NEW METHODS FOR SOLAR CELLS MEASUREMENT BY LED SOLAR SIMULATOR

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ABSTRACT

A solar simulator for solar cells is an important tool to measure their performance. At present, xenon and halogen lamp is used at most laboratories. It is considerably accurate, but the facility is so large and so expensive. Therefore, a solar simulator using LED (light-emitting diode) lamps is proposed, that is low-cost and portable, and was invented to its capability. Its capability was preliminarily evaluated by examining an illuminance distribution using simulation. Although a light inhomogeneity is one of the problems to be solved, it was shown that an unevenness of illumination is about 3%. Secondly, in terms of spectral property, absolute spectral responses by plural usage of different LEDs were also estimated. An overall measurement concept and procedure by the LED simulator are discussed and proposed.

1. INTRODUCTION

It is necessary to measure the photocurrent of solar cells for determining the price and the PV system design. Although a solar simulator with xenon and halogen lamps measures solar cells in doors, at present, one must resolve a number of issues, including those related to unevenness, measurement error at manufactory and cost. A solar simulator with lamps is considerably accurate, however, cost and size problems of the facility prevent us from using it anyplace. Since the facility is so large, the application of Reference Cell Method causes the measurement error by the several calibration. Additionally, the assessment of the established PV modules has not been measured.

The standard of the irradiation spectrum by each kind of cells is ruled for raising the precision of measurements. However, by nature, the application of Reference Cell Method causes errors.

Recently, LED lamp has widely been used for a traffic signal and an illuminator because of their longer operating life and high energy efficiency. The technique developed in the present work establishes the evaluation method with LED equipment for solar cells measurement. This paper is intended to report the results of examining the capability of evaluating methods with the equipment using LED for solar cells measurement. The tests have been calculated using simulation.

2.METHOD AND MATERIALS

2.1 Outline of the illuminant simulation

The equipment with LED for solar cell measurement must satisfy the following conditions; use LED of plural colors (4 or 6 colors used in this paper), arrange all LED on the same plane like display. The reason is for illuminating with plural colors because of the bright line spectrum of LED, and for manufacturing small equipment. The schematic illustration of the equipment is shown in Fig.1. The traditional solar simulator condenses their lights with an integrator lens, in contrast the equipment with LED illuminates an object directly.

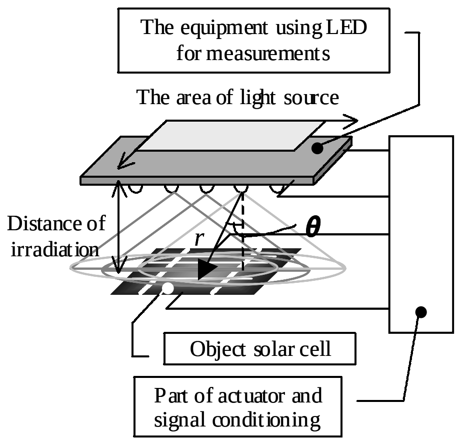

Fig.1 A schematic diagram of the measuring equipment

In solar cell measurements the incident light requires illuminating the whole object as flat as possible. In the case of using plural LED, especially the light tend to be lacking in uniformity, their unevenness was calculated by the illuminant simulation. The equipment has 4 or 6 different wavelength chip-type LED, that colors are blue, red, IR (infrared radiation), white and so on. We assumed that these LEDs are put in matrix at even intervals (if it uses LED of 6 colors, arranges to the hexagon as a unit), and the distance between the same colors is 8 mm (and is 12 mm with 6 LEDs.) and that between each LED is 4 mm. The examples of LED arrangement is shown in Fig.2(a),(b). The equations used in a illuminant simulation are as follows:

$$I(x,y)=\sum_{i=1}^{n}\frac{I_{ls,i}(\theta_i)}{r_i^2}\cos\theta_i$$

where $I(x,y)$ is the irradiance at the measurement point, n is a number of LED, I_{ls} is the irradiance of LED, θ and r are the angle and the distance from the light source to the measurement point, shown in Fig.1.

