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Studying of Optical Properties of Cylindrical Lenses Array Solar Concentrator

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ABSTRACT: In this research solar concentrates have been designed by using cylindrical lenses array , that concentration solar radiation beneath the system where placed solar cells; to reduce the effective area and regulate spread of radiation, subsequently increment of solar cell efficiency by increasing the intensity that reaching to it.
Plano convex cylindrical lenses array have been designed by using optical design software (zemax) used normal incident beam at system ($\theta=0^{\circ}$) and then using inclination angles. Of incident beam ($10^{\circ}-90^{\circ}$) to illustrate the angle influence of design efficiency. The results show priority of second sample in power at receiving surface at any incident angle .

KEYWORDS : Cylindrical lenses, zemax , Acceptance angle , solar cell.

I. INTRODUCTION

The idea of using solar energy it is most important subject that interesting by human this ways to using solar energy its varying according to society needs for it . there are two kinds of solar energy : thermal and photovoltaic which used and approved by solar concentrators.
Solar concentrators are used to reduce effective area and illumination homogenizer . the most important of solar concentrators are lenses and spherical mirrors that may produce (1000 C^{o}) , so they are use to water evaporation to operate vapor engine ,while plane mirrors can produce (250 C^{o}). solar concentrators that have widely applications because solar cells may suffer power deficiency by clouds and dust in atmosphere .

II. CYLINDRICAL LENSES

Cylindrical lens is concentrators light in one dimension line shape. This lens composed of one or two sides of cylindrical surface. cylindrical lens is submits of same formulas that spherical lens is depend on it in spite the image in one dimension. The lens materials are selected by specific properties like refractive index, thermal properties and mechanical properties the most famous material that used in lens production is (BK7) which has useful characteristics in optics field, the table (1) illustrates some of important characteristics of (BK7) :
Cylindrical lens has refraction power in vertical axis and no power in horizontal axis line image is produced in cylindrical lens by using point source as shown in figure (1); Cylindrical lenses have many applications like laser Scanner ,laser printers and 3D photography Also used for laser line generator and image area adjustment , finally it is used for astigmatism. Using of solar power has been wildly studied from researchers because it is very important subject that provides clean energy [1].
R.A. Zakhidor and A. Ismanzhanov are study in (1980) atmospherically conditions and its effectiveness of solar concentrator system[2], V.L. Smirnor and S.N. Trushenskii are study in (1988) annual deviation law of solar tracing and its influence of solar radiation intensity [3], In (1999) solar concentrators performance has been studied by W.D. Childs ,his research lead him to confirm efficiency of dish concentrators about (25%), while plane mirrors concentrators about(14%) [4], In (2003),cylindrical solar concentrators have been designed by F. Sulaiman and B. Singh, this concentrators parabola shape that simulated by computer program [5].

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Properties	Value
Refractive index (n_d)	1.519 nm
Industrial Cost	relatively few
Coefficient of thermal expansion	$7x10^{-6}\ C^{-1}$
Rigidity	610 N/m^2
Density	$3.148 g/cm^3$

Table 1. some important properties of the glass type (N-BK7)

