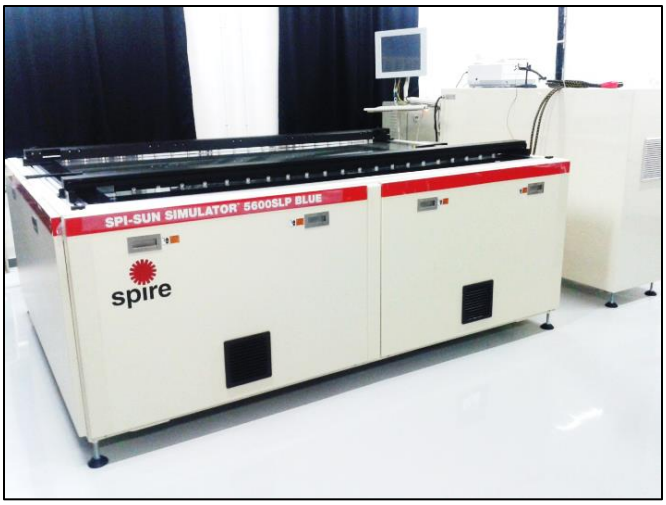
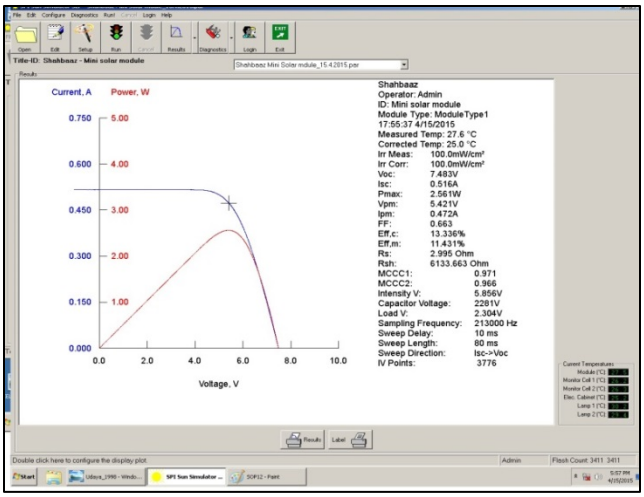
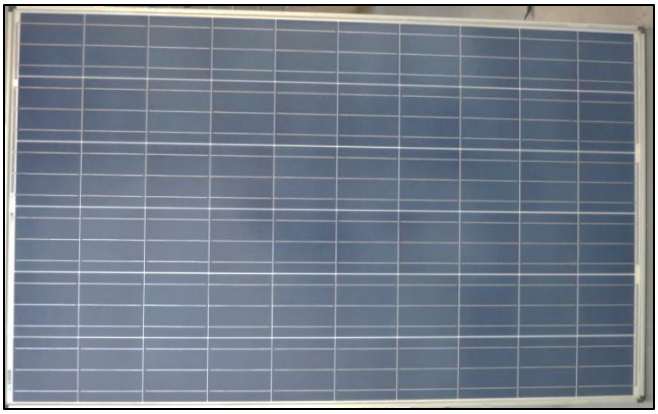
Standard Operating Procedure (SOP)

For

SPIRE Solar Simulator







National Centre for Photovoltaic Research & Education (NCPRE)

1.**Basic Safety Precautions** for operating the SPIRE Simulator

a) Do not work alone. The SPIRE Solar Simulator is a High Voltage Equipment, which produces dangerously high voltages when the Lamp Supply is turned ON. Always have someone in the Lab who can help in case of emergency.

b) Wear Lab shoes, rubber gloves and eye protection sunglasses.