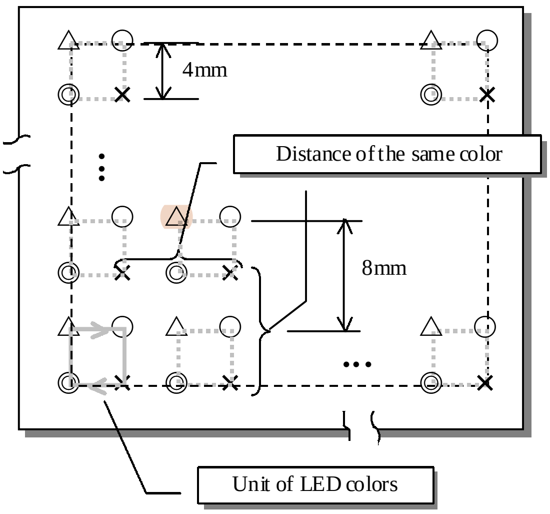

Fig.2(a) The examples of LED arrangement (using LED of 4 colors)

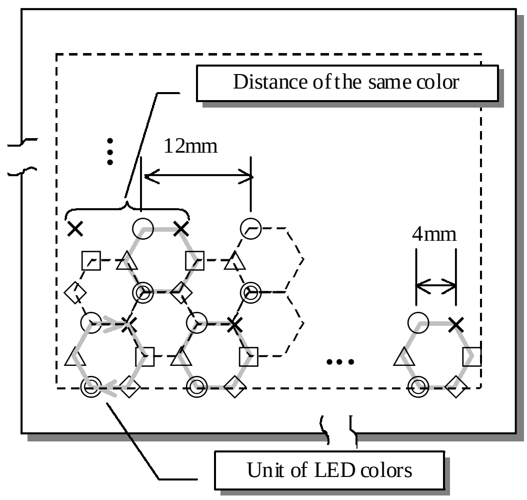

Fig.2(b) The examples of LED arrangement (using LED of 6 colors)

2.2 Measurement method of photoresponse with LED

Photovoltaic current is determined by the light-source spectral irradiance and the spectral response of the solar cell. The present solar simulator with lamps can recreate the reference solar spectral irradiance distribution approximately, however, LED is not good enough to reproduce the radiant intensity and the width of the spectrum. Therefore, we proposed the method of estimating spectral response using LED. And the photocurrent I_{sc}, under the circumstances irradiated by the reference sunlight, can be written by the expression;

$$I_{sc}=\int_{\lambda_1}^{\lambda_2} I_s(\lambda)\cdot F(\lambda)d\lambda$$

where λ_1 and λ_2 are the shortest and longest wavelength, $I_s(\lambda)$ is the absolute spectral response, and $F(\lambda)$ is the number of photon of the incident radiation by the wavelength.

A measuring procedure of spectral response for solar cell with LED is proposed. At first, the part of the signal conditioning measures the photocurrent among illuminating the solar cell under test with a monochromatic light that is modulated; that is the absolute spectral response at the wavelength of the irradiation. The rest of colors is operated, in the same way. The way of measuring spectral response is equal to the traditional one, approximately. The calculating flow is schematically shown in Fig.3. Secondly, the signal conditioner calculates for fitting the theoretical photocurrent formula into the discrete absolute spectral responses by the nonlinear least square method[1].

