International Journal of Engineering & Technology, 7 (3.7) (2018) 585-589

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

An Analysis Method of the Temporal Instability and the Non-Uniformity of the Chip-On-Board Light Emitting Diodes Solar Simulator

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Abstract

The purpose of this paper is to test the temporal instability of irradiance and the non-uniformity on the test plane of the COB-LEDs based solar simulator. This study followed the process according to the IEC 60904-9 standard. The 3×6 arrays of COB-LEDs consume the total power of about 900 watts and are installed on the aluminium profile heat sink. The illumination area is about 448 cm^2. The switching power supply was used to supply power to the LEDs. The research tool is the irradiance instruments that were calibrated by the secondary standard Pyranometer. The results found that the COB-LEDs solar simulator met the standard IEC 60904-9 in Class -CB. The results confirmed that this innovative idea can be applied to make the best LEDs based solar simulator. For future works, the author planned to improve the non-uniformity and temporal stability to meet the A Class.

Keywords: *IEC 60904-9 standard; COB-LEDs; solar simulator; class of quality*

1. Introduction

The main purpose of the solar simulators is to provide performance measurement of photovoltaic devices or irradiance tests. Usually, a solar simulator is used for two main applications. They are an I-V measurement of PV cell and irradiance exposure. The most solar simulator consists of three major components. There are (1) Light sources and power supply. (2) Filter devices for modifying the spectrum of light to meet the standard classification. (3) The control mode of operation such as steady state control, single pulse control, and multi-pulse control. The solar simulator is separated into 3 types: (1) Terrestrial PV system air mass 1.5(AM 1.5) Global solar simulator. (2) Terrestrial concentrating PV system AM 1.5 Direct solar simulator. (3) Space PV system AM 0 solar simulator [1]. This study will focus on the 1st type because it is appropriate for used for the solar cell testing. The terrestrial PV system AM 1.5 Global solar simulator is divided into two types of source: (1) Lamps as the light source, and (2) Light emitting diodes (LEDs) as the light sources. The LEDs have more advantages over the conventional lamp such as long lifetime, energy saving capability, low temperature, small size and economically beneficial especially the chip-on-board LED (COB). The COB-LED technology describes the mounting of a bare LED chip in direct contact with the substrate to produce LED arrays. The advantage of COB-LED over traditional surface-mount LED technology is that the packing density of the LEDs is much higher. This contributes to higher intensity, improved uniformity and a more compact package than the surface-mount LED technology. The COB-LED can be implemented into various form factors, for example, a number of packaging methods, allowing much greater design flexibility and the light are greater spectrum accuracy and uniformity [2]. Usually, the IEC standard and ASTM standard is used for testing the performances of the Solar simulator. Three parameters that are recommended to test are a spectral match, Irradiance Non-uniformity, and Temporal instability. Then all standard provides three classifications for the different level of the sun simulator's performance. In this paper, the focus will be on the study of only the Non-uniformity irradiance. Summary of the review of articles relating to the LEDs based solar simulator: Trend of the development is the LEDs based, and LEDs mix with Halogen lamp. The structures of those sun simulators look complicated have big size but the small testing plane, is hard to design the heat extracting system, and a lot of wire connecting. The previous sun simulator does not have that used Chip-on-Board High power LEDs (COB-HP-LEDs: 50Watts each) to be the light source.

The author came up with the new idea to design and construct the LED solar simulator by using COB-HP-LEDs for I-V characteristic measurement of the solar cell. The purpose of this paper is to test the temporal instability of irradiance and the non-uniformity on the test plan of the COB-LEDs solar simulator. The experiment test is based on the methods recommended in the IEC 60904-9 edition 2(2007). The limit of this study, the author could not test the spectral match between the light sources.

2. Literature Review

The study of Bilss was showed the idea of developing the solar simulator based on LED combined with Halogen lamp. This solar simulator is confirmed in class BAA at the irradiance of 100 W/m2 [3].

In 2011, Krebs reported the LED solar simulator that can generate the light conforming to the spectrum of AM 1.5 G. The simulator irradiance is equal to 743 W/m2, and the room area is about 1.7x4.3 cm2 [4].

