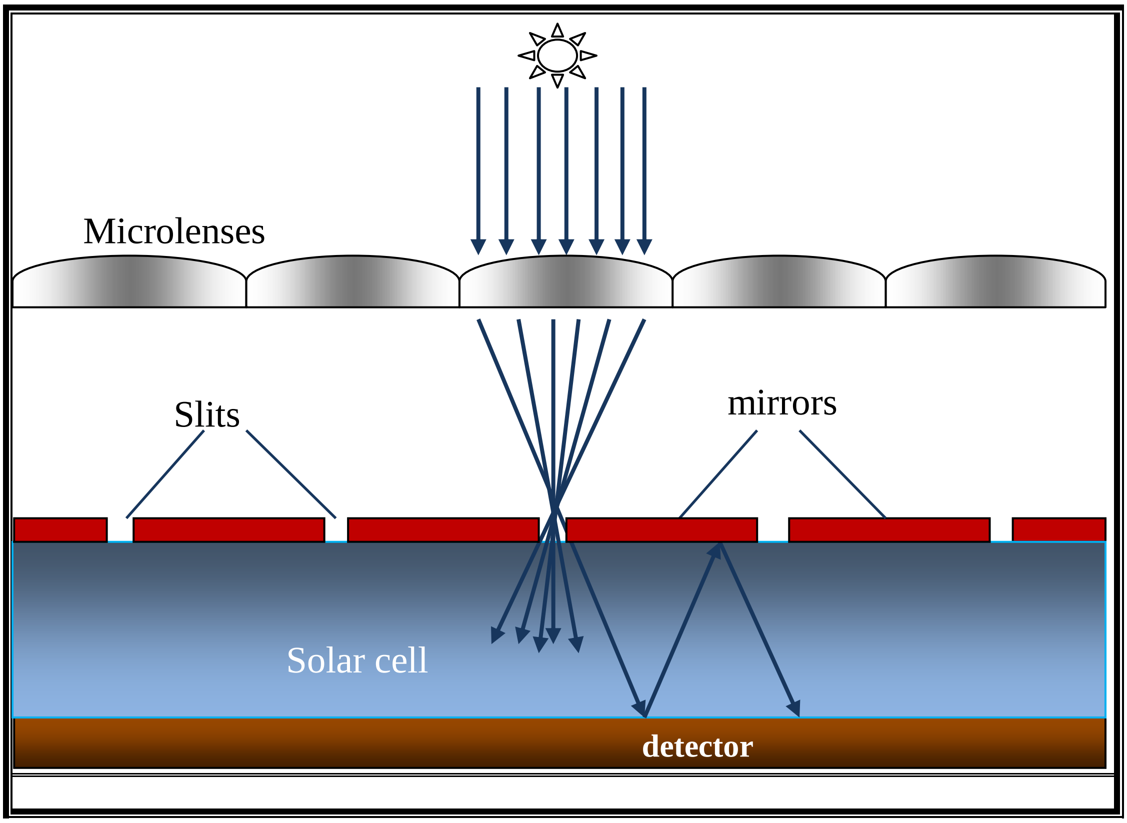

Figure (1): trapping light of solar concentrator system

II. OPTICAL DESIGN

Zemax optical design software has been used to study the effect of solar concentrator which put on the upper part of the optical system, To study the effecting of (1000 rays) and (1watt) from the source (sun) and measuring the effect by detector which reads the total hit of rays and total power after experiencing multi reflection between the slices and the lower part of Solar cell where the detector is fixed.
The material of lenses is N-BK7 which has a broad Spectral Transmission and high heat resistance. Silicon which has band gap matching photon energy of Solar radiation has been used to design Solar cell.

III. RESULTS

To evaluate the efficiency of the optical system used the detector viewer that using in non sequential ray tracing mode in zemax program. the light hit the detector many times by internal reflections, then increasing total rays that hit the detector; increasing photon absorption due to increasing optical path.
To measures total hit (T .H) and total Power (T .P) and irradiance distribution (E_e) of the rays that entering the optical system give clear picture about efficiency of the system.
Figure (2) illustrate detector measurement of different width of slits for variable incidence angle of trapping system, to evaluate effect of slits width and acceptance angle (The maximum angle that give a good efficiency and it is very considerable for solar concentrator).
The figure (2) illustrate the maximum values of detector measurements at normal incidence angle ($\theta = 0^\circ$) of all used samples which has different slit width (0.1-1mm) with different incident angle (0°-70°) , The acceptance angle of (25°) for all samples. The Figure illustrates priority of slit (0.1 mm) and then (0.2 mm) and so on. Because the narrower slit make maximum trapping so decreasing ray escaping chance out the system.

