

ACCESSORIES

Flashing Solar Simulators:

Contact factory for your flashing solar simulator needs for testing cells and/or panels.

Reference Cells:

The Reference Cells incorporate a 2 x 2 cm cell (embedded in silicon resin), either mono-crystalline or poly-crystalline, and are shunted inside the body by a precision resistor. This configuration gives an output voltage usually between 100 and 150 mV for an irradiance of 1 kW/m². The main features are:

- Lightweight black anodized aluminum body
- Cell protected by glass window
- Holes for ease of mounting
- Available in poly- or mono-crystalline
- Mainly designed for use with PET Solar Simulators
- Optional Temperature-sensor

Non-Uniformity Testing:

The uniformity testing/mapping system is a very convenient and easy way to check the uniformity of the Solar Simulator Light Beam. Manual and semi-automated versions are available. The system includes all the necessary equipment to check the uniformity. This includes a 6x6 matrix Test Grid for customer specified area. The grid is designed to test 36 points (6 x 6) over the area of illumination as per ASTM Standard E927-04. The cell in the Test Cell Fixture is calibrated to a traceable standard for 1 sun. Hence this cell can be used not only to check uniformity but also adjust the intensity of the Solar Simulator to 1 sun intensity. The Test Cell Fixture has a silicon cell; however, other type of cells (supplied by customer) can be incorporated in to the Test Cell Fixture to better match the spectral response of customers' cells. However, special grids can be supplied or made by the customer to test more or less points in the area of illumination.

Temporal Stability Testing:

The temporal stability testing system is a very convenient and easy way to check the stability of the Solar Simulator Light Beam. The system includes all the necessary equipment to check the stability. The cell in the Test Cell Fixture is calibrated to a traceable standard for 1 sun. Hence this cell can be used not only to check temporal stability but also the uniformity of the light and adjust the intensity of the Solar Simulator to 1 sun intensity. The Test Cell Fixture has a silicon cell; however, other type of cells (supplied by customer) can be incorporated in to the Test Cell Fixture to better match the spectral response of customers' cells.

Extended Warranty

Our products carry standard two-year warranty. An additional one year extended warranty is available at additional cost at the time of equipment purchase. Please contact the factory.

For more information on our products, visit our website www.photoemission.com or contact (805) 482-5200 or mamini@photoemission.com.

REPRESENTED BY:



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Photo Emission Tech., Inc.

Your Best Source for :

- **Steady State (continuous) Solar Simulators - Class A or Class B (50mm x 50mm to 300mm x 300mm Area of Illumination)**
- **Flashing Solar Simulators – Class A (2m x 2m to 2m x 6m Area of Illumination)**
- **I-V Measurement Systems (up to 20A and up to 40V Capability Systems)**
- **Cell Testers (Solar Simulator & I-V Measurement System)**
- **Panel Testers (Solar Simulator & I-V Measurement System)**
- **Flexible Design for easy customization**



SS150A Class A Solar Simulator
Area of Illumination
150 mm x 150 mm

SS200B Class B Solar Simulator
Area of illumination
200 mm x 200 mm

SOLAR SIMULATORS

Solar Simulator – Introduction

A solar simulator is a xenon light source; however a xenon light source is not a solar simulator. Through the use of reflectors, special air mass filters and integrating optics, the properties of the light beam can be modified to meet the three main characteristics of light beam specified by international standards to make a xenon light source into a solar simulator. These international standards define three classes of solar simulators; Class A, Class B and Class C and the acceptable tolerance for the three main characteristics, namely spectral match to sunlight, non-uniformity of the light beam and stability of the light beam over time.

There are two types of solar simulators available in the market for cell testing. First is “Steady State” (SS) system and the second is the “Pulsed Simulator” (PS) system. Pulsed simulators can be single-pulse or multi-pulse type. PS systems have lamp life that is typically between 40,000 to 1 million flashes, whereas the SS systems have a typical lamp life of 1,000 hours of continuous operation. Most PS systems typically have a flash duration of 2 ms to 10 ms; this means that the cell testing, i.e. I.V. measurement system must be able to perform the test within this short duration. Testing in this short duration is not a problem but generally means fewer data points for the I.V curve. It also means that the cell to be tested must be able to respond to the light in this short time duration. As a result it is important to know the response time of the device to be tested. All Photo Emission Tech, Inc. (PET) Solar Simulators are steady state systems based on xenon lamp technology, giving one of the closest matches to spectral irradiance of sun. We offer several models with different area of illumination. The models range from 50mm x50mm to 300mm x 300mm area of illumination for both class A and class B systems. All models have a standard one sun intensity that can be adjusted +/- 15%. If lower intensity values are required then neutral density filters can be used. Custom models with higher intensity are also available.