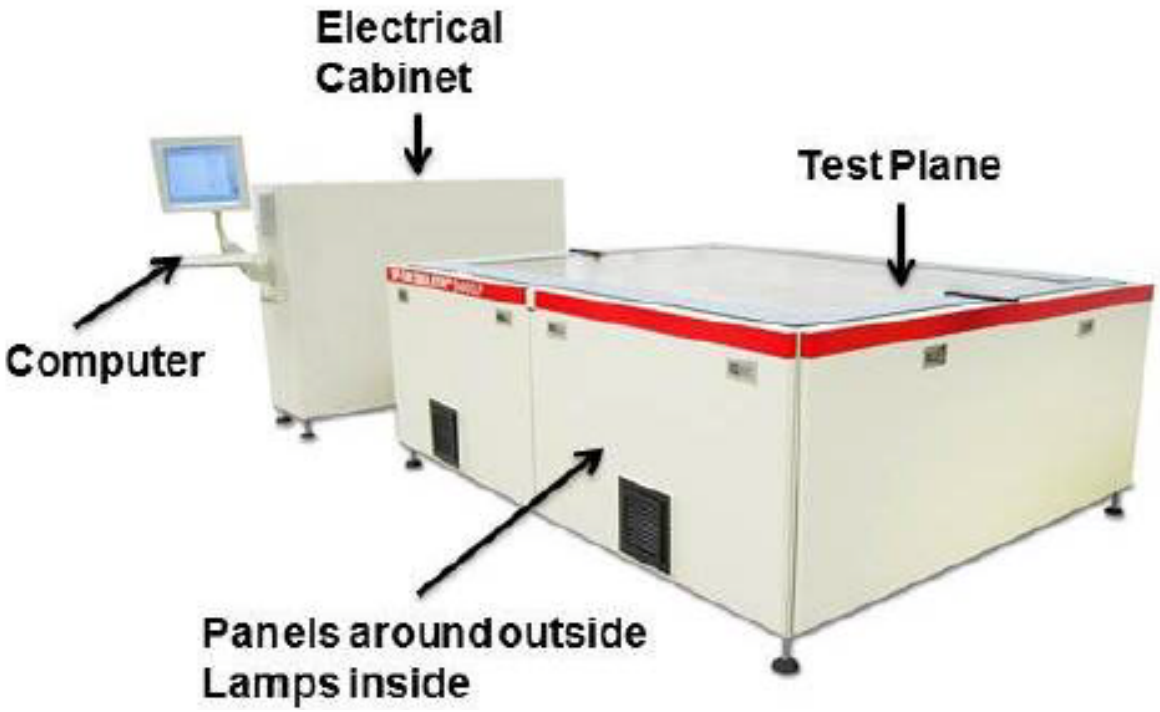
c) Never assume anything without checking it out yourself.

d) Do not place anything directly on top of the Simulator Top Glass.

e) Do not touch the simulator's module test leads when an I-V curve measurement is going on, as you may get a high voltage shock.

2.Main Components of the Simulator

Figure 8: Light Box, Computer, and Electrical Cabinet

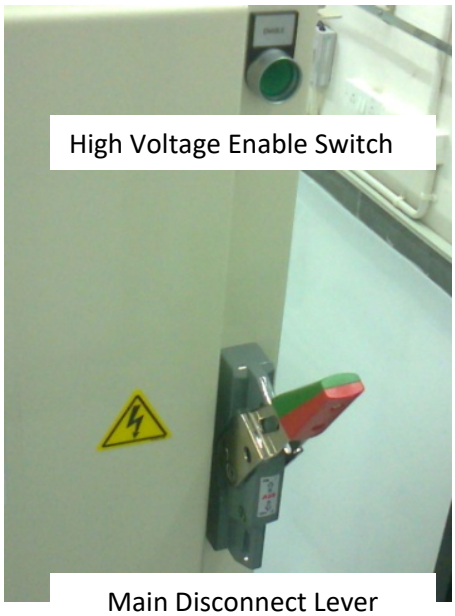


3.**Powering up** the System :

a) Pull up the Main Disconnect Lever on the body of the Electrical Cabinet to switch on the Simulator.

b) Press the Green Button above the Main Disconnect Lever. This turns ON the High Voltage Power Supply to Lamps.

c) Simulator has to be powered up **at least for 15 minutes** before doing Module measurement. Also, the room temperature should be 25 deg. C. so set the ACs to 20 deg. C at least 15 mints. Before starting the measurements.



Main Disconnect Lever

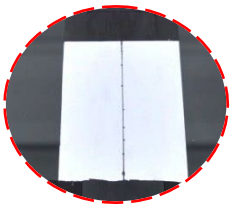
4.**Calibrating the Simulator** for the PV Technology of Test module

a) Select the Reference Module (from the Module Rack) based on the PV Technology of the test module. SPIRE has supplied Reference modules for mono-crystalline silicon, multi-crystalline silicon, amorphous silicon, CIGS and CdTe technologies.

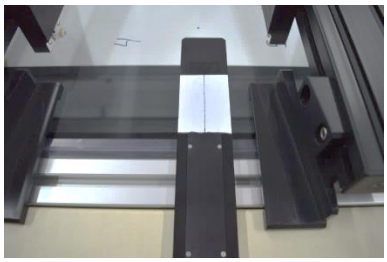
b) Clean the Reference Module and also the Glass on top of the Light Box of the Simulator with help of dry lint free cloths

c) Measure the breadth of the reference module and based on this, separate the module-support rails, maintaining equal distance on both sides from the monitor cell (= half the module breadth + extra 3 mm on either side). The centre of the monitor cell is marked for your aid.



d) Now place the module (active area facing downwards) on the support rails in such a way that edges of module lies on the positions marked in picture and then slowly push it towards the other end, ensuring that the module is supported by the rollers in the railings.



