Study Of Spectral Behavior Of Silicon Solar Cells Under Total Solar Eclipse Of 22 July 2009

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Abstract **- The performance and behavior of the Polycrystalline solar cell (at different wavelength) is influenced by the spectral solar distribution. The solar cell responds differently in terms of voltage in an open circuit .The Silicon solar cell spectral response can be used as a tool to sensitize the solar spectral variations.[2]This paper shows how a solar cell responding differently to different wavelengths of light by utilizing various coloured light bandpass filters of fixed wavelengths band ranges ;which are placed in direct contact with the solar cell placed right on the top of the solar cell surface during total solar eclipse and study the effect of the eclipse on the generation of voltage and help in proposing a way to develop a more efficient method of using light for generation solar energy for efficient solar energy harvesting and various solar cell applications.[1]**

Index Terms – Solar Eclipse , Silicon Solar Cells , Spectral Behavior,Global Irradiance, Atmosphere , Ionosphere,Ozone Layer, Wavelengths,UV Radiation, Voltage , Current.

INTRODUCTION:

The various types of solar eclipse are recursive phenomena and this event provides an opportunity to various aspect of earth's atmosphere,the solar energy.

During the solar eclipse it is observed the rate of sunlight diminishes at a particular/fixed rate and towards the totality the Umbra of the moon sweeps across the top of the atmosphere over the location under the totality path due to which the limb darkening effect takes place and it affects the global irradiance (GI) , direct irradiance (DI) and actinic flux (AF) This effect leads to wavelength dependent changes in the measured solar spectra showing a much more pronounced decrease in the radiation at the lower wavelengths. It has been observed that there is a faster decrease of GI at lower wavelengths than the higher ones[3][20]. In the past research have been conducted to study how the ozone layer changes and study the physical processes that take place in the atmosphere during the time of the totality due to absence of the sunlight. It has been observed that most of the effects take place that affect the environment at a very small micro level and they affect at very small rate which can be hardly measured. For example in Case of flora the changes takes places chemically as the intensity of light decreases due to which there is decrease in the intake of CO2 absorption.[2]

Eclipses are connected with the rapid and short-
time, impulse-like decrease of solar energy flux reaching the area of its visibility, which can be exactly predicted before the occurrence of the phenomenon. Therefore, they cause noticeable changes in the atmosphere, whose main energy source is solar radiation.[2]

Due to quick and short lived impulse, the decrease of solar energy flux it causes noticeable changes in the earths atmosphere[2] . There is a observed decrease in Ozone during the solar eclipse[4] and also there is a decrease in the diffused light with respect to the direct solar radiation increasing more that the shorter wavelength side of the UV spectrum[4].It is observed that the UV radiations contribute to the ionization process of the earths atmosphere which can disrupt the satellite communications especially GPS signals to some extent. Significant changes in the signal have been verified during the time of the eclipse which induce errors in the signal[5][6]. There are also chemical and physical changes occurring in the ozone at the time of the eclipse due to radiation[16].Solar UV radiation contributes to ionization process of the ionosphere and the boundary layer which is in direct contact with the ground thus

absorbing short wave radiations. Especially, the impact on atmospheric Temperature,Pressure and Humidity is important, as the stability and convective processes intensity process changes. The spectral distribution of light during the eclipse is of importance from research point of view. Ideally, Thermocouple-based sensors should record such spectral intensity, as their spectral response is linear for the whole spectrum. Thus spectral intensity of the incident radiation may be recorded easily. Considered as photo devices, solar cells may also help recording such spectral variation.[2] Solar cells are also considered to be more sensitive to measure the changes in the Ozone and it is seen that the response is highly sensitive to frequencies of shorter wavelengths in the visible spectrum i.e. between 0.4 micrometers to 0.5 micrometers[13].
Present research works include mainly studying the effect of the variation of solar radiation during the total solar eclipse on the behavior of solar cell parameters and effect
different wavelengths of different coloured lights with help of various coloured light filters.

limb darkening effect (LD) which mainly depends on the geometry of the eclipse becomes relevant and needs to be taken into account. Measurements of radiative quantities below table describes the element of the total solar eclipse on 22nd July 2009[3][7][20]