Standards for Solar Simulators

Three international organizations have defined the standards for solar simulators. These organizations and the standard for solar simulators are;

- American Standards for Test and Measurement (ASTM, standard reference # E927 – Standard Specifications for Solar Simulation for Terrestrial Photovoltaic Testing) has defined American standards.
- International Engineering Consortium (IEC, standard reference # IEC 904-9 – Solar simulator performance requirements) has defined the European standards.
- Japanese Standards Association (JSA) has defined Japanese Industrial Standards (JIS C 8912 – Solar Simulators for Crystalline Solar Cells and Modules, and JIS C 8933 - Solar Simulators for Amorphous Solar Cells and Modules) for Japan.

All of these standards are very similar. Following is an overview of the American standard.

- There are three classes of systems defined
- Class A
- Class B
- Class C

Each class defines the following properties of the light beam and how well it matches the properties of the sun light;

- Total Intensity in a specific range of wavelengths (400-1,100nm for AM1.5)
- Non Uniformity of Total irradiance
- Temporal instability of irradiance
- Spectral match to sun light within a given range for each Air Mass

ASTM E927 STANDARD			
Table 1 Classification of Simulator Performance			
Characteristic	Simulator Class		
	A	B	C
Non-Uniformity of Total Irradiance	±2%	±5%	±10%
Temporal Instability of Irradiance	±2%	±5%	±10%
Spectral Match to Table 2- All Intervals	±25% or 0.75 – 1.25	≤±40% or 0.60 – 1.4	≤-60/+100% or 0.4 – 2.0

I-V MEASUREMENT SYSTEMS

Max. Current Range	±20A
Max. Voltage Range	±40V
Measurement Resolution	16 bit
Measurement Mode	Fixed or Auto
Measurement Time(Light)	50-500 ms Typical <200 ms
Dark Measurement Time	100-2000 ms
Max Point per Curve	4096
Max. Data Acquisition Speed	100 kHz
Maximum Cell Throughput	1200/h With Robotics (Optional)
Phase	Single
Voltage	115-230
Frequency	50-60 Hz
Max. Power Consumption (with Peltier cells)	240W
Average Power Consumption (without Peltier cells)	30 W
Curve Correction to STC (if necessary)	IEC 80891, JRC ANDERSON options
Advance Fitting of I-V Curves	SEM, DEM or VDEM options
Options	Cell Classification, Thermal Coefficients of Voc & Pm Irradiance Monitor & Correction Temperature Control

Ordering I-V Measurement System

The I-V Measurement System/Cell Characterization System model numbers should be determined as follows:

CC-V-WW-XX-YY-ZZ

Where: **CC stands for Cell Characterization**

V - Specifies the maximum current measuring capability:

- 1 – 1A capability
- 3 – 3A capability
- 5 – 5A capability
- 15 – 15A capability
- 20 – 20A capability

WW - Specifies cell temperature control provision:

- TC - Temperature Control Provision (0-600 C)
- NT - No Temperature Control Provision

XX – Specifies Cell Holding Provisions:

- VA - Vacuum Holding Provision
- NV - No Vacuum Holding Provision

YY – Specifies # of Cell Contacting Probes:

- ST - Standard 4 Probes
- MU - Multiple Probes

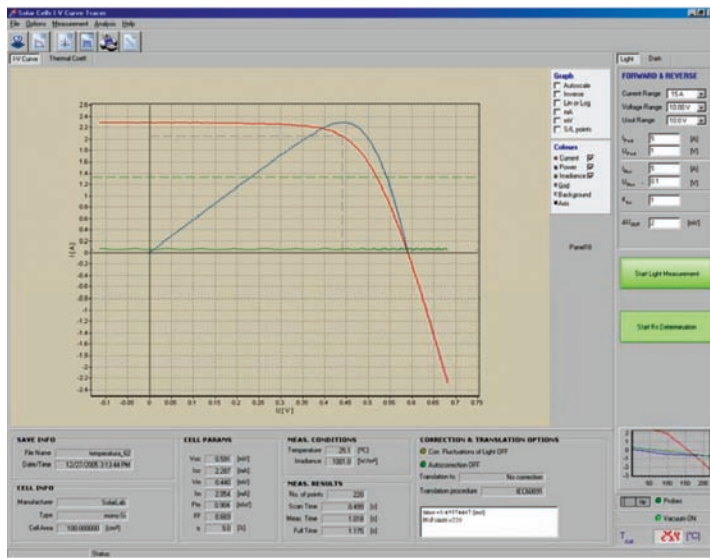
ZZ – Specifies Cell Contacting Provision:

- MA - Manual Contacting Provision
- SA - Semi-Automatic Contacting Provision
- AT - Automatic Contacting Provision

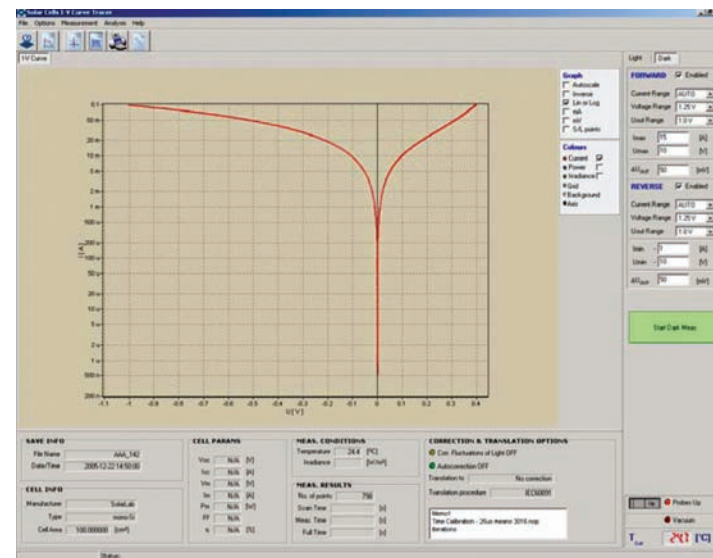
For example - Model # CC-5-TC-VA-ST-MA is an I-V Measurement system with 5A current capability, with Cell Temperature Control option, Vacuum Cell holding provision, Standard 4 probes and Manual Cell Contacting. In addition please specify the largest cell size to be tested.