NOTE : Do not place the PV Module directly on top of the Simulator Top Glass as this may scratch the glass.

e) Connect the PV Terminals to the Simulator's crocodile clips (RED cable to +ve terminal of Module and BLACK cable to the –ve terminal).

NOTE: No damage will be done if connected wrongly, but the IV curve would not come.

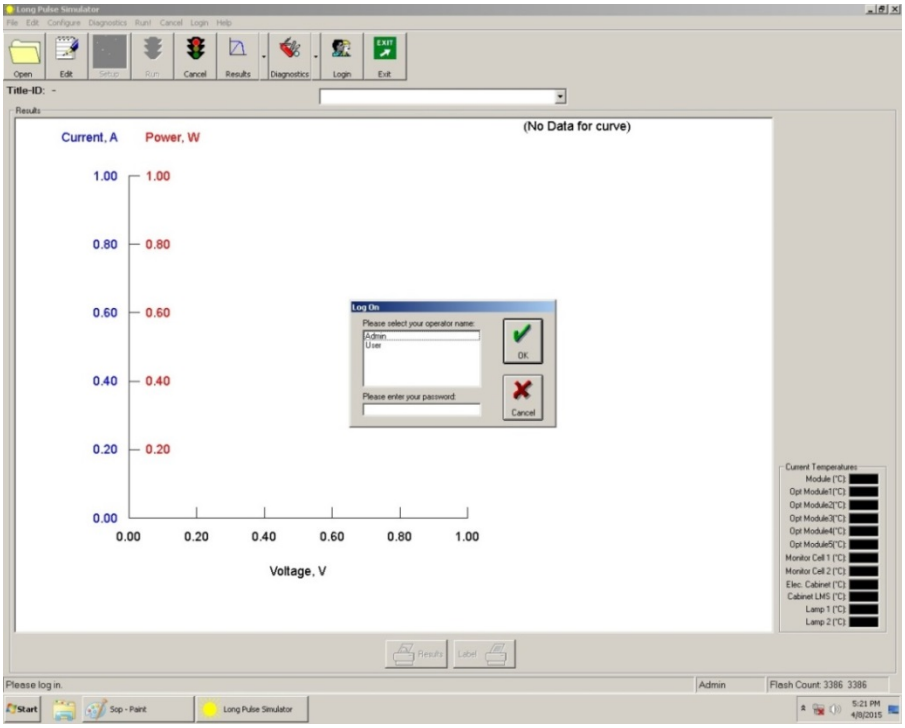
f) Place the Infra-Red sensor stand on the module support railing. The sensor should face the centre of one of the solar cells and its height from the backsheet should be adjusted to ≤ 1 cm. **Avoid** placing the base of the Temperature Sensor stand (or any other object) on the Simulator glass, close to the monitor cells and/or PV Module (inside the measurement area of the simulator).

g) Now come to Spire simulator computer, and open the SPI-Sun Simulator SLP software.

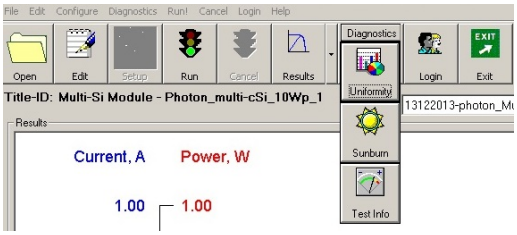
h) Enter the following username and password to open the software:

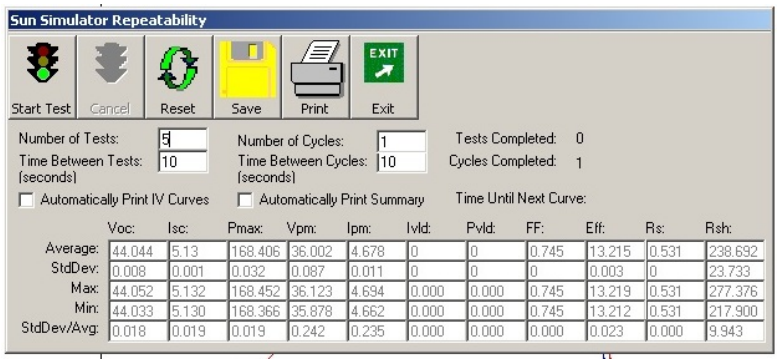
Username : User

Password : ncpre

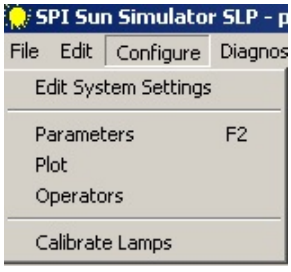


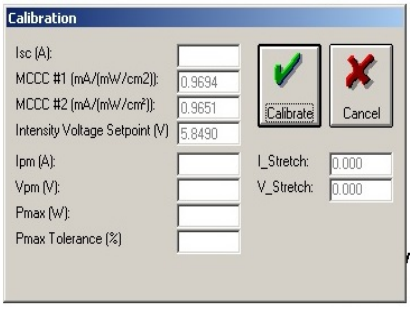
i) Go to **Diagnostics** option and from the drop-down menu, choose **Sunburn** test. Perform the Sunburn test at least 10 times (helps to warm up the lamps).