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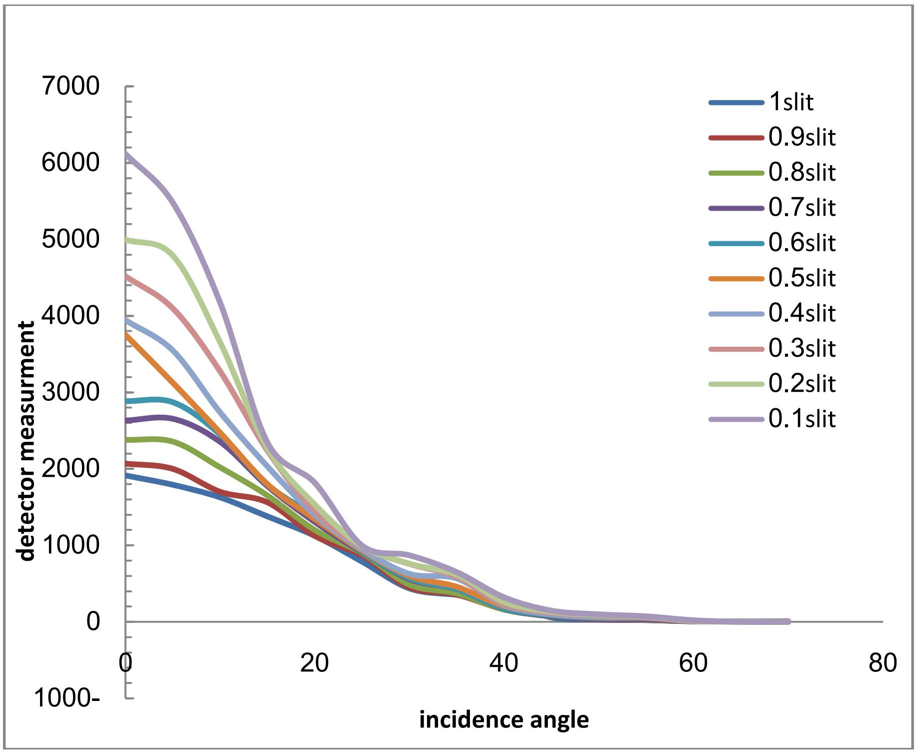

Figure (2) :detector measurements of different slit width at different incidence angle

Figure (3) illustrates detector measurements for trapping solar system has different thickness (1 – 5 mm) of solar cell at different incident angle. the difference of cell thickness may be used in multi layers cell that has broad spectral absorption. The figure shows priority for cell sample of thickness (1 mm) and decreasing the detector measurements by increasing incident angle.