EXAMPLES OF I-V MEASUREMENT SCREENS

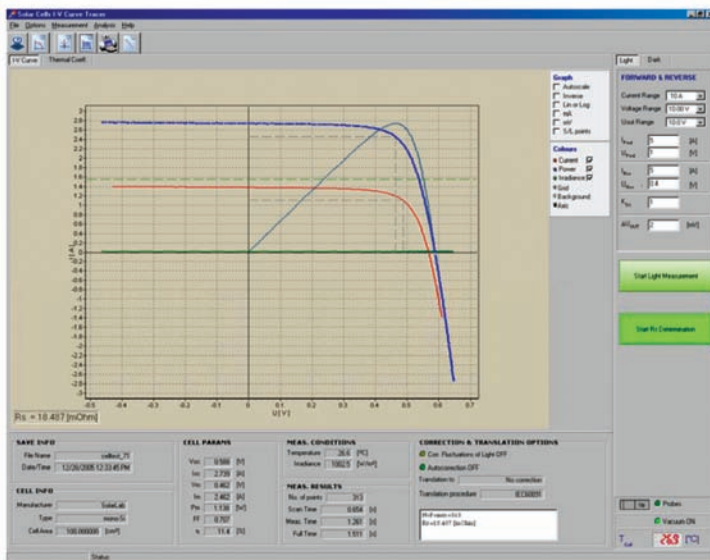
EXAMPLE OF "LIGHT" MEASUREMENT



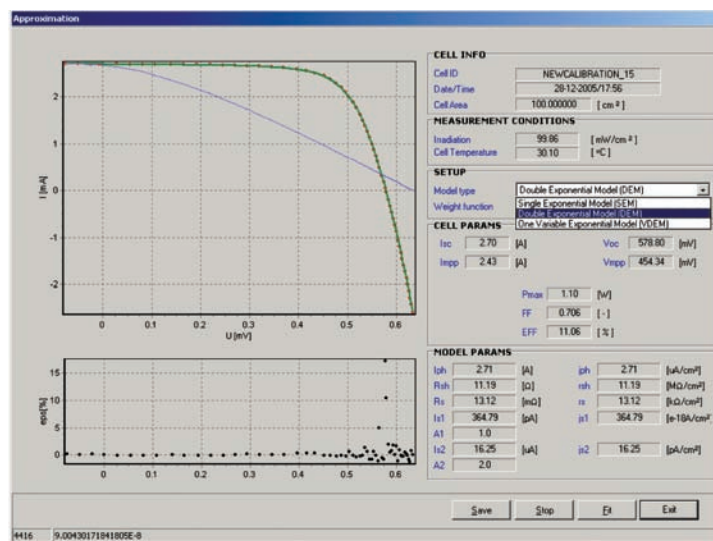
EXAMPLE OF "DARK" MEASUREMENT



EXAMPLE OF CELL'S SERIES RESISTANCE DETERMINATION ACCORDING TO IEC-60891 STANDARD



EXAMPLE OF CELL'S I-V CURVE FITTING TO DOUBLE DIODE EQUIVALENT ELECTRICAL MODEL



SOLAR SIMULATORS

In order to classify a Solar Simulator as a "Class A" system, it must meet all three requirements specified under class A, i.e. the non-uniformity of total irradiance must be $\pm 2\%$, the temporal instability of total irradiance must be $\pm 2\%$ and the spectral match in each wavelength interval must be $\pm 25\%$. In addition, the total intensity must be 100mW/cm^2 for AM1.5G.

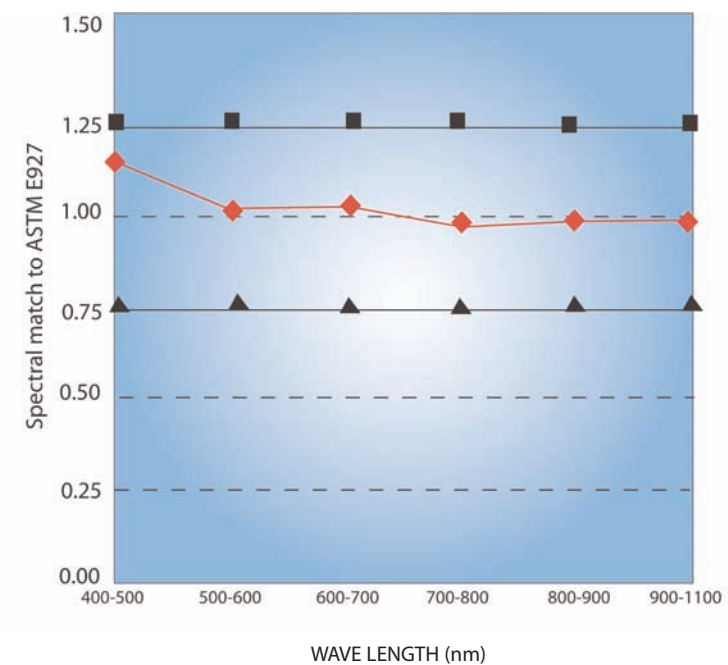
Even though the individual wavelength bands have a seemingly large tolerance, the overall intensity still has to match the specified one sun intensity. Even though the standard allows wide tolerance, most good quality solar simulators have much better spectral match in each waveband than that allowed by the standard.

ASTM is in the process of implementing a revised standard which will allow the classification of a solar simulator with three letters, such as AAB etc, where the first letter in the class designation refers to the non-uniformity class of the system, second letter in the class designation refers to the temporal instability class of the system and the third letter in the class designation refers to the spectral match class of the system. The new standard still allows a single letter designation. For example a Class A signifies that the solar simulator meets all three requirements of class A.