j) Go to Configure option, first click on **Parameters**, open the parameters of reference module, comeback to Configure option and then click on **Calibrate Lamps**. Calibration window will open; now enter the reference module's short circuit current (I_{sc}) value (from the calibration certificate) into the I_{sc} (A)

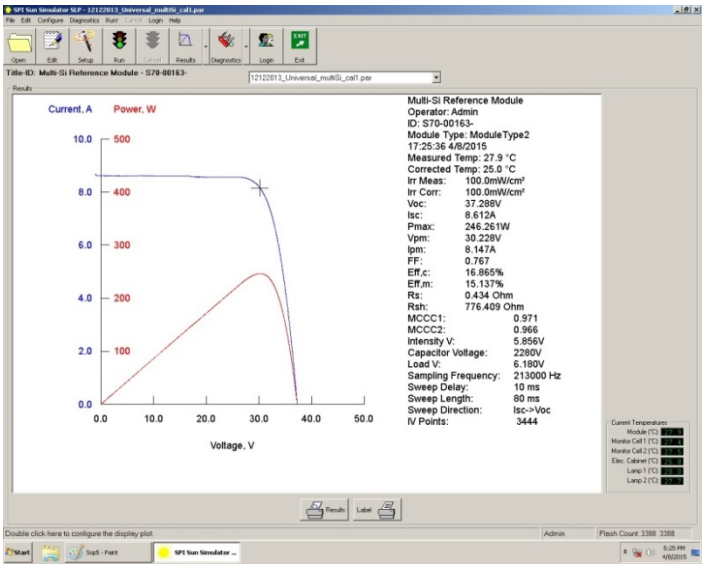




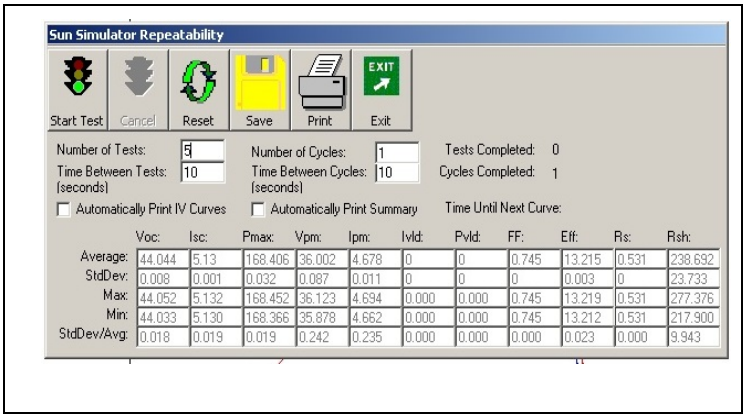
option, without disturbing the remaining options and click on **Calibrate**. This will calibrate the lamps for that PV technology.

k) Once the lamps get calibrated by the reference module, you have to cross check the entered I_{sc} with I-V curve $I_{sc,}$ both values should be same. If not then you have to re-calibrate it again.

l) You can see the status of module, electrical cabinet & lamps' temperature in the right bottom corner.



m) Go to **Diagnostics** option and from the drop-down menu, choose **Sunburn** test. Perform the Sunburn test to check the variability in the Isc values measured by the simulator.



n) Remove the electrical connections from the reference module, and unload it from the solar simulator.

