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Determining Efficiency of I-V Solar Cell Curve for Optical Concentrator Design

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Abstract – Photonic technology has taken a very important role in concentrating to produce solar energy that it can be useful improving energy efficiency and reducing environmental impact significantly. Using photonics properties will get an impact on product design, manufacturing processes and performance. Our research aims to design optical concentrators using solar cell, and PV produces electricity. With the optical elements in special design, a large portion of silicon PV cells in a solar panel can increase the absorption of photons in order to obtain maximum efficiency from each photon. Solar energy is concentrated into PV cells using a system of linear Fresnel lens originally efficiency reaches 32% and thereafter to reach 40% without this lens system is replaced by holographic planar concentrator. With this planar concentrator technology, solar cell modules can generate more energy in all conditions compared with standard modules of the same size of silicon PV cells. But applying a new photonics technology with the existing of plasmonic solar concentrator efficiency of up to 32.6-62.4% can be expected by number of specific measures for how to accelerate this development of photonics technologies.

Keywords: *efficiency; photovoltaic (PV); optical concentrator; Fresnel lens; holographic planar concentrator (HPC) plasmonic solar concentrator (PSC);*

I. INTRODUCTION

Photonic technologies [1,2,3] have been applicable to produce electricity and to reduce the high cost of electric power source. For this purpose, many concentrating systems have been developed to concentrate the incident sunlight radiation onto the solar cells whose area is only a fraction of the concentrator area on which the sunlight falls such as parabolic mirrors or Fresnel lenses , holographic lenses and plasmonic surface. [4] There are two models of solar energy concentrators, thermal and PV includes its transmission grid and reflection respectively. Our paper is aimed to study and realize the holographic concentrators [5,6,7] adjusting the spectral distribution of the photovoltaic cells to the solar spectrum by the dispersion of hologram. Photonics is the science of light and how it can be harnessed, covering its generation, manipulation, and capture for utilisation in an enormous variety of applications, as evidenced by its increasing pervasiveness in our everyday lives. We use photonic technologies to light up our homes, offices and cities, to harvest renewable energy from the sun, to make telephone calls or surf the Internet, to enable early medical diagnosis and treatments, to establish clean and efficient manufacture of a multitude of everyday products, or to provide reliable security systems to protect us as we travel. Already, over 90 percent of all the data transferred for telecommunications is transmitted by optical fibre. In microelectronics, storage media and microprocessors are produced using optical techniques and in production engineering, laser techniques are systematically gaining ground in metrology and manufacturing. Last but not least, photovoltaic solar energy systems provide clean electricity to millions of people. Using PV solar cell will reduce the more expensive semiconductor material of “thin film planar” as the solution to decrease cost, as shown in Figure 1 where the PV solar cell efficiency can be improved by measuring solar cells performance corresponding to the power ratio fill factor, FF which can need be generated by the solar cell (under maximum power conditions (connected to a suitable charge) to the product of open circuit voltage, V_{oc} and short circuit current, I_{sc} related to the I-V solar cell characteristics, as shown in Figure 2. The solar cell efficiency, η can be calculated from these parameters and the characteristic area of the PV solar cell, as the ratio of area of the PV solar cell and incident solar power, P_{in} which depend on V_{oc}, open circuit voltage and I_{sc}, short circuit current, also FF, fill factor that correspond to the ratio of power need to be generated by the solar cell under maximum power conditions, P_m. [13]

$$\eta = \frac{P_m}{P_{in}} = \frac{V_{oc} \times I_{sc} \times FF}{incident \quad solar \quad power} \tag{1}$$

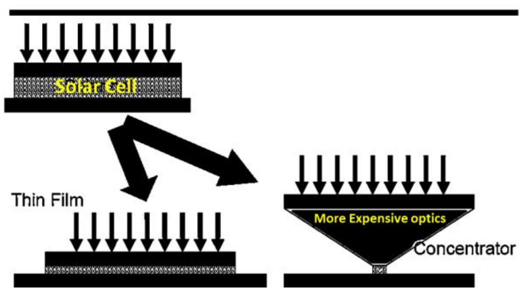

FIGURE 1. Solar cell area using Fresnel lens and thin film.