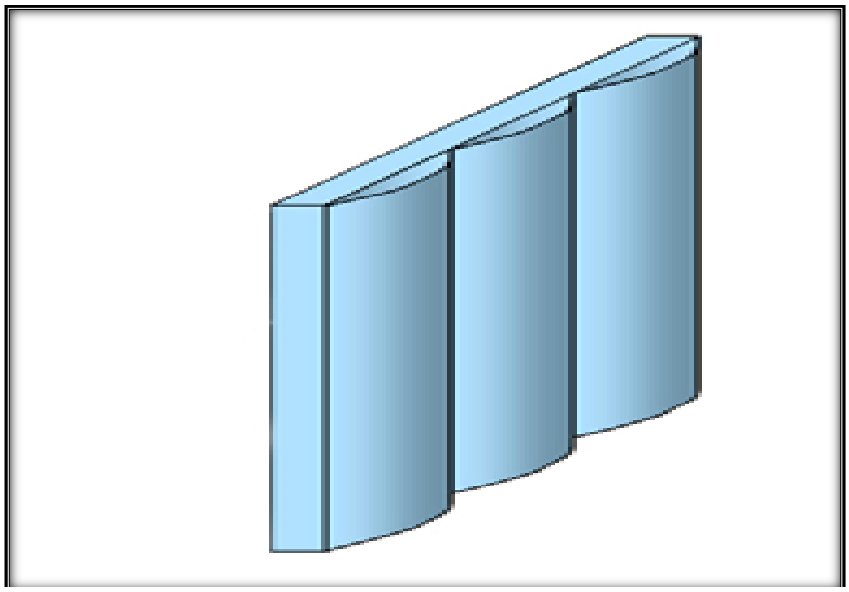

Fig. 1. Plano-Convex Cylindrical lenses

III. DESIGNING

Zemax is optical design program that used to designing and analyzing optical systems zemax has powerful technical and accurance performance [6] . It is working by ray tracing mode in to optical elements like lens and mirror, and stray light by non-sequential ray tracing mode plano convex cylindrical lenses array has been designed by zemax that have dimensions (10x10cm), Thickness (1 cm), radius of curvature (R =1.2 cm) and number of lenses (10 lenses) ,BK7 glass has been selected to fabricate the lenses .this optical system working by sequential ray tracing mode in zemax . equivalent focal length of this lenses is represented by equation :

$$\frac{1}{f} = (n-1)[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)d}{n_1 R_1 R_2}]$$

Where f equivalent focal length of lenses is ,n is refractive index of BK7 , d is lens thickness and R_1 ,R_2 are radius of curvature of first and second surface of lens respectively. finally the solar cells are fixed beneath the array to concentrate solar radiation.

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In this work ,analyzing methods to evaluate optical system including spot diagram ,en squared energy and irradiance distribution that zemax provides this methods. Spot diagram is rays data due to ray tracing in to receiving surface . Spot diagram includes geometrical distribution of light rays in spot have radius of RMS about (68%) of power. Spot diagram produces useful information about image quality ,geometrical spot value and radiation distribution. Ensquared energy refers to power accumulation at receiving surface for point source ,and the provide a general description of point spread function .

IV. RESULTS

Figure (2) illustrates ray spread diagram at receiving surface that positioned at lenses a ray of (1 cm) ,figure shows lines represented concentrated rays from cylindrical lenses making solar cells receiving concentrator rays ,science increasing cell efficiency.

Figure (3) illustrates (3D) irradiance distribution at receiving surface that represents radiation . Intensity per surface. Figure shows symmetrical distribution of irradiance on parallel axis that represents longitudinal axis of cylindrical lenses so cylindrical lenses makes re spreading of rays at receiving surface and concentrate rays over solar cells that fixed by parallel lines at receiving surface.

Figure(4) illustrates en squared energy diagram of receiving surface .the Figure shows energy graduated of minimum at the center approaching to maximum when cover the overall surfaces the energy is stable constant when increasing area the Figure shows zigzag line for used system because system gives different energy distribution at receiving surface.

Figure(5) illustrates ray distribution diagram at receiving surfaces for different incident angle $(0^{\circ}, 20^{\circ}, 40^{\circ}, 60^{\circ}, 80^{\circ})$. The acceptance angle of this system is $(0^{\circ}, 20^{\circ}, 40^{\circ})$ that give irradiance about (80%) of ray distribution ,while angles $(60^{\circ}, 80^{\circ})$ gives less than (80%).

The geometrical feature of this system gives staying of ray concentration over longitudinal lines where solar cells are fixed ,even incident angle is vary ,because this axis is parallel and closed ,so even rays deviation from lens , this rays are concentrate at a lined line where next solar cells are fixed.

The rays distribution diagram appropriate for this design even incident angle is that reach about (40°) to give (80%) of irradiance.

