Photovoltaic Testing System (PTS)

This system includes either a 150W Xenon or 250W QTH lamp and a monochromator to tune the light source. A source meter used as an active load permits operating the test cell at various load conditions, including short-circuit, compensating for a series resistor required to sense the current produced by the modulated monochromatic light. This sensed current plus a reference signal at the frequency of the light modulation are both fed into the precision lock-in amplifier to allow measurement of the photocurrent generated by the modulated monochromatic light.

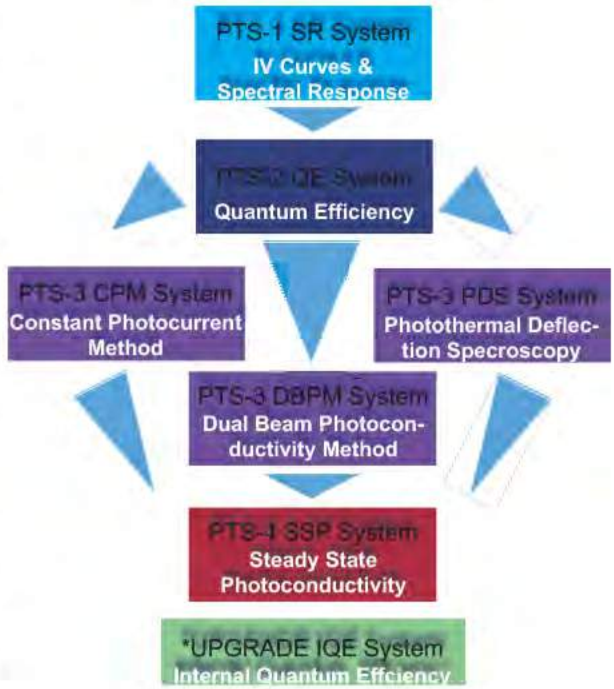
The PTS-1 features all the software required for I-V Curves and Spectral Response measurements. Main parameters of these measurements are displayed by the software, including the most important graphs typically required by researchers and the industry. Optionally, our software development group offers to develop whatever is required to meet your demands.

Unless a different request is made, the geometry of the light from the Monochromator is controlled to illuminate only a small section of the solar cell (typically 2~5 diameter), ensuring that 100% of the monochromatic irradiance contributes to the output signal. NOTE: Spot size must be smaller than the 5mm diameter reference detector.

The PTS-1 system includes a SCIRUNSR I-V-Test measurement system, precision lock-in amplifier and system software. The software controls the Monochromator, source meter and lock-in amplifier to automatically measure the I-V characteristics and SR versus wavelength, plotting the result(s) on screen and outputting calculated values, including Voc, Isc, Pmax, Fill Factor, and the raw measurements to a standard file format.

Additionally, the PTS-1 can be upgraded with an optional light tight sample chamber, vertical adjustment components, sliding sample holder, and thermal control (either cooling or heating) for the sample holder. While these additions are not required for operation of the system, including them will ease your operation of the system. While the basic PTS-1 system offers researchers a good starting package for I-V and SR measurements, the true power of the system is in its ability to seamlessly upgrade to a more versatile system. The PTS-2 includes all the capabilities of the PTS-1, plus the additional ability to measure Quantum Efficiency. This improved system also includes a bias solar light and the necessary power supplies and controllers.

PTS Cell Testing System



*Available for PTS systems 2, 3 & 4 only

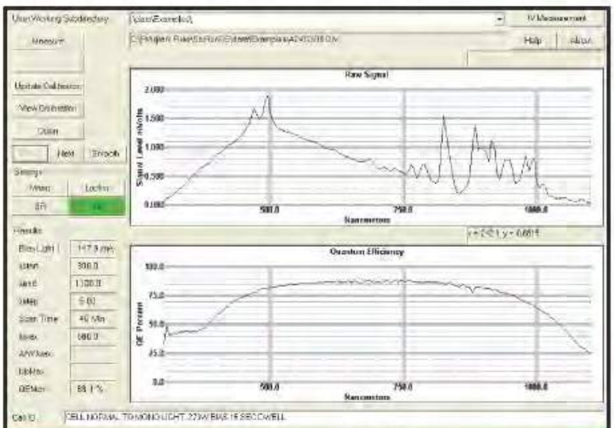
The Spectral Response and Quantum Efficiency measurement systems provide an overall "external" QE value that doesn't consider that some of the light is reflected or transmitted by the photosensitive sample. From the point of view of cell efficiency this is the most important factor. However, to measure the QE of the cell material itself apart from these losses - the internal quantum efficiency or IQE - the reflected and transmitted light must be measured and mathematically deducted so that only the light absorbed by the solar cell is considered in the QE calculations. This optional upgrade can be applied to the PTS-2 or the PTS-3 systems.