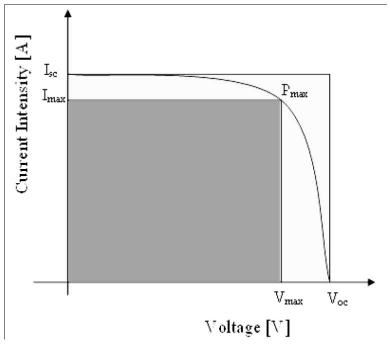

FIGURE 2. Tracing IV-solar cell Curve used in the design of the new concentrators, measured under standard conditions. The measurement was performed on a 123 mm x 125 mm cell.

II. PHOTONICS TECHNOLOGIES

Photonics makes use of advanced technology to realize high value products and services, but its roots lie in the fundamental source of our planet's energy – the capture of light from the sun by photosynthesis in plants. This fundamental 'photonic' process can be used to generate or to conserve energy, to reduce greenhouse gas emissions, to reduce pollution, or to yield environmentally sustainable outputs.Therefore, photonics covers a broad range of photonic technology applications such as photovoltaic electricity generation that can improve energy efficiency and reduced pollution. To save energy and reduce carbon dioxide emissions, we must find more efficient ways to produce and consume energy. Photonic offers a solution for both. The following applications of photonic technologies are expected to have the biggest impact in the short term, namely: photovoltaic cells to generate electricity solar energy. These predictions show that photonics will be a driver to get profitable growth what does advantage and more stimulate job in photonics with holographic and plasmonic PV [10,11,12] and all system applications and so further stimulate employments. The traditional technology transition to the new all-digital technology uses lenses photonic sensors, intelligent and integrated with photovoltaic systems in which all can be included directly in the development of infrastructure that contributes to the realization of solar energy generation is positive and significant. From this sector is expected to photovoltaic for solar concentrator was 30%. With this technology, developed a new method for the rapid design and evaluation of solar concentrators, as shown in Figure 2 by tracing the area of IV Solar Cell Characteristics.

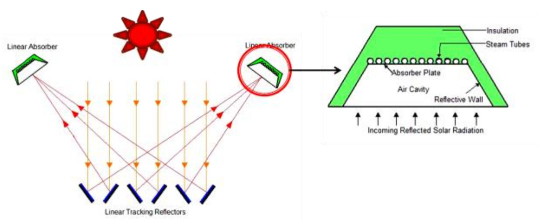

FIGURE 3. Linear Fresnel reflector

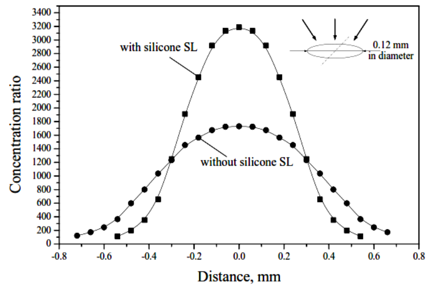

FIGURE 4. Optical transmittance of a sample with a glass-silicone structure, simulating a composite Fresnel lens, in comparison with that of a conventional acrylic Fresnel lens.

of different concentrator systems can be compared. Steps of this method is to carry out a simulation optics of the concentrator, the first in order to get the distribution of radiation on solar cells for every angle of incidence, both in order to get a reflector structure is applied to the concentrator available, and a third in order to take the distribution of radiation in solar cells, including when the outcome daily/monthly/yearly account.

III. SOLAR ENERGY CONCENTRATOR DESIGN

Fresnel Solar Concentrator Design

If our societies are to save energy and reduce emissions of carbon dioxide, we will have to find more efficient ways to produce and consume energy, and photonics offers solutions for both. The problem to be solved is long-term stability of solar light concentrators. For solar energy concentrator with a linear Fresnel reflector (see Figure 3. The tendency is to replace materials "traditional" acrylic polymers are more stable environment. The research team Loffe [8] directs research on the composite structure of the Fresnel lens [12], in which the sheet silicate glass (front side of the module) serves as a superstrate for transparent silicone (inside) with Fresnel microprism. At focal spot measurements for the small-aperture area lenses, a probe cell with a hole of 0.12 mm in diameter calibrated with respect to photocurrent scanned a "sun image". The results for the cases with and without silicone SL are shown in Figure 4.