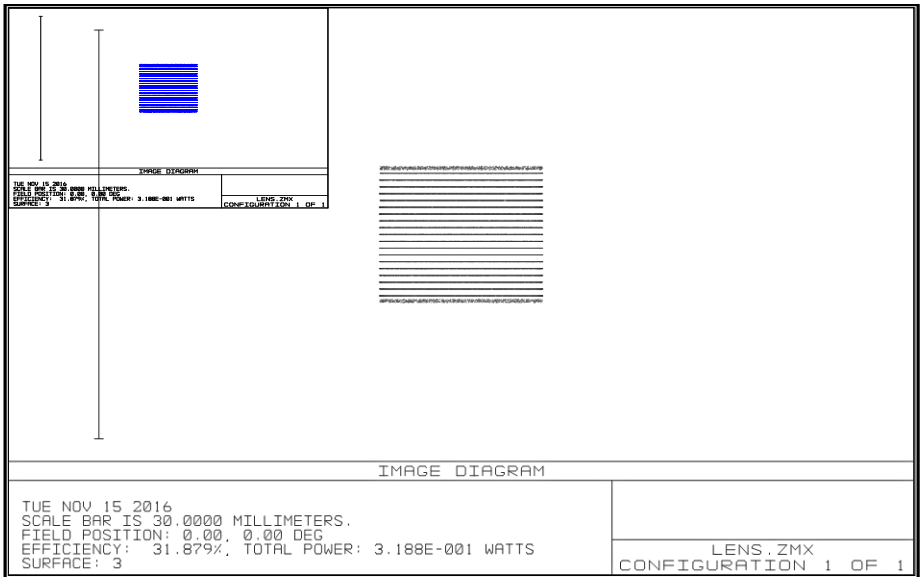

Fig. 2. Spot diagram of receiving surface

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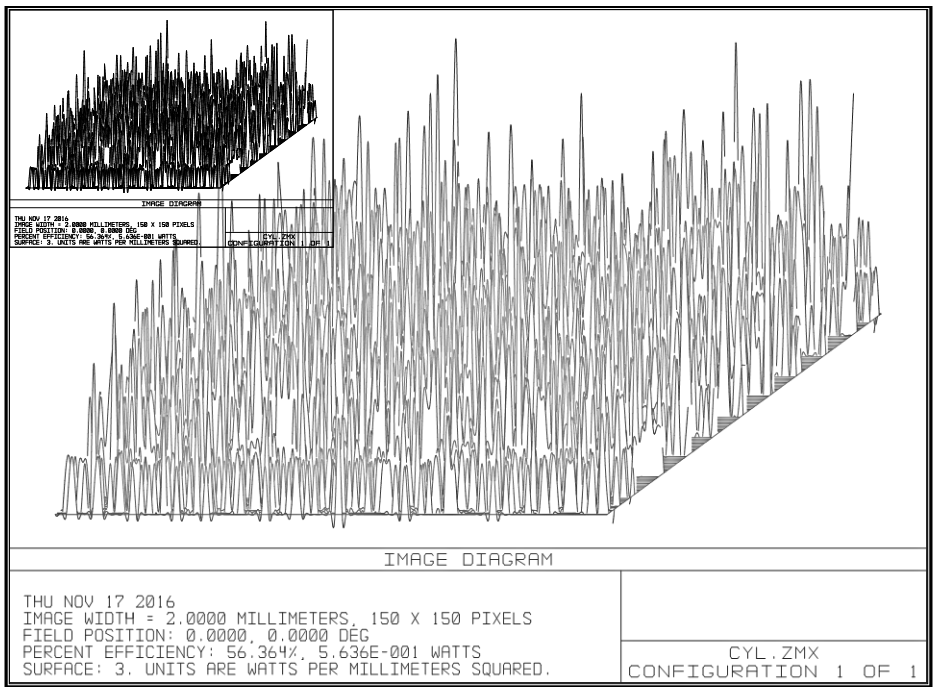