Kolberg did the research “Development of tunable close match LED simulator with extended spectral range to UV and IR”. This project used 800 LEDs to generate the artificial Sun conforming to the AM 1.5 G. The artificial Sun light temporal stability is about ±3. They found that this simulator has economic worthiness more than the Xenon based solar simulator [5].
In accordance with the paper of Bazzi which reported the LEDs based solar simulator using 56 LEDs with 6 colors having 5 × 10 cm2 of testing room. This system can produce light with the irradiance spatial uniformity of less than 10% [6].
Moreover, the study of Namin explored the outputs of the LEDs based solar simulator from single-color LED array and multi-color LED array that was driven by high voltage pulse at 10 ms. They found that the red and blue LED array can generate irradiance at 1000 W/m2, but the white and green LED array can generate irradiance at 400 W/m2. The irradiance spatial uniformity matches with class B [1].
The report of Novickovas as show that the LED-based AAA class solar simulator, employing only 19 high-power emitters for a usable illuminated area of at least 5 cm in diameter with at least 1000W/m2 of irradiance. The so-called A class spectrum was also achieved for the larger area of more than 6 cm × 6 cm [7].
Lastly, Ghandi was present the solar simulator that used the LED plus Halogen lamp as light sources. The results show that the spectral match better than 6 %, and the non-uniformity on the test plane meet with standard class B. The test area is about 156.25 cm2 [8].

3. Materials and Methods

3.1 The Light Source

The light source of this study is the eighteen of 50 watts of the chip-on-board light emitting diodes (COB-LEDs). The technical detail as follow; Power 50W, VF=32-34V, IF=1.75A, CCT=2850-3050K, Flux=4000-5000 lm, Wave range 270-750 nm, with the warm white. They are installed on an aluminium anodize heat sink the dimension are 31.5 cm. × 23.2 cm. × 5 cm. At the back of the heat sink have thirty fins with the electric fan ventilation system. The luminance area is 28 cm ×14 cm. There are 3 sets of the 300 watts of switching power supply, to feed power to the eighteen of COB-LEDs. The diagram of the light source as shown in Figure 1b. Inside of the test room was installed the mirror wall (Figure 1a).

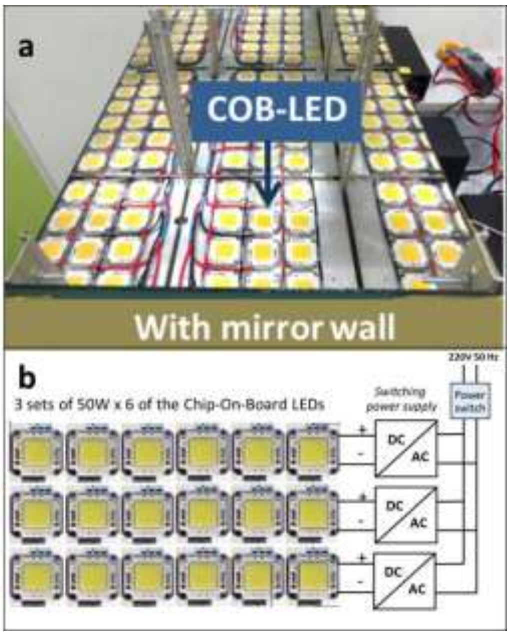

Figure 1: (a) Testing room with the mirror wall (b) the chip-on-board light emitting diodes connecting diagram.

3.2 IEC 60904-9

This study reference from the IEC 60904-9 (Photovoltaic device-Part 9: Solar Simulator Performance requirements). The IEC 60904-9 is the testing standard for testing the solar simulator for the indoor case. That is used for solar cell V-I characteristic test. This standard needs to test in the three categories. There are (a) The spectral match (b) The Non- uniformity of irradiance, and (c) The temporal instability of irradiance [9].

The spectral match: The spectral match can measure by using the Spectroradiometer. That should measure the irradiance in each wave range of the band width of the light. (Bandwidth, nm) The measured results would compare with the standard value of AM 1.5 G in each wave range band. Find out the percentage of the spectral match.

Non-uniformity of irradiance: The non-uniformity of irradiance on the test plane is the percentage of the difference of maximum irradiance and minimum irradiance over the sum of maximum irradiance and minimum irradiance. According to the IEC 60904-9 standard will be divided the test plane into 64 equally size test positions (8×8). Then measure the irradiance from each position and take a minimum and minimum value of irradiance to calculate the percentage of non-uniformity by using an equation (1).

$$\text{Non-Uniformity}(\%) = \left[\frac{\text{Irr}\max - \text{Irr}\min}{\text{Irr}\max + \text{Irr}\min}\right] 100 \quad (1)$$

Where Irrmax is the maximum irradiance(W/m2),and Irrmin isthe minimum irradiance (W/m2)