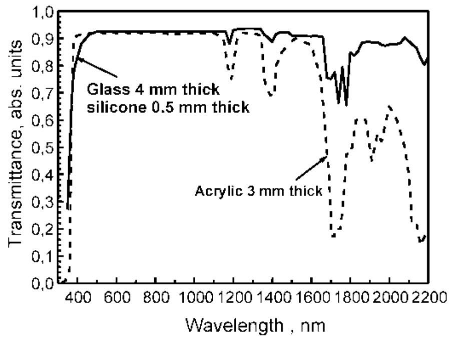

FIGURE 5. Evaluation of the local concentration ratios across the focal spot in the "Fresnel PL with/without silicone SL» system. The primary lens is 40x40 mm^2 in aperture area at the focal distance of 85 mm.

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Concentration ratio as high as 3200x has been measured for the "PL + SL" system. This value has to be taken into account at the structure and contact grid optimization of the cells intended for use with such concentrator systems. The concentration ratios may be increased in the systems with Fresnel lenses of higher quality. In turn, microprism itself was formed by the polymerization of silicone compounds directly on glass sheets by using a mold which negatively profiled. The advantage of this approach is based on a high UV stability of the silicone, excellent resistance to thermal shock and high/low temperature, good adhesive properties in a stack with silicate glass. The average thickness smaller than the prism ensure the absorption of sunlight is lower than acrylic Fresnel lens with a thickness of "ordinary" (see Figure 5).

Holographic Solar Concentrator Design

With a specially designed holographic optical element (HOE), as shown in Figure 6. [9]. a large portion of the expensive silicone photovoltaic cells in a solar panel can be replaced.with this Holographic Planar Concentrator (HPC) technology, the solar modules produce more energy in all conditions when compared to a standard module with an equal area of silicone PV cells. Holographic lenses are able to disperse and to focus solar radiation at the same time. The dispersion of the solar radiation into different spectral bands focused onto spectrally matched solar cells improves the electric efficiency of photovoltaic collectors better than the conventional systems. Holographic lenses may be reproduced from a master and are suitable for cheap mass production, as shown in Figure 7.

Plasmonic Solar Concentrator

Nanophotonic application to plasmonic solar concentrator (PSC) are not confined, where is requirement on cheaper solar cell and more efficient huge. Appear that no that doubt photovoltaic research will get gain greatly from plasmonics, one that can be enable quality material purpose contemns with lower cost and can give solar cell with high performance and low cost, as shown in Figure 8 [6].

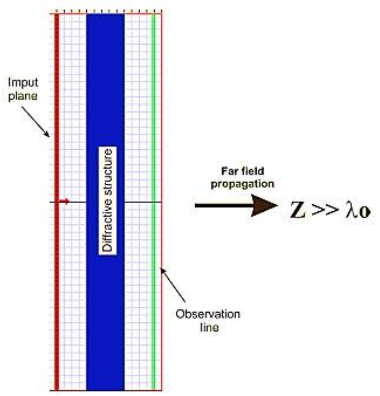

FIGURE 6. Holographic solar concentrator (HPC).

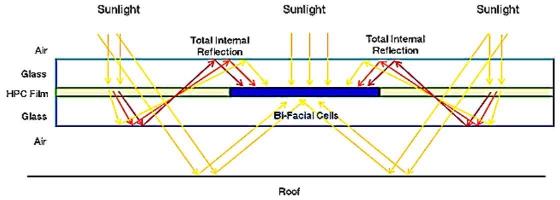

FIGURE 7. Diffractive structure of Holographic Optical Element with far field propagation, distance Z >> λ_0

IV. RESULTS

The results of this study discuss solar concentrator has 3 study designs. First, the use of Fresnel lenses shown that there is a potential need for achromantic especially in the blue area, the Second, the use of holographic lenses obtained ratio higher concentrations in an efficient diffraction profile. Holograms perform concentration at desired regions of solar spectrum. Rejection of infrared illumination reduces heating of solar cells. Third, the study of the solar cell plasmonic structure design potentially very promising. This is possible due to a drastic reduction in the active semiconductor layer thickness and performance of materials in conjunction with the charge carrier transport slightly.

With the optical elements in special design, large parts of silicon photovoltaic cells in a solar panel can increase the number of photon absorption and obtain maximum efficiency from each photon. Solar energy is concentrated into PV cells using a system of linear Fresnel lens originally efficiency cannot exceed 32% and thereafter to reach 40% without a Fresnel lens system is replaced by holographic planar concentrator (HPC) as shown in Figure 9.