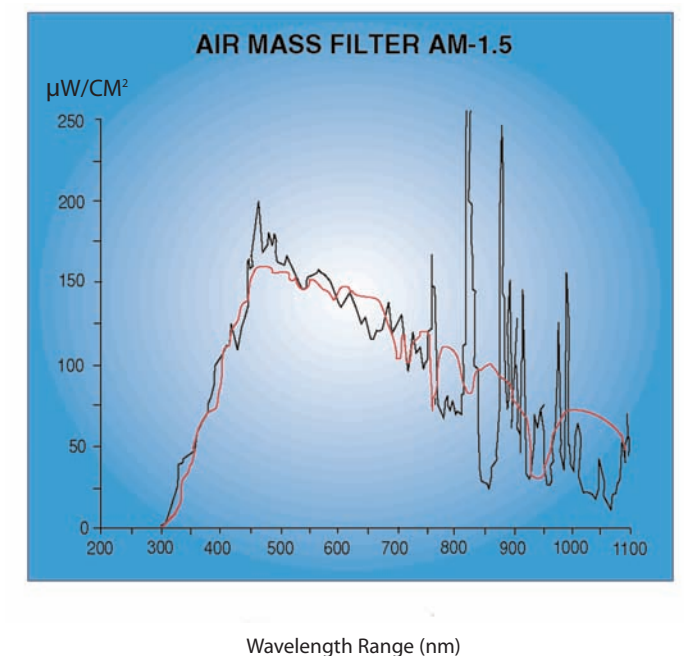
Applications

- Characterization of Solar Cells
- Lifetime testing to qualify materials, surface coatings/finishes etc. for space or on-the-ground applications. Since solar simulator can be powered on twenty four (24) hours a day, it accelerates the life testing. In addition to this life test acceleration, additional acceleration can be accomplished by increasing the light intensity of the solar simulator. A standard solar simulator is "one sun", which is equivalent to a light intensity of 100mW/cm^2 . If the intensity is increased to 200mW/cm^2 , then the solar simulator would be classified as having an intensity of "two suns".

TYPICAL ASTM SPECTRAL MATCH FOR CLASS A & CLASS B SOLAR SIMULATOR



TYPICAL SOLAR SPECTRAL IRRADIANCE FOR CLASS A & CLASS B SOLAR SIMULATOR



- ◆ PET Correlation To ASTM Values
- ASTM Class A Upper Limit
- ▲ ASTM Class A Lower Limit

SOLAR SIMULATORS CLASS A MODELS

	SS50A	SS80A	SS100A	SS150A	SS200A	SS300A
Lamp Type	Xenon					
Lamp Power	300W	300W	500W	1000W	2000W	4000W
Max. Illumination Area	5 cm x 5 cm	8 cm x 8 cm	10 cm x 10 cm	15 cm x 15 cm	20 cm x 20 cm	30 cm x 30 cm
Light Source	Steady State					
Air Mass Filter	AM1.5G Std., AM1.5D, AM1 & AM0 Optional					
Lamp Life	1000h	1000h	1000h	1000h	1000h	1000h
Intensity Adjustment Range	1000 W/m ² ± 15%					
Spectral Match	±25% or Better					
Temporal Stability	±2% or Better					
Non-Uniformity	±2% or Better					
Light Source Dimensions	74 cm x 33 cm x 36 cm	74 cm x 33 cm x 36 cm	74 cm x 35 cm x 66 cm	90 cm x 48 cm x 98 cm	110 cm x 54 cm x 105 cm	241 cm x 92 cm x 203 cm
Light Source Weight	24 Kg	24 Kg	35 Kg	70 Kg	140 Kg	150 Kg
Power Supply Dimensions	21 cm x 50 cm x 40 cm	21 cm x 50 cm x 40 cm	29 cm x 45 cm x 47 cm	58 cm x 45 cm x 55 cm	80 cm x 60 cm x 70 cm	100 cm x 68 cm x 60 cm
Power Supply Weight	26 Kg	26 Kg	35 Kg	70 Kg	140 Kg	150 Kg
Phase	Single	Single	Single	Single	Three	Three
Voltage (V)	110-220	110-220	110-220	220	220	220
Frequency (Hz)	50-60	50-60	50-60	50-60	50-60	50-60
Max. Power Consumption	0.8 KVA	1.0 KVA	1.7 KVA	3.0 KVA	5.0 KVA	8.0 KVA