The temporal instability of irradiance :The temporal instability of irradiance separates in two types. There are the short-term instability, (STI) and long-term instability, (LTI) that depending on the type of solar simulator. This study will focus on the steady state solar simulator for I-V measurement [9]. The STI will be related with the data sampling time. The LTI will be relating with the time of data acquisition that measure for the I-V characteristic of the solar cell under test. The calculate equation of temporal stability as shown in equation (2).

$$\text{Temporal stability}(\%) = \left[\frac{\text{Irr}\max - \text{Irr}\min}{\text{Irr}\max + \text{Irr}\min}\right] 100 \quad (2)$$

The IEC 60904-9 classified the standard of a solar simulator in three qualities of classes. There are Class A, Class B, and Class C. Each class will define the percentage of the spectral match, Non-uniformity and temporal instability of irradiance as shown in table 1.

Table 1: Classification of the solar simulator in the IEC 60904-9 standard

Class	Spectral Match	Non-uniformity	Temporal Instability
A	0.75 – 1.25 %	2 %	2 %
B	0.60 – 1.40 %	5 %	5 %
C	0.40 – 2.00 %	10%	10 %

Solar Power Meter and thermometer: (1) To measure the irradiance of the solar simulator in this study, the author used the solar power meter. The Solar power meter specification as follow; Range 0-2000W/m2, Resolution 1W/m2 Accuracy ±10W/m2, Range 400-1100 nm, Sampling time 1S. This instrument can interface with the computer by the USB port, and can operating as a data logger. The solar power was calibrated by the factory. (2) The digital thermometer that used in this study have a range -200°C to 1,370°C, Accuracy ±1°C, Resolution 0.1°C

4. Experiment

4.1 Prepare the Experimental Equipment's:

(1) COB-LEDs Solar simulator, (2) Switching power supply, (3) solar power meter,(4) Digital Thermometer with data logger, (5) Test plane with 64 drill position for placing the solar power meter. As shown in figure 2(a), (b) and (c).This showed that density played important role in influencing the thickness swelling of the particle boards.

4.2 Experimental Procedure:

The procedure that using for test the non-uniformity of irradiance as show in flow chart in figure (3). The step for experiment for testing the temporal stability as show in figure (4). The temporal stability and non-uniformity according with equation (1), and (2).

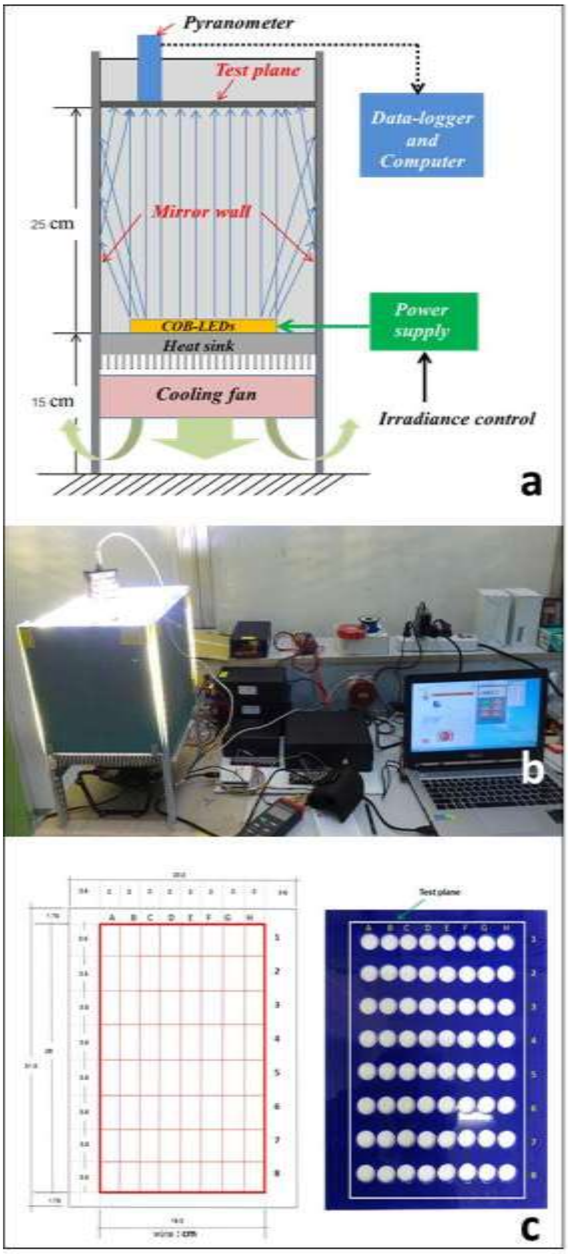

Figure 2: (a) COB-LEDs solar simulator (b) An experiment set up (c) The test plane (acrylic) size 448 cm2 define in 64 positions (A1-H8).