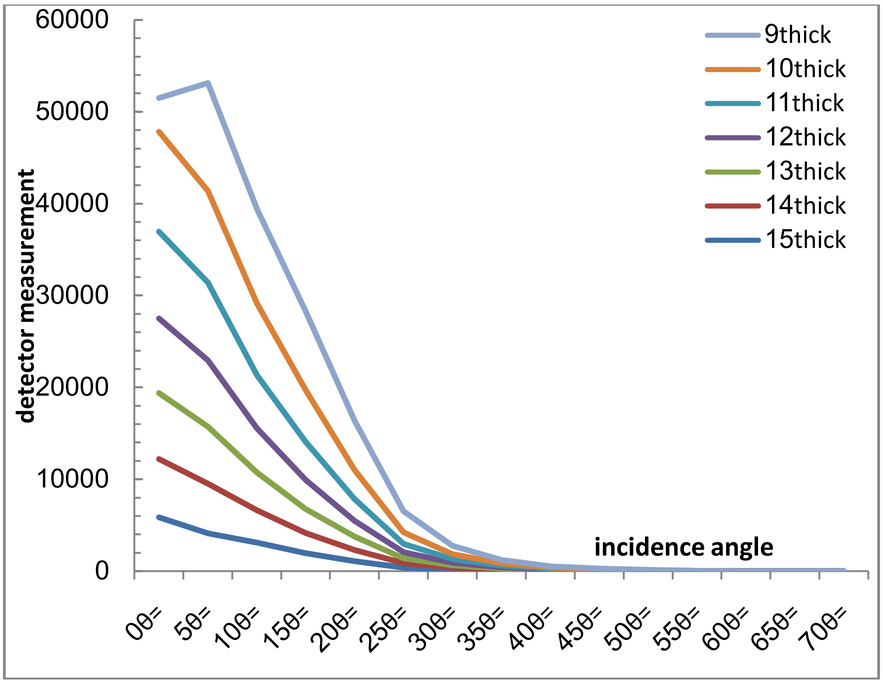

Figure (3): detector measurements of different thickness at different incident angle

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Figure (4): shows the relation between cell thickness and slit width in samples and illustrate gradient the curves gradually when increasing values of slit width and thickness .
Figure (5) : illustrate increasing total power that reach the detector when decreasing slits width at different angle and when decreasing incident angle at different slits width , Figure illustrate the curves decreases gradually when increasing values of angle and slits width.
Figure (6) :illustrate the variation of irradiance distribution (E_e) on the detector of each sample at different slit width and at different angle . the figure shows degradation of irradiance distribution when incidence angle is increased, and showing zigzag curves because of random ray incidence at detector, and limited number of ray has been investigated in the system (1000 rays).

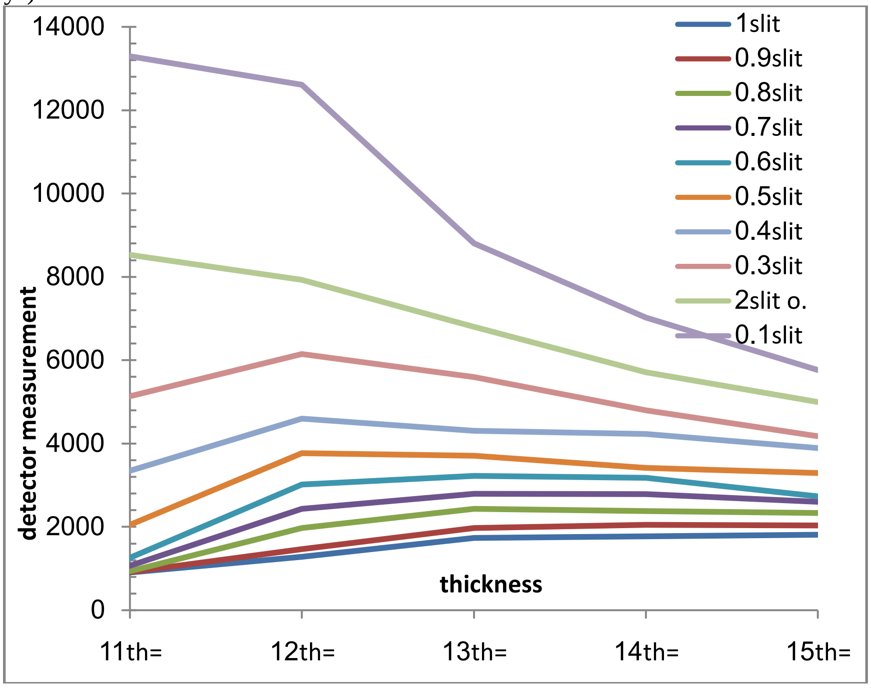

Figure (4): detector measurement of relation between thickness of the cell and slits width

