New Laser-Driven Light Source (LDLS)-based DSR measurement facility for calibration of reference solar cells

Khaled Mahmoud[1,2], Jae-Keun Yoo[3], Nasser Al-Qahtani[1], Hong Gyu Lee[4]

[1]*National Measurement and Calibration Center, Saudi Standards, Metrology and Quality Org. (NMCC/SASO), PO Box 3437 Riyadh 11471, Saudi Arabia,*

[2]*National Institute for Standards (NIS), PO Box 136 Giza, Code No 12211, Egypt,*

[3]*Division of Physical Metrology, Korea Research Institute of Standards and Science (KRISS), Daejeon, Korea*

[4]*PIMACS CO., Ltd, Seoul, Korea Republic.*

Corresponding e-mail address: k.abdelftah@saso.gov.sa / khaled55eg@yahoo.com

A newly established facility for calibration and characterization of solar cells at NMCC/SASO is presented. This multipurpose instrument can provide a complete set of data for solar photovoltaic (PV) devices including critical spectral and electrical parameters. The system comprises two main parts, first utilizes LDLS-based modulated (AC) source to measure the spectral responsivity of PV detectors and solar cells using the DSR technique, second uses solar simulator to study the IV-curves, measuring the short circuit currents and solar cell efficiencies. The first part will be used to measure the spectral responsivity in the wavelength range from 250 nm to 2000 nm, bias level up to 1.5 kW/m^2, with which, target measurement uncertainty below 1 % (*k* = 2, in the visible range) can be achieved.

INTRODUCTION

Solar energy has the ability to reduce greenhouse gases, global warming and provide increasing energy efficiency. As a sustainable resource of energy, solar energy is the type of energy that can solve the energy problems in the earth. Saudi Arabia is one of the countries that is reach with solar energy all over the year; this creates an ultimate opportunity to build its own solar power hub to meet its rapidly growing needs of electric power and to become a leading exporter of solar energy [1]. Those objectives motivate the NMCC/SASO (NMI of Saudi Arabia) to build a new facility for solar cell (PV) devices calibration and characterization to meet its challenge as NMI for supporting the emerging solar industry.

Solar energy industry requires the high accuracy testing of energy efficiency of photovoltaic devices, which is directly related to their performance and price. Measurement standards for testing the photovoltaic devices start from the calibration of reference solar cells as specified in the IEC 60904 series. The capability for the primary calibration of reference solar cells can be useful to study the technical issues in the development of new photovoltaic materials, and has impact to the general metrology of optical detectors. Measurement uncertainty for photovoltaics proved to have a big economic impact, which motivates NMIs to draw careful attention to the calibration and testing of the reference solar cells under specified conditions maintaining the traceability to WPVS.

Measurement of spectral responsivity is of considerable importance in radiometric, photometric, and colorimetric applications where the calibration of optical detectors is a fundamental requirement. For photovoltaic detectors, such as solar cells, in particular, the spectral responsivity is directly related to the energy conversion efficiency, which is one of the most important figures of merit to specify their performances [2].

The widely used scheme for the solar cell standards is the differential spectral responsivity (DSR) technique, which measures the responsivity of a photovoltaic detector under test (DUT) to the AC modulated monochromatic light under the strong broadband DC bias light. The DSR technique has been realized in many standard laboratories as [3-5] with different approaches and similar technique used to analyze the noise in the PV detectors responsivity measurement based on DSR scheme [6].

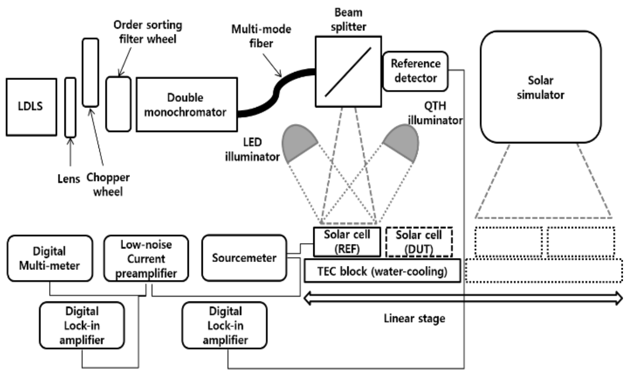

Figure 1. Schematic of the NMCC multifunction PV facility.