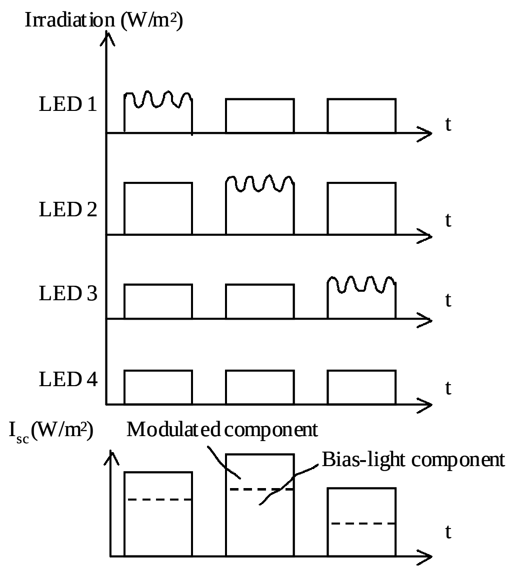

Fig.3 The calculating flow of spectral response using LED

3. RESULTS AND DISCUSSION

3.1 Light unevenness

Figure 4(a) shows the results of calculating the unevenness of the irradiation as a function of the light-source area and the distance between the solar cell and the light source when LED of 4 colors is used. And Figure 4(b) shows the unevenness when LED of 6 colors is used. The values used in the illuminance simulation are given in Table.1, and the distribution map of the unevenness are given in Fig.4(a-1,2)-Fig.4(b-1,2). The illuminated area is square 100 mm on a side, the angle of beam spread is 120 degrees. The unevenness decreases as the intervals between the light-source and the cell increases, before the minimum value is obtained. However, the unevenness increases reversely when the distance is larger than the minimum value. In the case of the close-in illumination, The difference in an irradiance between just below LED and except is shown in Fig.4(a-1). On the other hand, in the case of illumination apart from the object, the center of the cell is illuminated with the highest irradiance, shown in Fig.4(a-2).

Table 1. Illuminant simulation conditions

Arrangement type	Square	Hexagon	
Figure	Fig. 2(a)	Fig. 2(b)	
A number of LED colors	4	6	
Distances of each LED	4		(mm)
Distances of the same color	8	12	(mm)
Angle of beam spread	120		(deg)
Illuminated area	100*100		(mm2)

In the illuminant area, as the area widens, the evenness is reduced. It shows that, if set up the optimum illuminant area and the distance of the light-source and solar cell, the equipment can illuminate an object on the order of a 3% unevenness.

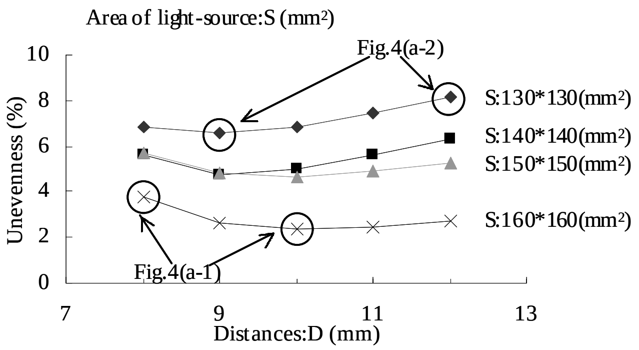

Fig.4(a) The unevenness using LED of 4 colors

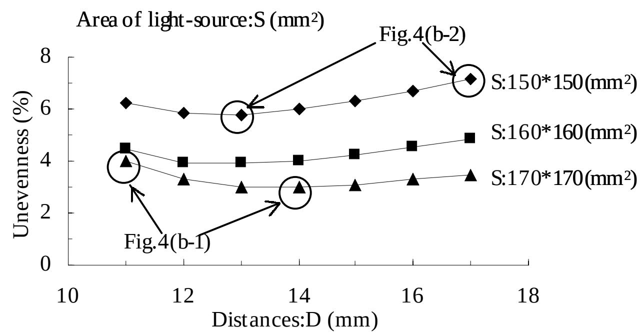

Fig.4(b) The unevenness using LED of 6 colors

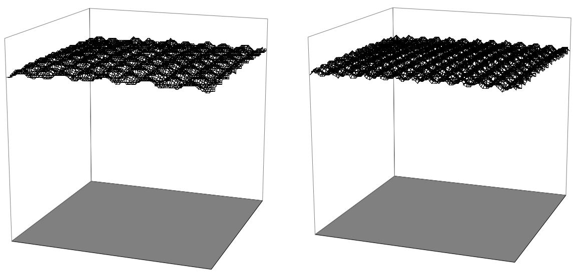

Fig.4(a-1) the unevenness using 4 colors
S:160*160(mm²),D:8 and 10(mm)

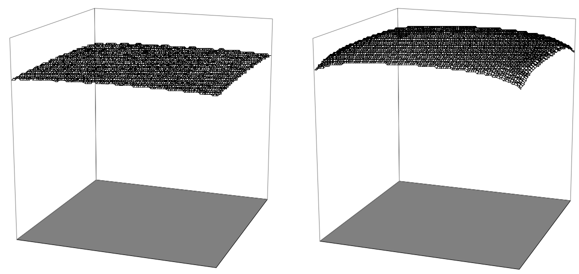

Fig.4(a-2) the unevenness using 4 colors
S:130*130(mm²),D:9 and 12(mm)