Total Solar Eclipse of 2009 July 22

TABLE 1

ELEMENTS OF THE TOTAL SOLAR ECLIPSE OF 2009 JULY 22

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Equatorial Conjunction:      02:34:07.29 TDT      J.D. = 2455034.607029
  (Sun & Moon in R.A.)     (=02:33:01.42 UT)

 Ecliptic Conjunction:       02:35:41.89 TDT      J.D. = 2455034.608124
 (Sun & Moon in Ec. Lo.)    (=02:34:36.03 UT)

      Instant of             02:36:24.37 TDT      J.D. = 2455034.608615
   Greatest Eclipse:       (=02:35:18.50 UT)

Geocentric Coordinates of Sun & Moon at Greatest Eclipse (DE200/LE200):

Sun:        R.A. = 08h06m24.115s       Moon:        R.A. = 08h06m29.643s
            Dec. =+20°16'03.00"                     Dec. =+20°20'07.03"
  Semi-Diameter =     15'44.50"          Semi-Diameter =     16'42.73"
   Eq.Hor.Par. =         08.66"           Eq.Hor.Par. =  1°01'19.84"
         Δ R.A. =       9.958s/h                Δ R.A. =     155.021s/h
         Δ Dec. =      -29.88"/h                Δ Dec. =     -684.39"/h

Lunar Radius    k1 = 0.2725076 (Penumbra)       Shift in       Δb =  0.00"
 Constants:     k2 = 0.2722810 (Umbra)       Lunar Position:   Δl =  0.00"

Geocentric Libration:     l =   0.8°        Brown Lun. No. = 1071
(Optical + Physical)      b =   0.0°          Saros Series =  136 (37/71)
                          c =  10.9°                  nDot = -26.00 "/cy**2

Eclipse Magnitude = 1.07990         Gamma = 0.06977          ΔT =    65.9 s


    Polynomial Besselian Elements for:    2009 Jul 22    03:00:00.0 TDT  (=t0)
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n	x	y	d	l_1	l_2	μ
0	0.2399887	−0.0032838	20.2642422	0.5304467	−0.0156322	223.388214
1	0.5563963	−0.1774582	−0.0078733	0.0000063	0.0000063	15.001003
2	−0.0000576	−0.0001344	−0.0000046	−0.0000128	−0.0000127	0.000002
3	−0.0000094	0.0000032	0.0000000	0.0000000	0.0000000	0.000000

Tan f_1 = 0.0046014   Tan f_2 = 0.0045784

At time t1 (decimal hours), each Besselian element is evaluated by:

$a = a_0 + a_1*t + a_2*t^2 + a_3*t^3$ (or $a = \sum [a_n*t^n]$; $n = 0$ to 3)

where: $a = x, y, d, l_1, l_2$, or μ
$t = t_1 - t_0$ (decimal hours) and $t_0 = 3.000$ TDT

The Besselian elements were derived from a least-squares fit to elements calculated at five uniformly spaced times over a six hour period centered at t_0. Thus the Besselian elements are valid over the period $0.00 \le t_1 \le 6.00$ TDT.

Note that all times are expressed in Terrestrial Dynamical Time (TDT).

Saros Series 136: Member 37 of 71 eclipses in series.

EXPERIMENT:

Step up:
Date:22 july 2009
Location:China,Zhejiang Province,Hangzhou,North Peak Lingyin temple

Latitude, Longitude: 30.00266559780204, 120.13910293579102
surface elevation being ~ 150 m above sea level
Type:Total Solar Eclipse
4 solar cell(Polycrystalline type, 2.5 x 2.5 inches ,4Volts,100 mA current) connected to multimeter with 3 optical bandpass filters[15] of different wavelengths from the visible light spectrum each placed on the top of the surface of the solar cell . Each cell was supported by a retort stand so that one can adjust the surface angle and incline it with respect to the Sun in order to get the maximum exposure to the sun during the time of the total solar eclipse. The generalized specification of the optical bandpass filters is as follows(Blue(S2) : { 450 ~ 495 nm, Frequency 670 ~610 THz },Yellow (S3): { 570 ~ 589 nm , Frequency 525 ~505 THz } , Red (S4) : { Wavelength ~620–740 , Frequency ~480 – 400 THz})placed each on the solar cell ;where S2,S3,S4 are the alias or names given to the bandpass filters.
Pressure and humidity measuring device
The measurements were carried out every minute to during the phases of the eclipse. The paper is interested by studying the effect of variation in radiation (spectrally and quantity) during the total solar eclipse on the output short circuit current (ISC) and open circuit voltage (VOC) of the Polycrystalline solar cells.