With this planar concentrator technology, solar cell modules can more result a lot of energy in all condition compared with by default module broadly same of PV silicone cell. Then photonics adjustment of technology new with marks sense using plasmonic solar concentrator (PSC), therefore efficiency can get to reach 32.6-62.4% expected. The normalized optical efficiency can be increased even further to 32.6% by using 3 plasmonic surface layers with a total thickness of 600nm and nanoparticle coverage of 12.3% in each layer, which is the optimum configuration with the efficiency of the PSC, 62.4% photons lost of nanoparticle absorption raised to

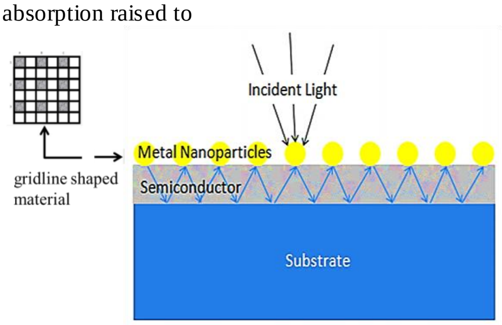

FIGURE 8. Plasmonic Solar Concentrator (PSC) using metal nanoparticles

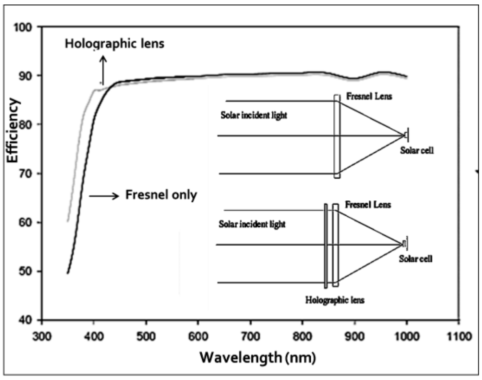

FIGURE 9. Efficiency profile of optical concentrator using Fresnel lens only (black) and Holographic lens (gray) tends to gain on 2%.

19 layers. Multiple layers ensure more interaction with light including a stronger dye absorption yielding a higher optical efficiency of the device. Still scattering remains the main driver of the optical efficiency and if too many layers are included Ohmic losses start to dominate and worsen as shown in Figure 10.

V. DISCUSSION

1. The study of Fresnel design shows that a potential of achromatisation needs mainly in the blue region.
2. Holographic lens could be designed for higher concentration ratio and on the diffraction efficiency profile.
3. Plasmonics solar cell structures potentially very promising, It allows the drastic reduction in the thickness of the active semiconductor layer and simultaneously boots the performance from materials with poor charge carrier transport.
4. There is no doubt that photovoltaic research will benefit immensely from plasmonics, enabling use of low quality low cost materials and *delivering cells with high performance and low cost.*
5. The applications for plasmonic solar cells are endless. That can be the need for cheaper and more efficient solar cells is huge.
6. In order for solar cell s to be considered cost effective, they need to provide energy for a smaller price than that of traditional power sources such as coal and gasoline.
7. The movement toward a greener world has helped to spark research in the area of plasmonic solar cells.

Currently, solar cells cannot exceed efficiencies of about 30% (First Generation). With new technologies (Third Generation), efficiencies of up to 32.6-62.4% can be expected. With a reduction of materials through the use of thin flm technology) (Second Generation), prices can be driven.

VI. CONCLUSION

A number of specific measures presented for :

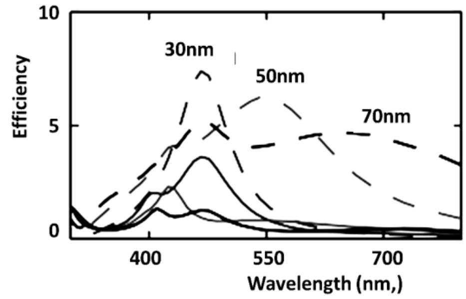

FIGURE 10. efficiency profile of absorption (solid) and scattering (dashed) using PSC with cross sections of sphere radii of 30nm, 50nm and 70nm.

1. Solar concentrator has involved accelerating to develop cause of photonic technological applications. Science progress can increase application using up promotion this to extensive society.
2. Sunlight becomes a natural energy resource changed humanlife needs in the future.
   a. Solar energy research will be a more interesting area as photonic energy resource that continued widely to develop.
   b. Solar energy research will become a growing area of renewable energy research and needs to increase the number of grid connected as hybrid energy systems in the future.

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