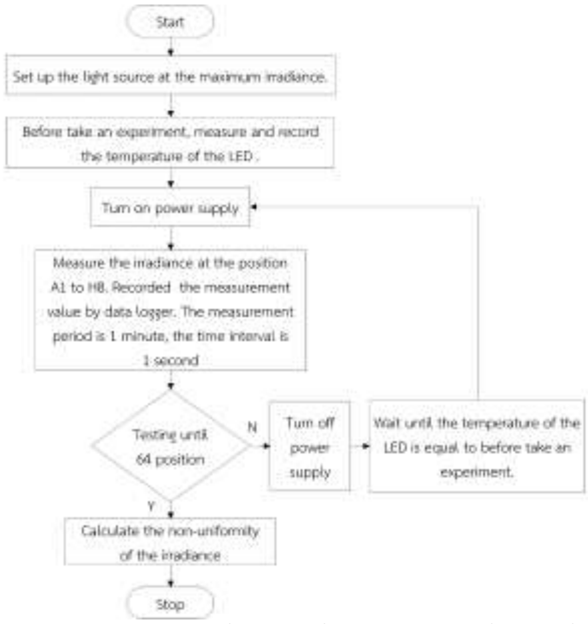

Figure 3: The experimental flow chart for test the non-uniformity of irradiance

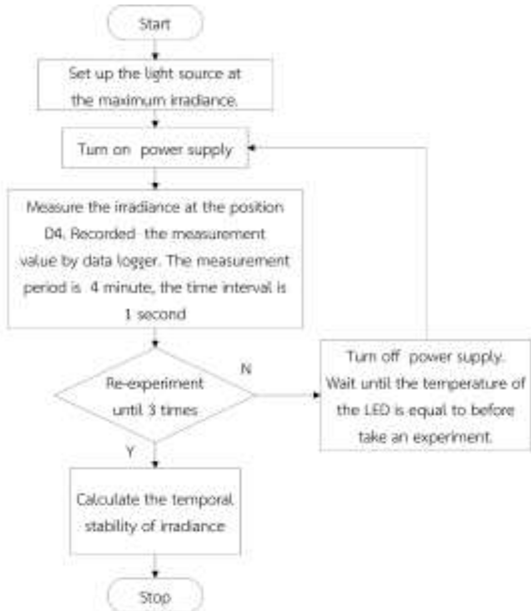

Figure 4: The experimental flow chart for test the temporal stability of irradiance

5. Results and Discussion

5.1 Non-Uniformity of Irradiance

The measured results show that the highest irradiance on the test plane is about 772.7 W/m2 The lowest is equal to 627.0 W/m2. The average value of irradiance over the test plane is around 699.0W/m2.The calculation results of non-uniformity on the test area 448 cm2 (16cm ×28cm) is equal to 7.42 % that meet in class-C of the IEC 60904-9. The non-uniformity pattern as shown in figure (5). However, If consider the smaller area by the same measurement data, such as on 336 cm2 (12cm x 28cm). The trend of result found that the non-uniformity is about 4.89% that meets in class-B. In the same way, on the test area is about 112 cm2 (8 cm x 14 cm), the non-uniformity is equal to 1.82 % that will meets in class-A. The comparative of the test area as shown in figure (6).

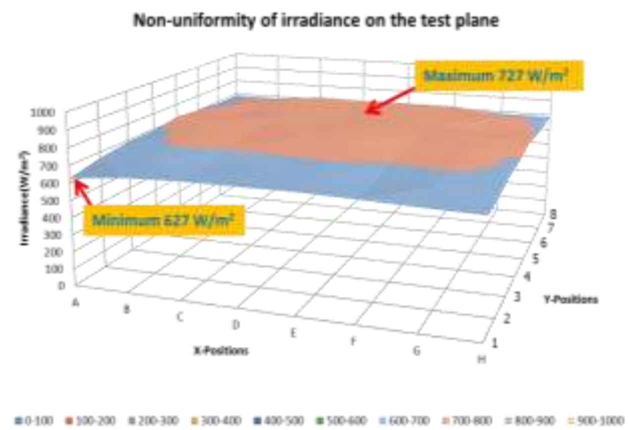

Figure 5: The experimental result of non-uniformity of irradiance on the test plane