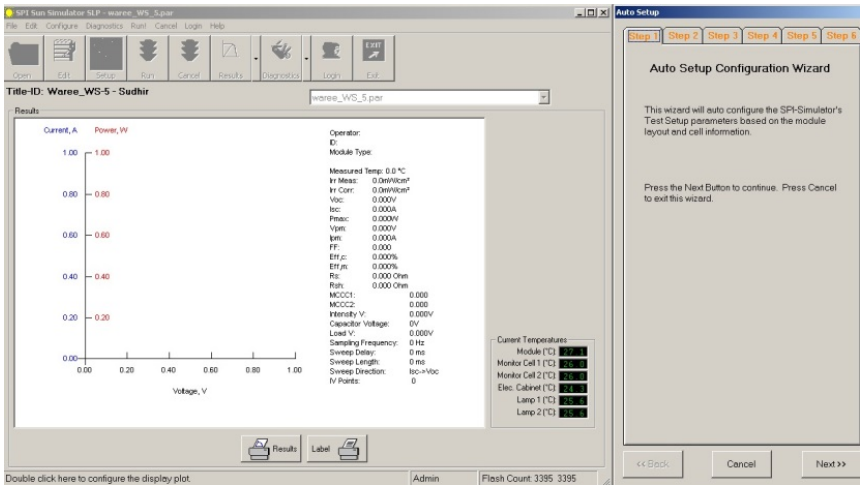
5.Measuring the Test Module

a) Measure the length & breadth of the test module and also of one of the cells in the module (needed to calculate the cell & module areas) and count the number of cells in series and parallel. In case of pseudo-square solar cells, the exact cell area can be obtained from the website : http://www.pvlighthouse.com.au/calculators/Wafer%20calculator/Wafer%20calculator.aspx

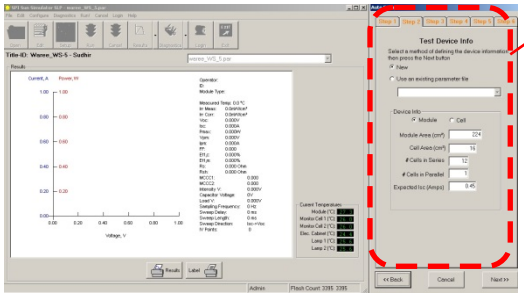
b) Load the test module into the simulator following the procedure described above for the calibration part. Make the electrical connections and place the IR sensor as described above.

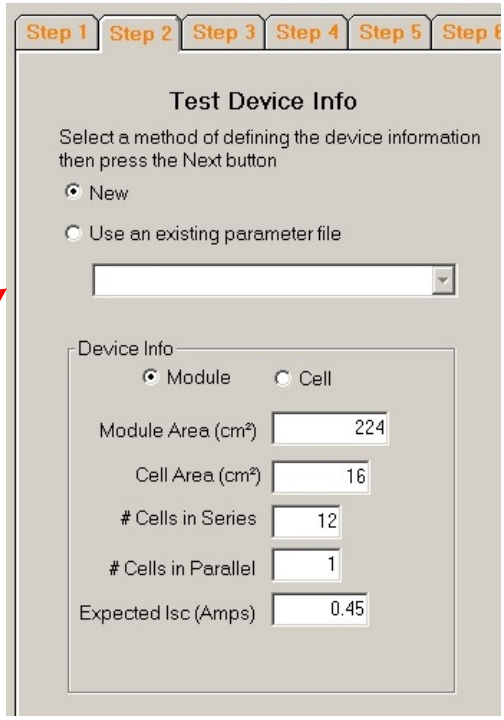
c) Click on Setup option from Spire software window.

d) Auto Setup Configuration window will open, click on "Next" after reading the content of Step-1 window. This will automatically take you to Step-2.



e) In Step-2, if the parameter file of this module already exists, then click the radio button on "Use an existing parameter file", and then select that file. Else, if it's a new module, fill the information of the test device and then click on Next.





f) In Step-3, Verify device connection (module to simulator cable connection) and then click on Next.

g) Step-4, "Testing: Please stand by while the system tests the module", will automatically take you to Step-5.

h) In Step-5, "verify the I-V curve" means compare the measured I_{sc} value with IV Curve provided by module manufacturer(error within the manufacturer's tolerance band, usually 3%, is acceptable). Click on Next.

i) In Step-6, save the parameters on folder: **C:/NCPRE/Parameters/*your-name*** folder with date, then click on **Finish**.

j) Save the I-V curve to **C:/NCPRE/IV curve/*your-name*** folder with date.

k) Now, remove IR thermocouple sensor, disconnect the cable connection between module and simulator and then takeout your module from simulator rack. Copy the I-V data in your CD or you can take printout of your module I-V curve.

l) Turn Off the simulator main switch from Electrical panel and then cover the simulator.

m) Make the entry in the Spire Simulator logbook.

Note:-

(i) Module lab RA or JTA will help you in the measurement.