SOLAR SIMULATORS CLASS B MODELS

	SS50B	SS80B	SS100B	SS150B	SS200B	SS300B
Lamp Type	Xenon					
Lamp Power	150W	300W	500W	1000W	1430W	2500W
Max. Illumination Area	5 cm x 5 cm	8 cm x 8 cm	10 cm x 10 cm	15 cm x 15 cm	20 cm x 20 cm	30 cm x 30 cm
Light Source	Steady State					
Air Mass Filter	AM1.5G Std., AM1.5D, AM1 & AM0 Optional					
Lamp Life	1500h	1000h	2000h	1500h	1500h	1500h
Intensity Adjustment Range	1000 W/m ² ± 15%					
Spectral Match	±25% or Better					
Temporal Stability	±2% or Better					
Non-Uniformity	±5% or Better					
Light Source Dimensions	74 cm x 33 cm x 36 cm	74 cm x 33 cm x 36 cm	74 cm x 35 cm x 66 cm	160 cm x 42 cm x 60 cm	160cm x 42 cm x 60 cm	213 cm x 57 cm x 78 cm
Light Source Weight	24 Kg	26.5 Kg	46 Kg	68 Kg	72 Kg	90 Kg
Power Supply Dimensions	21 cm x 44 cm x 36 cm	21 cm x 44 cm x 36 cm	21 cm x 44 cm x 36 cm	21 cm x 44 cm x 36 cm	21 cm x 44 cm x 36 cm	21 cm x 44 cm x 36 cm
Power Supply Weight	12 Kg	12 Kg	12 Kg	12 Kg	12 Kg	12 Kg
Phase	Single	Single	Single	Single	Single	Three
Voltage (V)	110-220	110-220	110-220	220	220	220
Frequency (Hz)	50-60	50-60	50-60	50-60	50-60	50-60
Max. Power Consumption	0.5 KVA	0.7 KVA	1.5 KVA	2.0 KVA	2.5 KVA	5.0 KVA

I-V MEASUREMENT SYSTEMS

An I-V measurement system measures I-V curves of solar cells and calculates critical cell performance parameters including short circuit current (I_{SC}), open circuit voltage V_{OC} , fill factor FF, maximum current (I_{MAX}), maximum voltage (V_{MAX}), maximum power (P_{MAX}), and efficiency (η) and saves them automatically on hard disk drive. In addition, with optional hardware, cell's temperature and irradiance level is measured and stored for future analysis.

The turn-key system includes rack-mounted electronics and testing chuck. The rack-mounted electronics includes an industrial computer, LCD monitor, keyboard and mouse (in a storage drawer), electronic load, installed software for I-V Curve testing and cell holder assembly. The software can automatically operate the shutter of most solar systems for ease of use.

These systems are intended for customers who already have a Solar Simulator. Those who plan to purchase a **PET Solar Simulator** as well, will receive an integrated system, where the cell testing assembly is an integral part of the solar simulator structure. With its wide range and high accuracy of measurement as well as unique software features, the system can be an excellent tool for research applications in a laboratory. It may also be used on a production line as the end-of-line tester/sorter of the manufactured solar cells (SC), with optional software for classifying cells into 16 different categories. Curves are measured using common four probes (Kelvin) technique. System meets all requirements of the IEC 904-1 standard.

I-V Measurement System main features are:

- Measurement of light and dark I-V curves
- Short measurement time (typically < 500 ms for light measurements)
- Advanced signal filtering procedure enables I-V measurement under strongly fluctuating light sources (e.g. up to ±5%)
- Calculating cell series resistance according to IEC 60891 standard
- 3 curve correction to STC procedures implemented
- Wide range of measured current values (10µA up to 20 A)
- 16 bit measurement resolution
- Procedures enabling fitting of measured I-V curve to either of three equivalent diode models
- Facilities enabling fast routine determination of thermal coefficients of basic parameters of a solar cell
- Correction of measured I-V curve to any other conditions than those recorded during the test
- Advanced, easy to use measurement software

Model CC-3 I-V Measurement System



Cell Holder Assembly

The cell holder assembly has provision for vacuum (supplied externally) holding the cell during testing. Contacting of the cell can be effected in several different ways. Due to the flexible nature of the cell contacting mechanism cells can be contacted from back only, front only or both front and back simultaneously. There are two standard arms that have multiple probes 10mm apart to make front contact with the cell bus bars. Semi-automated cell contacting would allow the user to manually lower the probe arms to make contact with the cell bus bars whereas optional fully automated contacting would make contact with the cell using a linear thruster that requires an external compressed air source. With the fully automated cell contacting, when the user initiates the I-V measurement, the software activates the vacuum to hold the cell, lowers the cell contacting arms and opens the solar simulator shutter to fully automate the I-V measurement of the cells.

Provision is made to install a detector to monitor the intensity fluctuations and if desired, normalize the I-V readings for one sun condition.

Options:

- **Cell temperature control**
- **Multiple contacting probes**