National Institute of Standards & Technology

Specifications

Standard Reference Instrument Series 6014

Calibrated Reference Photovoltaic Cell

Description: This standard reference instrument (SRI) is a packaged photovoltaic (PV) cell that is calibrated to give the short circuit current, I_{sc}, of a 20 mm PV cell under a well-defined reporting condition, such as the standard reporting condition defined by the IEC 60904-3 or ASTM G173 international standards (i.e., the standard sun corresponding to a total incident irradiance of 1000 Wm^{-2} with the cell at 25 °C), or a low-irradiance indoor light such as LEDs or fluorescent lighting. The end user of the reference instrument uses it to measure the effective irradiance incident on their PV devices under test (DUT) for the purpose of electrical characterization, to adjust or monitor the light intensity of a solar simulator or another light source, or to transfer the calibration to a secondary cell.

The NIST PV cell calibration method is a primary method called the differential spectral responsivity (DSR) technique, performed in irradiance mode, and has direct traceability to SI using other NIST calibrated specimens. These measurements are performed under low power, low frequency modulated monochromatic light combined with a higher intensity, steady-state broadband light beam called the light bias. The AC generated currents in both the solar cell and a monitor detector that is used for beam irradiance monitoring, are then measured, and amplified by a lock-in amplifier system. The monitor detector signal combined with the solar cell's modulated signal collectively define each discrete spectral responsivity data point that is processed as the absolute irradiance spectral responsivity of the solar cell R [$A. m^2. W^{-1}$] as a function of wavelength λ [nm]. Upon completion of this measurement, the I_{sc} of the solar cell will be calculated, using a well-established measurement equation

Design, construction, and technical measurements leading to the production of this SRI were performed by Dr. Behrang H. Hamadani at NIST's Building Energy and Environment Division within the Engineering Laboratory.

Customers should choose and specify the reporting condition under which they want their SRI to be calibrated. Multiple reporting conditions can be specified for the same instrument. Currently NIST offers calibrations under the following six reporting conditions and at 25 °C:

1. 1.5 air mass global spectral irradiance (direct + diffuse) as tabulated in the IEC 60904-3 with a total irradiance of 1000 W/m^2.
2. Zero air mass solar spectral irradiance for space applications as tabulated in the ASTM E490 with a total irradiance of 1366.1 W/m^2.
3. A NIST-constructed white LED light source with a correlated color temperature of 3000 K, illuminance of 1000 lx and a total irradiance of 2.93 W/m^2.
4. A NIST-constructed white LED light source with a correlated color temperature of 4000 K, illuminance of 1000 lx and a total irradiance of 3.11 W/m^2.
5. A NIST-constructed white LED light source with a correlated color temperature of 6000 K, illuminance of 1000 lx and a total irradiance of 3.70 W/m^2.

6. TL84, a CIE-based illuminant source representing a fluorescent lamp with a correlated color temperature of 4000 K as tabulated in the SEMI PV80 Standard, fixed at an illuminance of 1000 lx and a total irradiance of 2.97 W/m^2.

Specifications: The reference instrument consists of an anodized aluminum housing that accommodates a diced 20 mm × 20 mm silicon solar cell wafer (or other stable, well-characterized PV materials if available). The solar cell is mounted onto a small, printed circuit board and the board is fitted into the body of the housing with good thermal contact and a temperature sensor (thermocouple) for monitoring its temperature. It is also electrically wired in a 4-probe configuration and can be externally measured using a 4-probe cable. A clear or filtered glass window is epoxied to the top of the housing to protect the cell, and if filtered, for altering the input spectrum reaching the solar cell. The SRI is designed and packaged at NIST. It is constructed from custom parts and commercially available components.

The SRI 6014 is calibrated for irradiance spectral responsivity R [A. m^2. W^{-1}] of the PV cell as a function of wavelength λ [nm] and the calculated short circuit current, I_{sc} [A], of the instrument under the requested reporting condition at a temperature of 25 °C ± 1 °C. Uncertainty values for the short circuit current of the instrument are typically 0.52 % (k = 2). For silicon with a clear optical window, the measurement spectral region is typically from 280 nm to 1200 nm. The solar cell at the heart of this instrument is a carefully chosen diced Si cell with linear properties over the irradiance region of calibration. Even so, the measurements are performed under an appropriate level of bias light. The SRI is expected to remain stable for at least three years from the date of calibration if not deployed outdoors under continuous operation. Potential drift in original calibration may be checked by periodical re-calibrations at NIST or another SI-traceable metrology lab with a similar calibration uncertainty.

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Gaithersburg, MD 20899
Certificate Issue Date: 23 September 2021

Delivery: Delivery dates will be determined on a case-by-case basis in coordination with the customer and based on the availability of components and NIST staff.

Shipping: The SRI will be packed and shipped to the customer by the NIST Building Energy and Environment Division. Shipping case dimensions and weight will be included in each quote. Customer will arrange and pay for shipping directly with the shipping company when informed by NIST that the SRI is ready for shipment. Customers are responsible for all customs duties, import fees, and shipping insurance.

Installation: Customer is responsible for setup at their location.

Support: Repairs or other follow-on work on SRIs may only be performed by NIST under a separate reimbursable agreement for services. Refer to SRI Terms and Conditions available here: https://www.nist.gov/sri/sri-terms-and-conditions.

References:

[1] B. H. Hamadani, J. Roller, B. Dougherty, F. Persaud, and H. W. Yoon, Absolute Spectral Responsivity Measurements of Solar Cells by a Hybrid Optical Technique, Appl. Opt. 52, 5184 (2013).

[2] B. H. Hamadani, J. Roller, A. M. Shore, B. Dougherty, and H. W. Yoon, Large-Area Irradiance-Mode Spectral Response Measurements of Solar Cells by a Light-Emitting, Diode-Based Integrating Sphere Source, Appl. Opt. 53, 3565 (2014).

[3] J. Roller and B. H. Hamadani, Reconciling LED and Monochromator-Based Measurements of Spectral Responsivity in Solar Cells, Appl. Opt. 58, 6173 (2019).

[4] IEC Standard 60904-3, Photovoltaic devices- Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data. (2008).

[5] ASTM Standard E490-00a: Solar constant and zero air mass solar spectral irradiance tables, (2006).

[6] B. H. Hamadani and M. B. Campanelli, "Photovoltaic Characterization Under Artificial Low Irradiance Conditions Using Reference Solar Cells," IEEE J. Photovoltaics, 10, 1119–1125 (2020)

[7] SEMI PV80-0218: Specification of Indoor Lighting Simulator Requirements for Emerging Photovoltaics (2018).

Users of this SRI should ensure that the Specifications Certificate in their possession is current. This can be accomplished by contacting the Office of Reference Materials: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/sri.