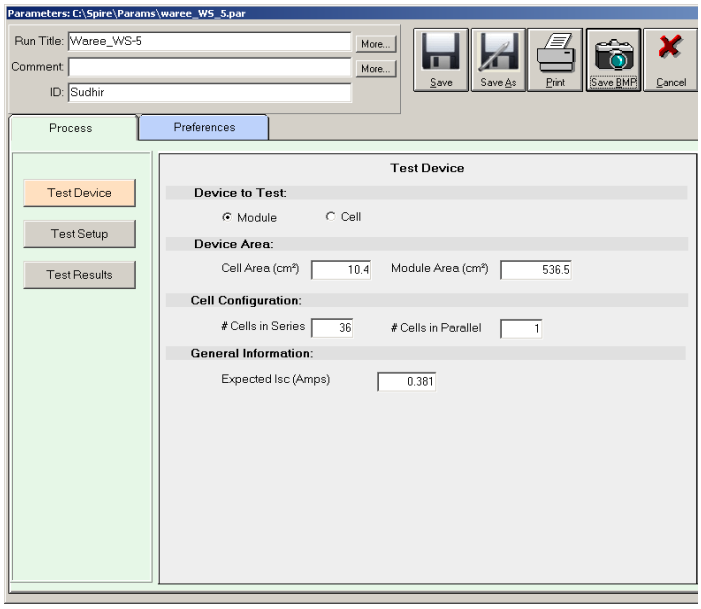
(ii) Keep the instrument & cable at its original place after the measurement. Violation of this will result in suspension of your authorization.

6.**Changing the Parameter File** to set up different Test Conditions

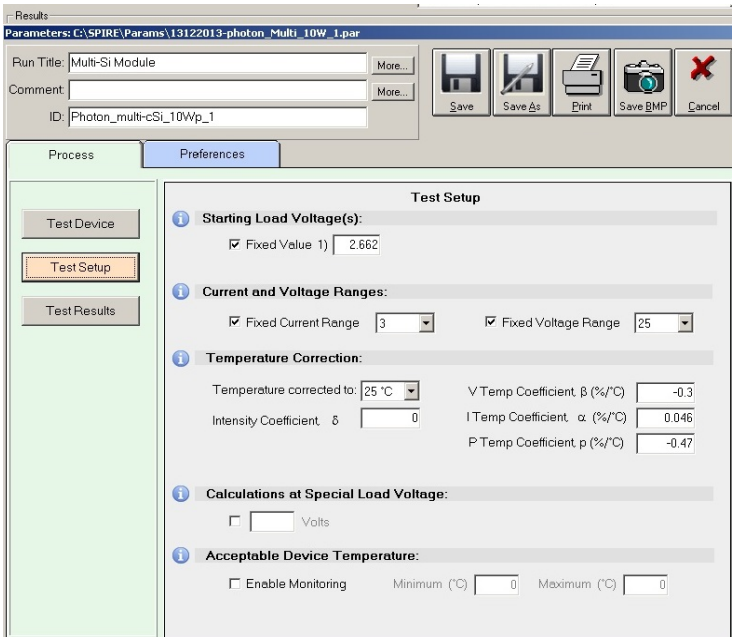
a) Click on the EDIT tab to access the Parameter File.

b) Under the **Process** tab, there are following sub-tabs:

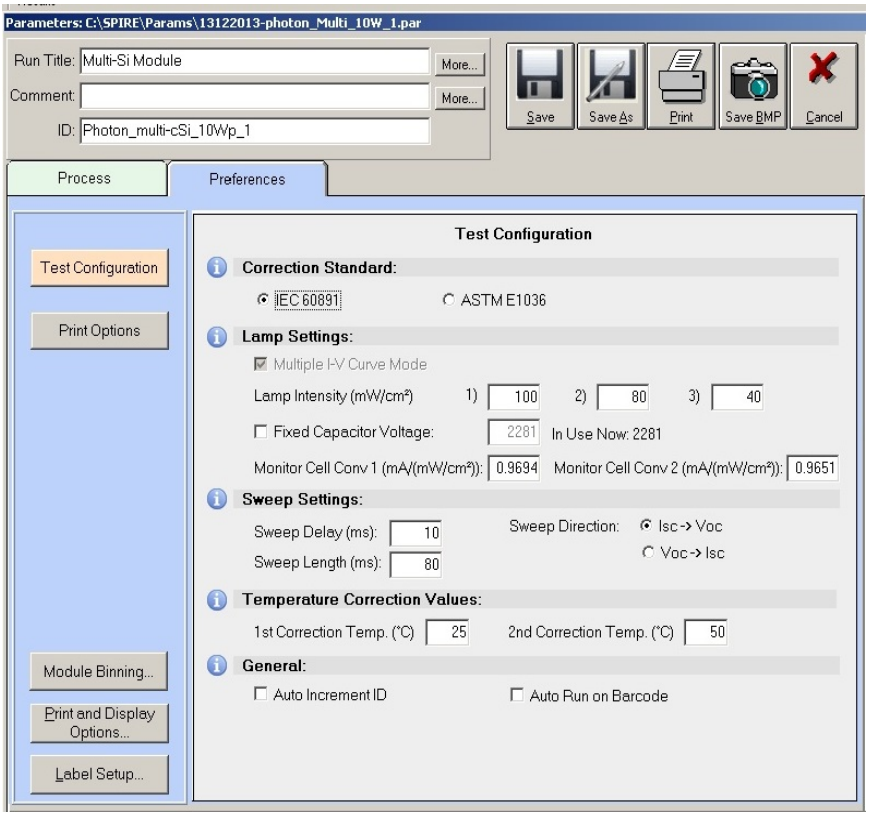
i. ***Test Device*** **–** Here one can change the cell area, module area and the number of cells in series and parallel (in case some wrong data has been entered previously).