Modeling Based On Important Assumptions and Solar Cell Characteristics Equations [8]

Considering Solar cell as a battery with light energy as the external power source resulting in an electrical voltage generated by charge separation driven by light rather than chemical reaction and hence considering the equations of electromotive forces (EMF) we have[9][10][14]

Vout = Iout*(r +R)

where Vout is maximum the output voltage , Iout is the maximum output current

R = 0 ohms in the case of the experiment
r is the internal resistance

so Vout= Iout *(r) ------- (1) [14]

V is a function of I where ‘r’ is constant value in derived equation i.e. 1 for our model

so equating using ratio proportion the values of Vmax , Imax and V (measured) we get the values of I and we get below graphs [17][18][19]

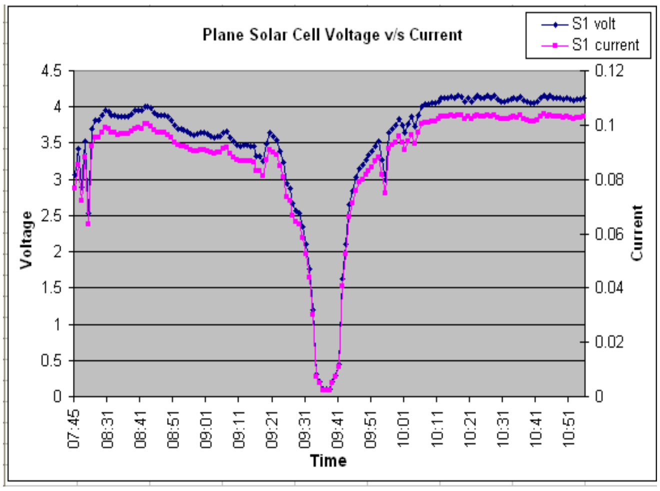

Fig No.1

Results and Discussion

From below figure from Fig No.1 - Fig No.4 represents the voltage v/s current projection for solar cells with and without filters. The current has been equated using our model equations in Equation (1)