Fig. 3. irradiance distribution of receiving surface

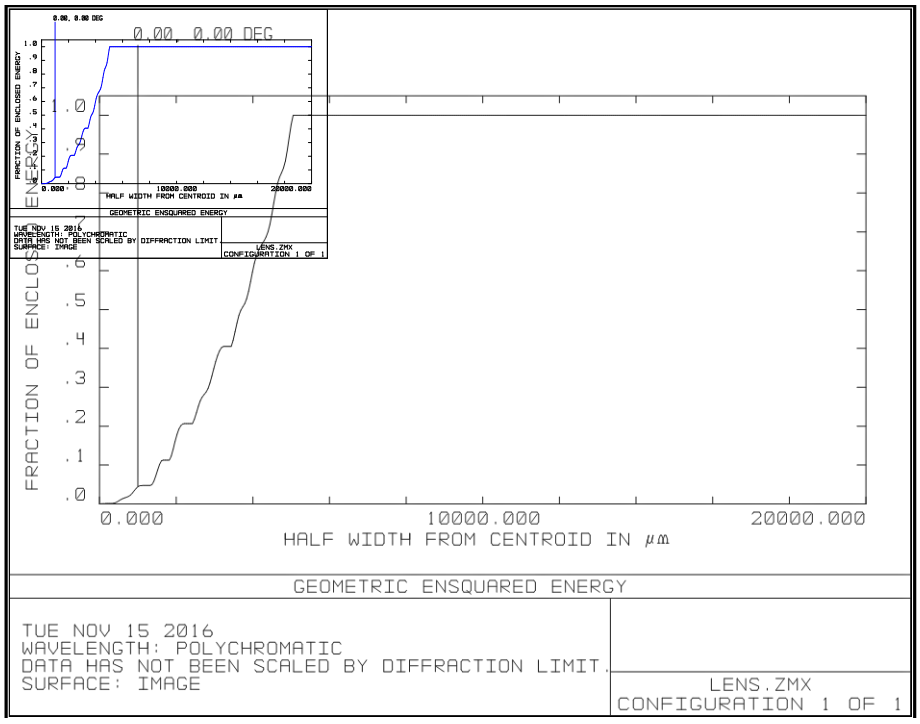

Fig. 4. insquared energy

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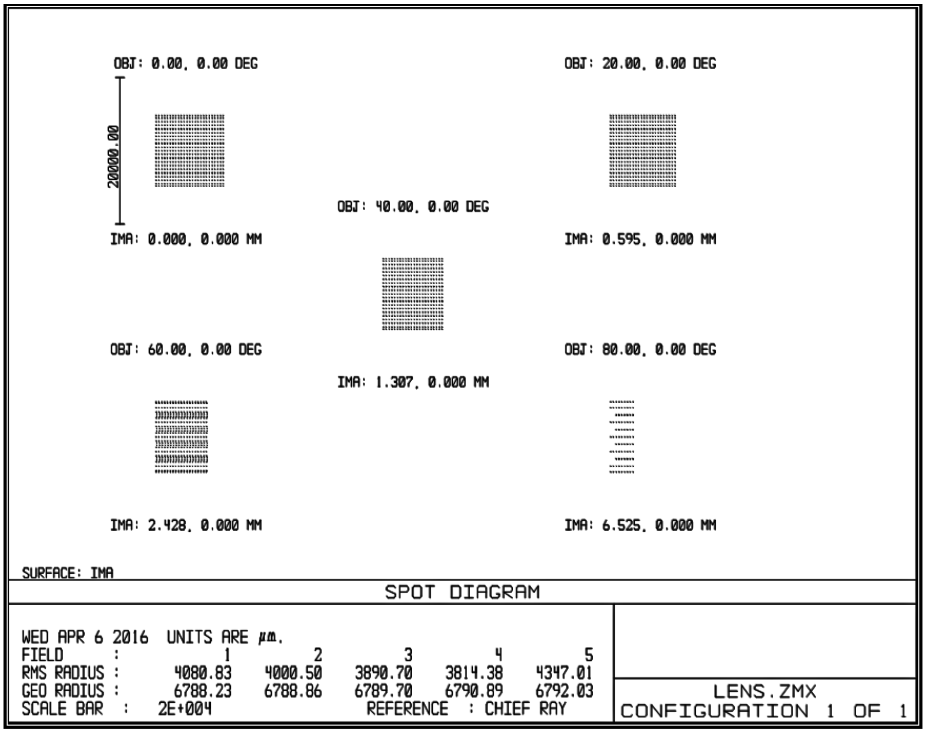

Fig. 5. spot diagram at different incident angle of solar radiation

V. CONCLUSION

We have obtained an improvement in optical system that represented by cylindrical lenses array solar concentrator that homogenizing and redistribution of radiation. This result due to reducing effective area of receiving surface and increasing solar system efficiency. The acceptance angle of solar system illustrates 60^0 degree of incident angle that give accepted efficiency.

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