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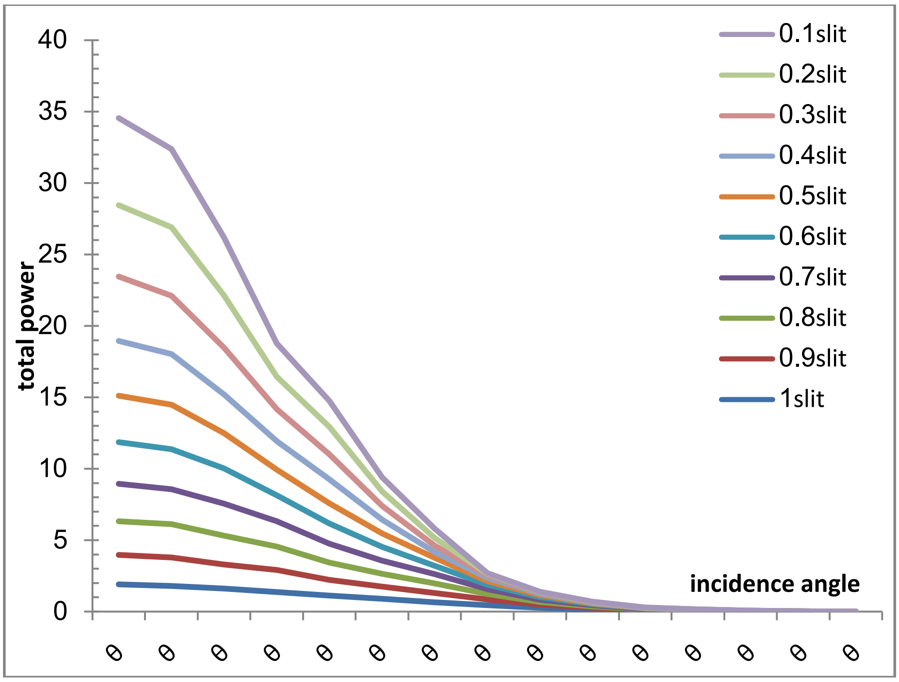

Figure (5) :total power of different slit width at different incident angle

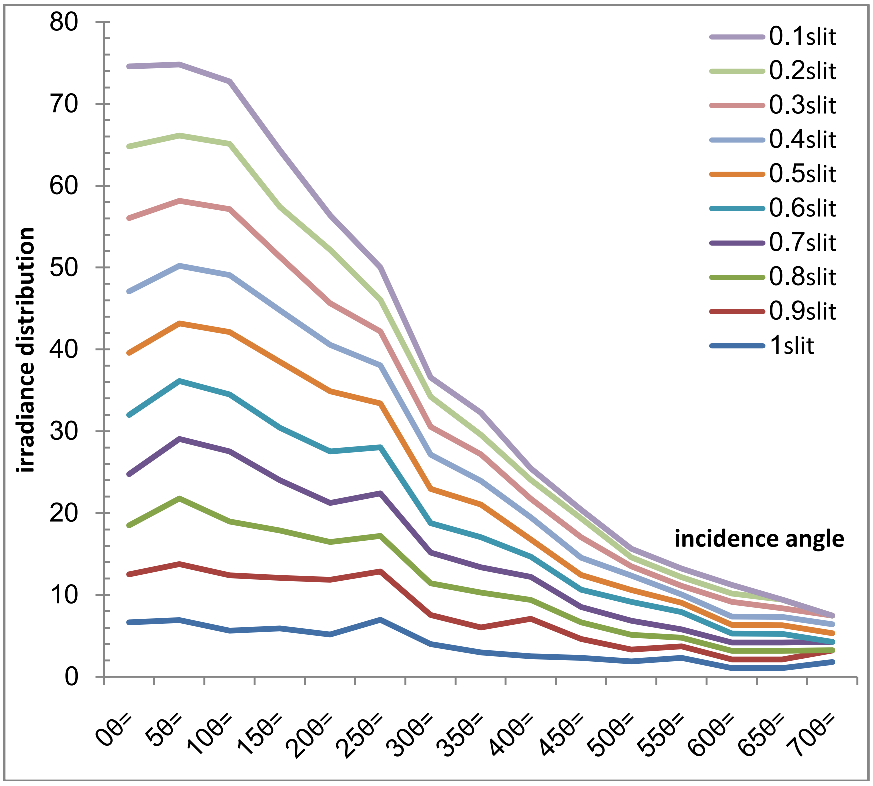

Figure (6): irradiance distribution of different slit width at different incident angle

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AUTHOR'S BIOGRAPHY

Name : Alaa Badr Hasan
Age : 45 years
Gender : male
Address : Baghdad, Iraq
Certification : Ph. D
Occupation : university teacher
Scientific title : Assistant professor
Occupation address: university of Baghdad
Specialization : physics / electro-optics
Language : Arabic & English