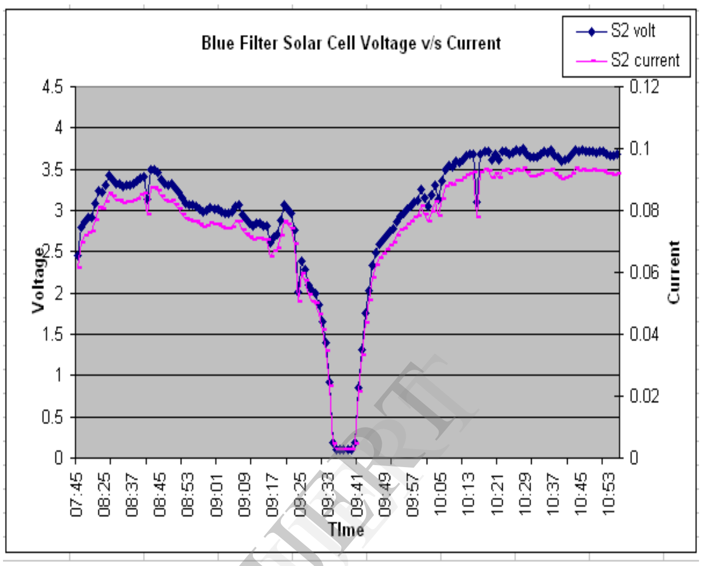

Fig No.2

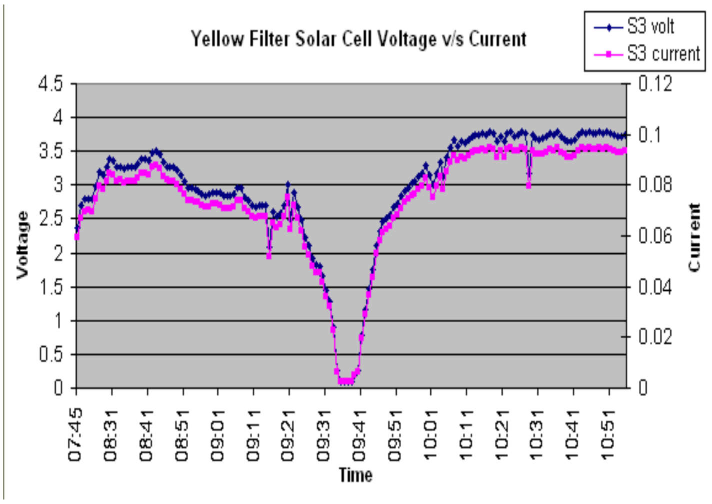

Fig No.3

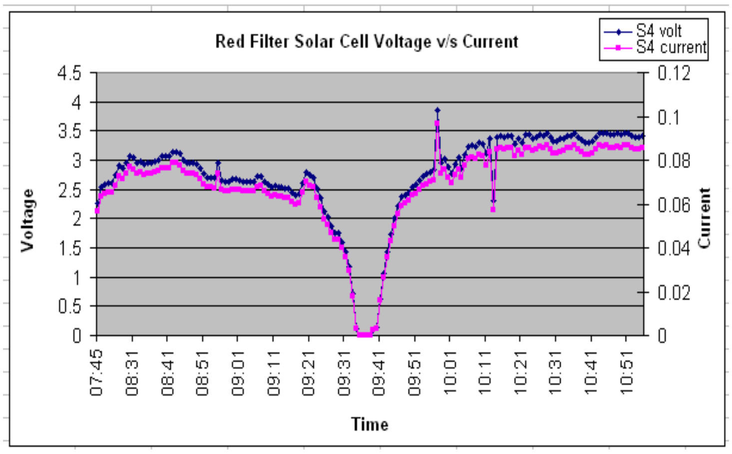

Fig No.4

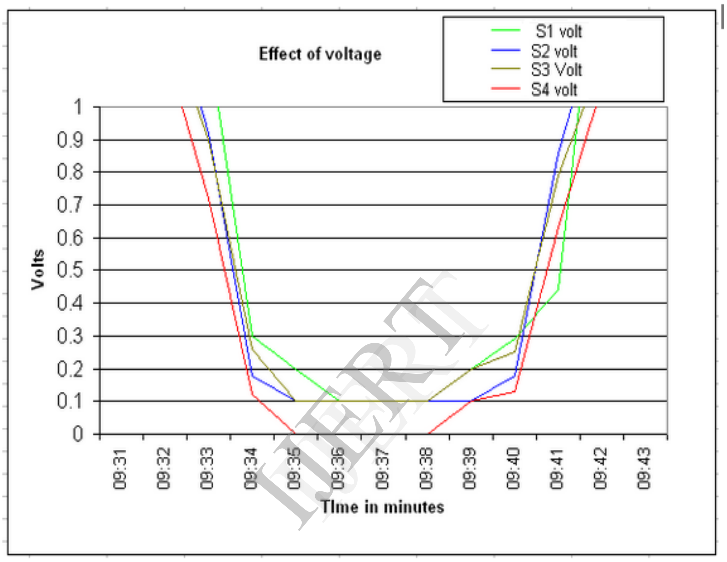

Fig No.5

Voltage readings were taken from the period before the first and the last contact and the period after the eclipse and they are mentioned in the figures mentioned above charts.

The graph of the voltage(Fig No.5) during the time of the totality and a few seconds after the totality detailed readings were taken and from the graph one can see that the solar cell responded faster to the yellow light i.e. from the filter S3(yellow). For S3(yellow) one can notice that from the period of 09:38 am Hangzhou Time ;the voltage increased steadily along with the S1 (without filter)voltage than compared to the voltages produced by S2(blue filter) and S4(red filter) and kept increasing steadily than compared to of S1 , S2 and S4 from period of 9:40 am to 9:41 am. When the totality approaches the voltage drop delays in case of the S3 (Yellow)and S1(Plain) it is observed in the readings from 9:34 am to 9:36 am.