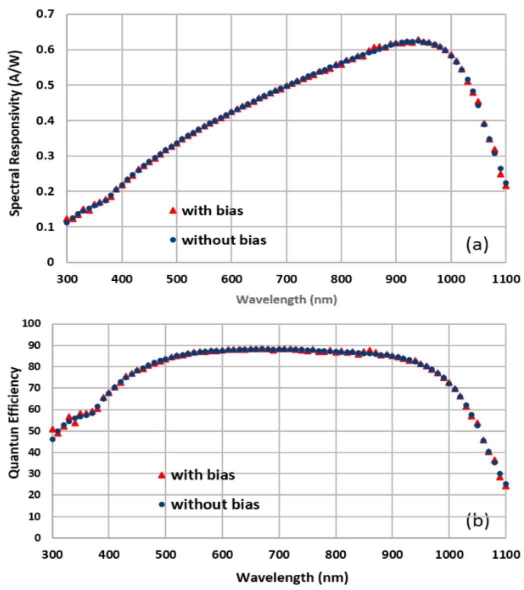

Figure 2. (a) Measurement results of spectral responsivity of reference solar cell using the LDLS-based DSR with bias (red), and without bias (blue) and (b) QE curves

INSTRUMENT

Figure 1 shows the full block diagram of our fully automated facility. Our apparatus, which is a combined multifunction system, comprises two main setups. First one for DSR measurements is based on LDLS-based modulated monochromatic source (ac) and extremely high output power LED-based illuminator + QTH based source as bias sources (dc).

Second Major setup comprises solar simulator with automation software tracing the current-voltage curves for full electrical characterization of solar cells of different sizes up to 152 mm × 152 mm, including the most critical parameters of PV cells, e.g. measurements of short-circuit current i_{SC}, open-circuit voltage V_{OC}, fill factor (FF) and energy conversion efficiency.

The new DSR setup will be used to measure the spectral responsivity in the wavelength range from 250 nm to 2000 nm, bias level up to 1.5 kW/m^2, modulation frequency range from 0.1 Hz to 100 Hz, with target measurement uncertainty below 1 % (k = 2, in the visible range) can be achieved.

Many traditional techniques been developed in standard laboratories to realize the DSR technique for spectral responsivity (SR) measurements. Traditional techniques commonly use incandescent or discharge sources with monochromator, or broadband source with spectrally selective filters (e.g. interference filters). Unfortunately, many drawbacks come with those traditional selections, e.g. low SNR, inherent instability and noise due to the aging characteristics of the used light source. Those sources have another limitations discussed in [7]. The new facility promises major advantage over traditional one, where it provides much higher monochromatic AC radiation throughput due to the use of high radiance LDLS coupled to multimode optical fiber offering optimum focusing on the DUT at the measurement plane.

PRELIMINARY FINDINGS AND CONCLUSION

Our first results of the spectral responsivity and quantum efficiency (QE) of sample reference solar cell shown in figure 2. The measurements show good agreement between the results of two test schemes (measurement with 14 mA bias light and without bias), which shows a good linearity of the DUT up to the bias level used in this test experiment. This presents a good advantage of using LDLS-based monochromatic radiation, which is expected to ultimately improve the accuracy by introducing much higher SNR with respect to the traditional techniques. This also would allow our lab to study the linearity of the PV detectors over many decades with lower uncertainties (< 1%). Moreover, traceability of calibration can be achieved by developing primary reference standards. The instrument presented here presents other advantages, e.g. better uniformity and stability characteristics and readiness for larger sample (DUT) size which would be shown throughout our current measurements.

The facility is promising to offer potential of applications in variety of metrological, industrial and research fields.

REFERENCES

1. G.W. Crabtree and N.S. Lewis, Physics Today, March 2007 sowie Prof. Eicke Weber, ISE.
2. J. Metzdorf *et al.*, Principle and application of differential spectroradiometry, Metrologia, 28, 247 (1991).
3. IEC 60904-8:1998, Photovoltaic devices Part 8: Measurement of spectral response of a photovoltaic (PV) device, International Electrotechnical Commission.
4. G. Zaid *et al.*, Differential spectral responsivity measurement of photovoltaic detectors with a light-emitting-diode-based integrating sphere source, Applied Optics, 49, 6772 (2010).
5. B. H. Hamadani *et al*, Versatile light-emitting-diode-based spectral response measurement system for photovoltaic device characterization, Applied Optics, 51, 4469 (2012).
6. Jae-Keun Yoo et al, Noise analysis in differential measurement of detector responsivity, Proceedings of NEWRAD 2014, Espoo, Finland.
7. H. Field, “Solar cell spectral response measurement errors related to spectral band width and chopped light waveform,” in Proceedings of IEEE 26th Photovoltaic Specialists Conference (IEEE, 1997), pp. 471–474.