ii. ***Test Setup*** – Here one can change the temperature coefficients and chose the temperature for I-V correction (select "None" to get the "as measured" I-V curve without any temperature correction). Care should be taken about the units of the temperature coefficients.



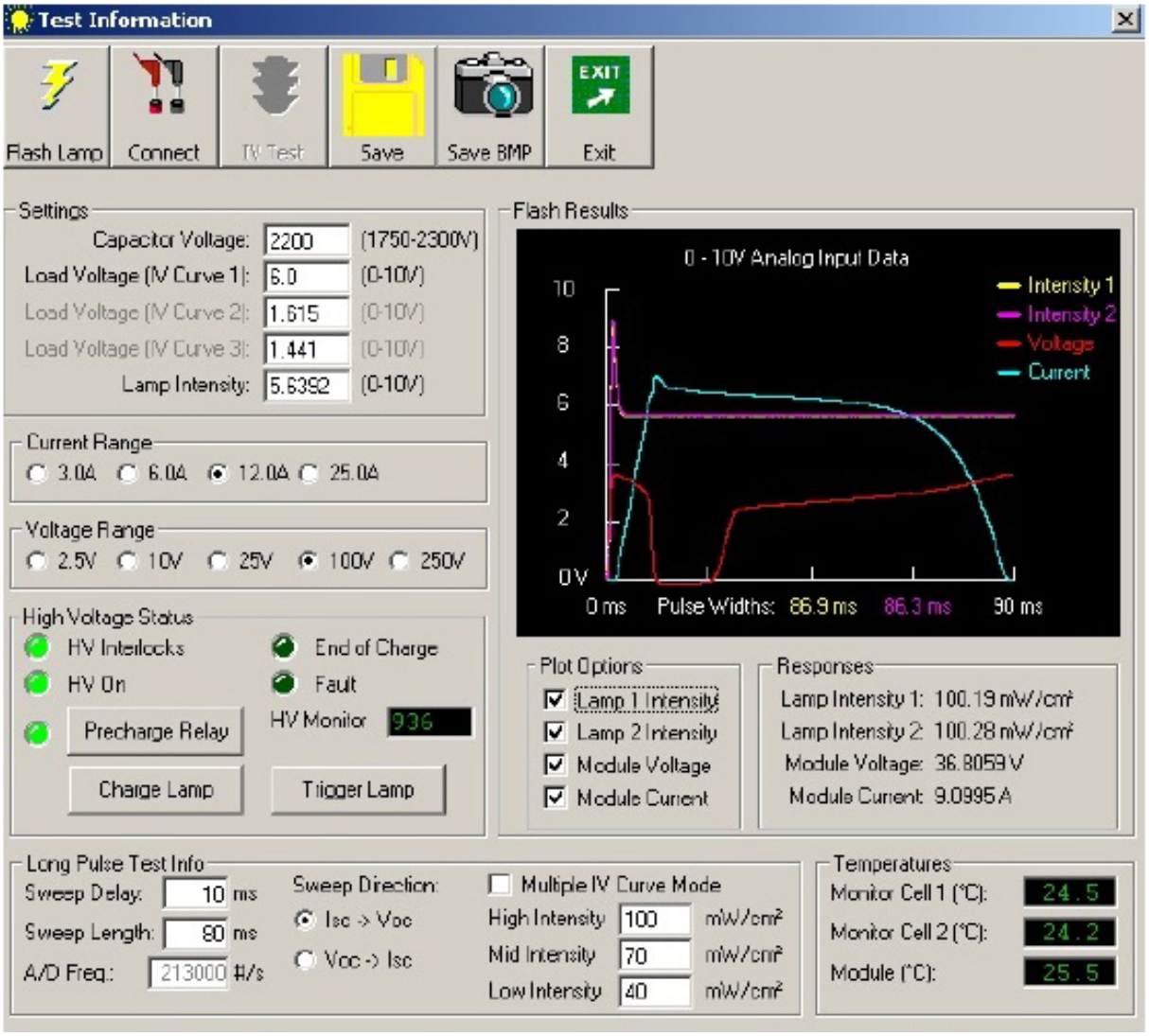
c) Under the **Preferences** tab, in the **Test Configuration** sub-tab, one can choose the I-V correction procedure (IEC or ASTM), Spire auto set with IEC Standard and change the Lamp Settings and Sweep Settings, which can be effectively adjusted from the **Test Info** window, as described in the later section.