The below graph Fig.6. verifies the trend of the behavior of the shorter wavelengths of the visible spectrum i.e. blue filter just before the solar eclipse starts and during the totality i.e the maximum phase. we can see that when the max phase is about to get over. We see there is a sudden drop in the blue current and there is a rise in the current by the red whereas one can see that the current remains steady i.e. middle order frequency of the visible spectrum i.e for yellow filter. The trend of the shorter wavelengths corresponds with the past studies i.e. gradual decrease in total ozone, followed by a symmetric increase after totality ,decrease in the ozone flux as a result of photochemical reaction [2] we can also see Larger deviations for longer wavelengths Red and an acceleration of the rate of this decrease is observed in the last minutes before totality[2]

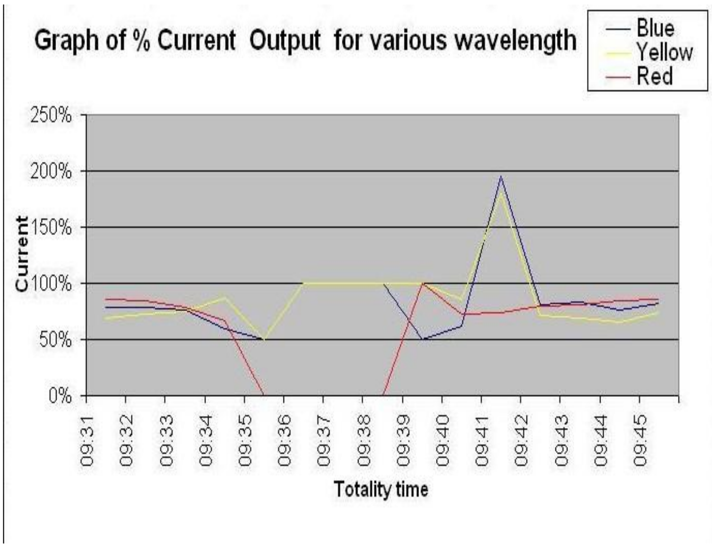

Fig No.6

APPLICATIONS

1) Can be used to measure the intensity of coronal mass ejection by further improvisation of the setup. At higher the intensity there can be a possibility of a disturbance or a kind of non linear trend to be observed in the violet and blue region (shorter wavelengths)of the visible spectrum due to the UV and high temperature of the coronal ejection. Coronal Mass Ejection Alerting system can be modeled on the basis of above setup it can show us the surge / spike in the voltage and we take the necessary steps before it can reach the earth. Also it is been observer that there is an increase in the X-Ray flux during this phenomenon a system can be modeled to detect and measure X-Rays and Gamma Rays using Silicon Solar Cells [24][25][26]

2) Can be used to measure the thickness of the ozone layer at various places with the help of monitoring the voltage in the blue and violet (shorter wavelength) region of the visible light spectrum at various locations. If there is a hole in the ozone due to pollution or other reasons then there has to be increase in the UV rays . so UV rays have to increase due to pollution as it affect the ozone layer and also ionized charged particles in the atmosphere

3) Various electronic circuits operate at various current and voltage. So we can choose to regulate the voltages and currents as desired with the help of the filters.

4) One can boost the efficiency of the solar cell by cutting down the light frequencies that has extra energies especially ones in the UV and violet region which goes waste in form of heat thus adding to the increase in temperature of the solar cell and decrease in the throughput. Photochemical up-conversion of the frequency 600–750 nm is converted to 550–600 nm can also lead to increase in throughput[21][22][23]

CONCLUSION

From the above experiment we can show that the solar cell responds differently to different frequency of lights when its passed through a bandpass filter in order to pass particular color wavelength of light in our case (Red , Blue and Yellow) during the eclipse. The solar cell responds well to the yellow light frequencies . There is a need to carry further research for studying the coronal mass ejection and various other forms of electromagnetic waves and their behavior using UV filters . Inferring to the above we can conclude that we can use the solar cell as a photo detector which can be used to study the activities of the sun and the UV radiation patterns from various regions and it can help in creation of a distributed model for detection of the electromagnetic radiation without using any costly equipment or radio frequency array using a simple circuitry comprising of UV filter .

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