Design of Light Trapping Solar Cell System by Using Zemax Program

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Abstract: square micro lenses array have been designed (by using Zemax optical design program) to concentrate solar radiation into variable slits that reaching light to solar cell. This technique to increase the efficiency of solar system by trapping light due to internal reflection of light by mirrors that placed between upper and lower side of solar cell, therefore increasing optical path through the solar cell, and then increasing chance of photon absorption. The results show priority of solar system that have slit of (0.2 mm), and acceptance angle of (20°) that give acceptable efficiency of solar system.

1. Introduction

Solar concentrators are most important solar system that deal with solar radiation and incident angle to increase efficiency. There are many configurations of solar concentrator designs, all of them reduce the effective area of receiving surface, one of those configurations is trapping light system [1]. Trapping light system uses holes or slits as a radiation windows to the system, also uses mirrors to increasing internal reflection of radiation into the system and don’t escape to outside of it.

In this work; trapping light concentrator system (figure 1) has been designed, including square micro lenses array (20X20 lenses) has area (20 cm²) with packing factor (100%) concentrate light at focal plane where a diaphragm (with slits) is placed to allow light passing through it and reaching the solar cell. The internal side of diaphragm has mirror to achieving internal reflections, and increasing optical path, consequently increasing photons absorption [2].
Trapping light system has been interested by researchers and designers, because of its importance to improve solar systems. J. Gjessing investigates the potential for light-trapping in thin silicon solar cells by the use of various photonic crystal back-side structures [3]. Jason H. Karp and Joseph E. Ford used a conventional concentrator photovoltaic (CPV) systems focus sunlight directly onto a PV cell micro-optic waveguide concentrators 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].

2. Optical design
zemax optical design program has been used to design the trapping light concentrator system, by using non sequential ray tracing mode of (1000) analyses rays and power of (1 watt). The total ray that strike the bottom of the cell and the optical power was detected by detector that fixed beneath the cell, also it has the same dimensions of the cell.

The type of borosilicate crown glass (BK7) has been used to designing lenses array, because of it has broad spectral transmission and highly environmental resistance. Despite of square lenses not favorable for imaging system because it has more aberrations than circular lenses, but it has perfect packing factor (100%) that is important in non-imaging system (solar concentrator), which the aberration is not considerable in system like that.

Crystalline Silicon has been used to designing solar cell, which has band gap matching photon energy of solar radiation that reaching the earth.

3. Results
there are many tools in zemax to evaluate design efficiency . The most important tools is the detector viewer that used in non-sequential ray tracing mode. It measures total incident rays hit the detector, and irradiance distribution that illustrate the optical power in unit area. Also detector give a picture about homogeneity of ray distribution.

Figure (2) illustrate detector measurements (T.H) of trapping system have different width of slits for variable incident angle. This procedure to evaluate effect of slits width of the system, and evaluate effect of incident angle and acceptance angle that is very considerable for solar concentrator systems, because sun position is vary during the day and must used maximum angle that give a good efficiency (acceptance angle).

Figure (2) shows different slit width (0.1 – 1 mm) with different incident angle (0° – 70°). It shows maximum values of detector measurements at normal incident angle (0°) of all used samples and acceptance angle of (25°), and shows curves degradation at increasing incident angle, this is normal effect because of design configuration that has narrow slits allow a certain ray direction to pass through into the system.

Figure (2) 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.

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 (2): detector measurements of trapping solar system have different slit width for different incident angle.

Figure (4) illustrates the relation between slit width and cell thickness. It shows detector measurements in all samples gradually decreases when increasing values of slit width and cell thickness.

Figure (3): detector measurements of trapping solar system have different cell thickness for different incident angle.
Figure (4): the relation between slit width and cell thickness

Figure (5) illustrates total optical power the reach the detector of trapping solar system have different slits width at different incident angle. It shows maximizing the power in all samples, but gradually decreases when increasing values of slit width and incident angle.

Figure (5): optical power of trapping solar system has different slit width for different incident angle.
Figure (6) shows the irradiance distribution ($E_e$) on the detector of samples that has different slit width at different incident angle. It shows slightly variations of irradiance distribution for all samples, because of design configuration nature that give internal reflections at all different samples.

![Graph showing irradiance distribution](image)

Figure (6): irradiance distribution of trapping solar system has different slit width for different incident angle.

References

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