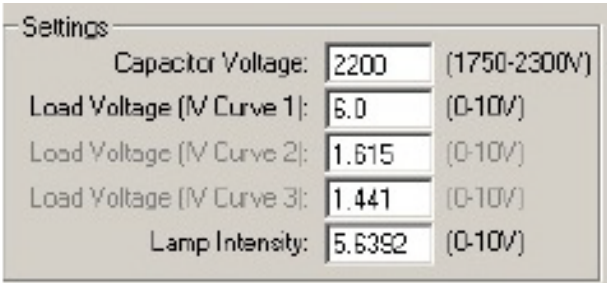
7. **Trouble shooting to improve I-V curve measurement**

a) To perform diagnosis of the I-V measurement and improve the curve, click on the DIAGNOSTICS tab and go to the TEST INFO tab in the dropdown menu. The screenshot of the **Test Information** screen is shown in the next page.

b) The **Flash Results sub-window** on the right side displays the light intensities of the 2 lamps, and also the measured current & voltage versus time profiles. The first trouble-shooting tip is to check that the Voltage curve (in RED) is first falling and dipping below the 0 Volts line, staying low for some time and then rising back (but not steeply). Also the Lamp intensities should be very close to each other in the flat part, and should not fall off at the far end, close to end of measurement (refer next point for its remedy).



c) In the SETTINGS sub-window, there are 3 parameters that can be altered:



i. ***Capacitor Voltage*** – It needs to be increased if the Light flash is dying (falling below 1000 W/sq.m.) before the I-V curve is completed. There is no Light Flash if its value is below 2000V. Chose values close to 2100V for single I-V measurements and values between 2200-2300V for triple I-V curve measurement.

ii. ***Load Voltage*** – It needs to be increased to increase the time the measured voltage stays below the 0V line ("-ve" voltage across module terminals i.e. module in reverse bias). The "true Isc" is obtained only if the Voltage across module is swept from "–

ve" to "+ve". Also more points can be obtained near the Isc value if the module voltage increases from "–ve" to "+ve" with about 45 deg. slope (i.e. should not rise very steeply). In order to obtain higher duration of "–ve" voltage, the LOAD VOLTAGE setting has to be increased. However, staying too long below this line would result in lesser measurement points near the Voc.

iii. ***Lamp Intensity*** – It is related to the Irradiance intensity. It is automatically set by the system during Lamp Calibration, to correspond to 1 Sun (1000 W/sq.m.). Changing this setting will alter the Irradiance (W/sq.m.) proportionately. As the Lamp ages, the Lamp Intensity value will progressively increase. Also the Lamp intensity value will vary slightly when calibrated with different technologies.

d) The **Current Range** and **Voltage Range** values need to be checked if the system is unable to measure the I-V curve of the connected module. Voltage Range should be closer than the expected module Voc and Current range closer than the module's expected Isc (note: in some special cases choose slightly higher values of voltage range & current range)

e) In the **Long Pulse Test Info**, there are 2 important parameters which may be altered for better measurements:

i. ***Sweep Delay*** – It delays the starting of the I-V measurement so that the lamps' light can stabilize (reach the plateau region after the Peak intensity). It should be minimum 10 ms. Choosing very high sweep delay may cause the Light intensity to fall below the required illumination before the I-V measurement is over, so it's better to keep this value fixed at 10 ms.

ii. ***Sweep Duration*** – The sweep duration is the time the simulator takes to measure each I-V curve. It has to be selected judiciously (50 ms is enough for crystalline silicon modules, but higher values close to 100 ms may be needed for slow responding and/or high capacitance module technologies).

Specification of components used in I-V measurement

1. Spire Sun Simulator

Brief System Feature

- Classification: A+A+A+
- Type & quantity of lamps: Single long pulse filtered xenon tube (2nos)
- Spectral Range: 300nm – 1100nm.
- Range of light intensity: 200 – 1100 Watts/m^2.
- Maximum power / module: 600 watts.
- Maximum module size: 2m (L) X 1.3m (W).
- I-V Resolution: 0.003%.
- Repeatability: <0.15%.

2. Solar Reference Modules

Reference Modules availability in NCPRE Solar Module Lap: Mono c-Si, Multi c-Si, a-Si, CIGS & CdTe.