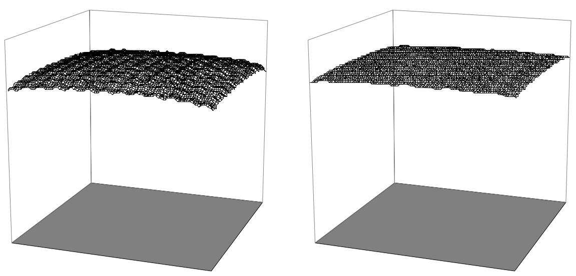

Fig.4(b-1) the unevenness using 6 colors
S:170*170(mm²), D:11 and 14(mm)

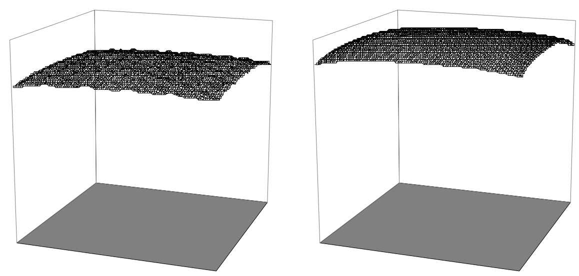

Fig.4(b-2) the unevenness usign 6 colors
S:150*150(mm²), D:13 and 17(mm)

3.2 Estimating of the absolute spectral response

The above procedure calculates the curve of the absolute spectral response. Fig.5(a) shows the discrete response with modulated light, and Fig.5(b) shows the spectral response curve after fitting the theoretical photocurrent formula of spectral response. The photocurrent of solar cells is estimated with bright line spectrum. Note, however, that the warrants future work on the care about the spectral response shift affected by incident intensity of irradiation.

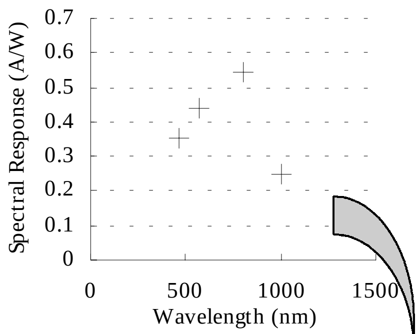

Fig.5(a) the discrete spectral response

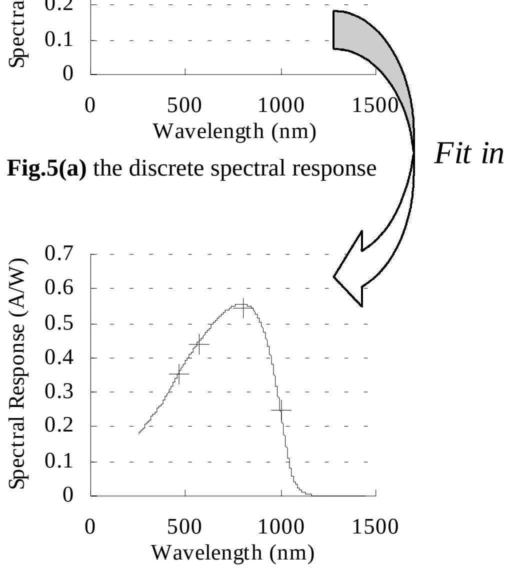

Fig.5(b) the fit spectral response curve

4.CONCLUSION

In the present work, the capability of the equipment using LED for solar cell measurements is examined. As a first step, the unevenness of the irradiation was calculated. In result, that can illuminate an object evenly. A target of the equipment is set to measuring the solar cell spectral response, and the measuring method with LED bright line spectrum and the process to calculate the spectral response illuminated with the reference solar irradiation are confirmed. The issues that the LED light intensity is not enough to measure a solar cell are remained, and the way to resolve is in review. The development of LED solar simulator will make the measurement, for example the evaluation of PV system put on a roof and the quality management at the manufacturing premise, easy.

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