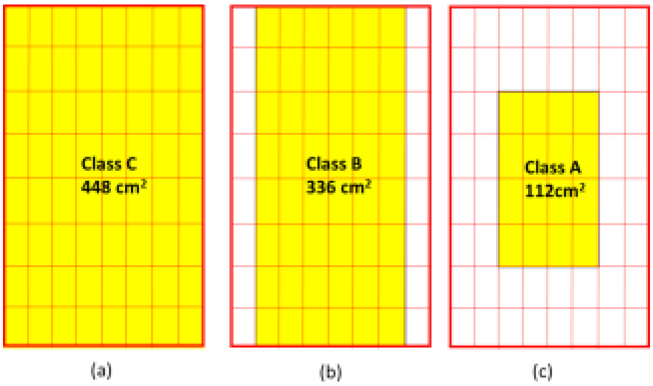

Figure 6: The non-uniformity of irradiance on the difference size of test plane at standard class A, B, C

5.2 Temporal Instability

The temporal instability of irradiance from the COB-LEDs based solar simulator. This study using the Long-term instability testing method [9]. To turn on the power supply continue to 4 minutes and give a worm-up time of LED is about 20 seconds [3]. The results found that the temporal stability is equal to 3.92 %. This mean that the temporal instability by the continuous running. It is meet the Class-B of the IEC 60904-9. The results as shown in figure (7).

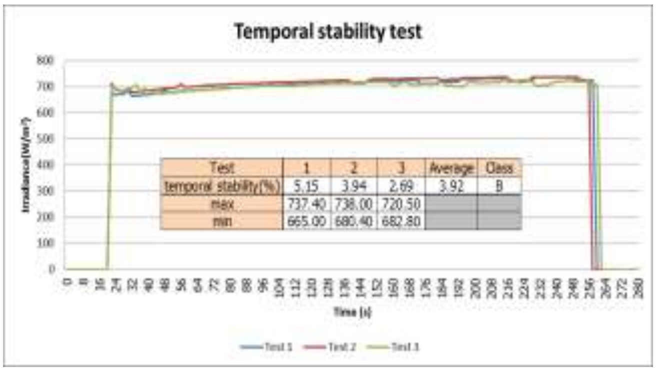

Figure 7: The measurement of temporal instability reach to Class-B

5.3 Define the Classification

From the experimental results, the temporal stability and non-uniformity of the artificial light of the COB-LEDs based solar simulator. The author should identify the classification on test area 448 cm2 (Table 2).

Table 2: Defind the classification of the COB-LEDs solar simulator

Parameter	Experimental results	Classification
Spectral Match (%)	No	N.A.
Non-Uniformity (%)	7.42	C
Temporal Instability (%)	3.92	B

5.4 Discussion

The non-uniformity of irradiance from this study is about 7.42 % (Class-C). But it will better until meeting with class-A at the center of the light source. That you can see the pattern of the irradiance on the test plane in figure 6(b). This shows that the non-uniformity depends on the installation pattern of the LED, and the distance of the test plane from the light source. This means that the non-uniformity of the irradiance could improve to meet the standard class-A. By extending the distance of test plane and the light source more than 25 cm. Harmonize with the investigated of Mohan and Shatat [10-11]. Moreover, if the distance increases the intensity of irradiance will decrease. The author has to install the number of COB-LEDs much more. The new design may be using 6 x 4 arrays of COB-LEDs. It will generate more irradiance than 772.7 W/m2 (from the previous design is 6 x 3 arrays of COB-LEDs).The temporal instability of the COB-LEDs based solar simulator is meet the standard class-B. To improve the temporal instability, the author has to use the high quality of power supply (low ripple voltage) and apply to LED by current control mode. According with the study of Photong [12] and Namin [1].

6. Conclusion

The idea realization to apply the COB-LEDs to be a solar simulator that used for V-I characteristic test of the solar cell. The quality of irradiance of the COB-LEDs solar simulator is meet the method of IEC 60904-9 in two schemes. There are (1) The non-uniformity of irradiance and (2) the temporal stability. The way to control the intensity of light is to control the DC voltage that supplies to COB-LEDs. The power loss from the heat when the LED was operated can perfect ventilated by using the 36 watts of the electric fan. The mirror wall in the testing room was necessary. The size of the test plane may be equal to the luminance area; it will affect the good non-uniformity of irradiance on the test area.

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