The PTS-3 allows the user the same ability to measure IV, SR, and QE as the PTS-1 and PTS-2 systems, but adds the powerful techniques of Constant Photocurrent Method (CPM, PTS-3-CPM), Dual Beam Photoconductivity Method (DBPM, PTS-3-DBPM), or Photothermal Deflection Spectroscopy (PDS, PTS-3-PDS).

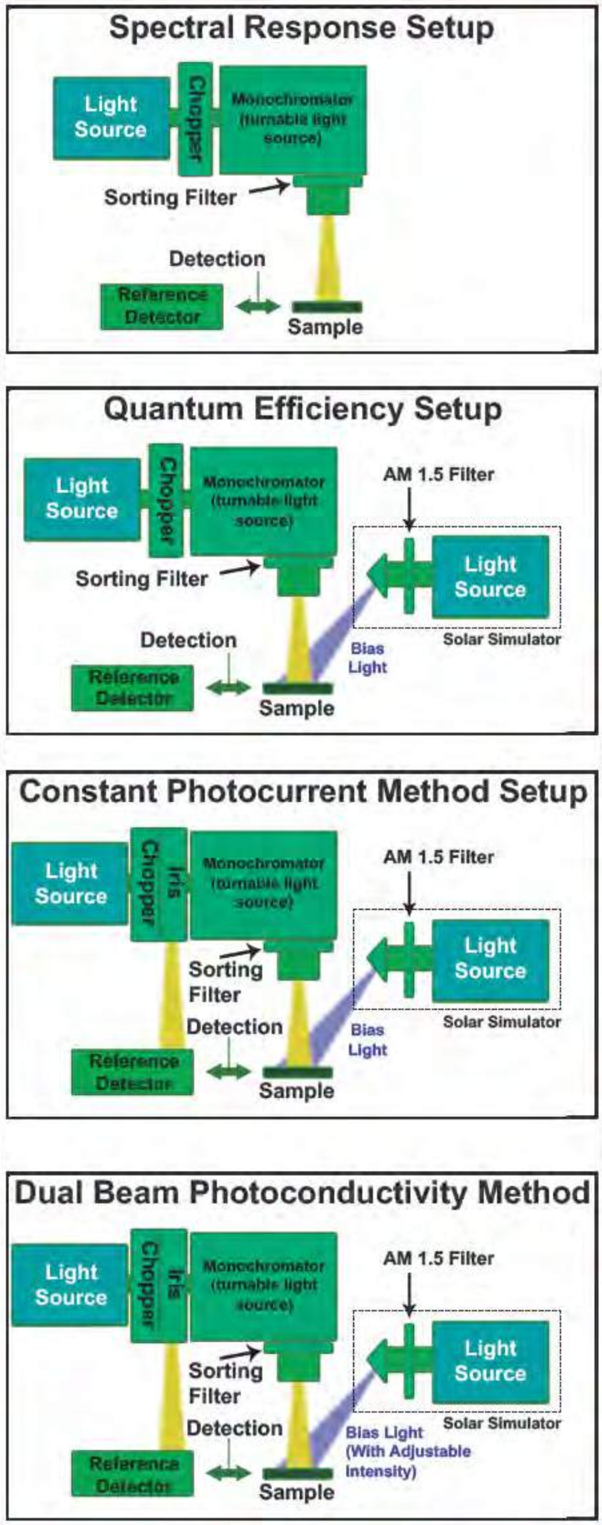
In the CPM technique, the photocurrent is maintained constant over the range of photon energy to get constant quasi-Fermi levels. Constant photocurrent implies that the steady state concentration and the lifetime of photogenerated electrons are constant, and thus the recombination mechanism is unchanged.

The CPM system illuminates the sample solar cell with a bias solar light source while a separate light source is modulated to cover a specific spectrum. The bias source ensures that the signal is not dominated by the non-linear response at low-level illumination of the cell, but rather gives a baseline response dependent on the wavelength of the modulated source (after the bias light signal is removed). This allows a highly precise measure of defect density of the cell, and as such gives researchers and manufacturers extremely sensitive information for their work.

The DBPM system is based on the same setup as CPM, but has additional capability to vary the bias light source intensity. This changes the electron and hole quasi-Fermi levels to yield additional information about defect states. While CPM measures bulk defect states below the dark Fermi level, DBPM can probe defects both below and above the Fermi level.

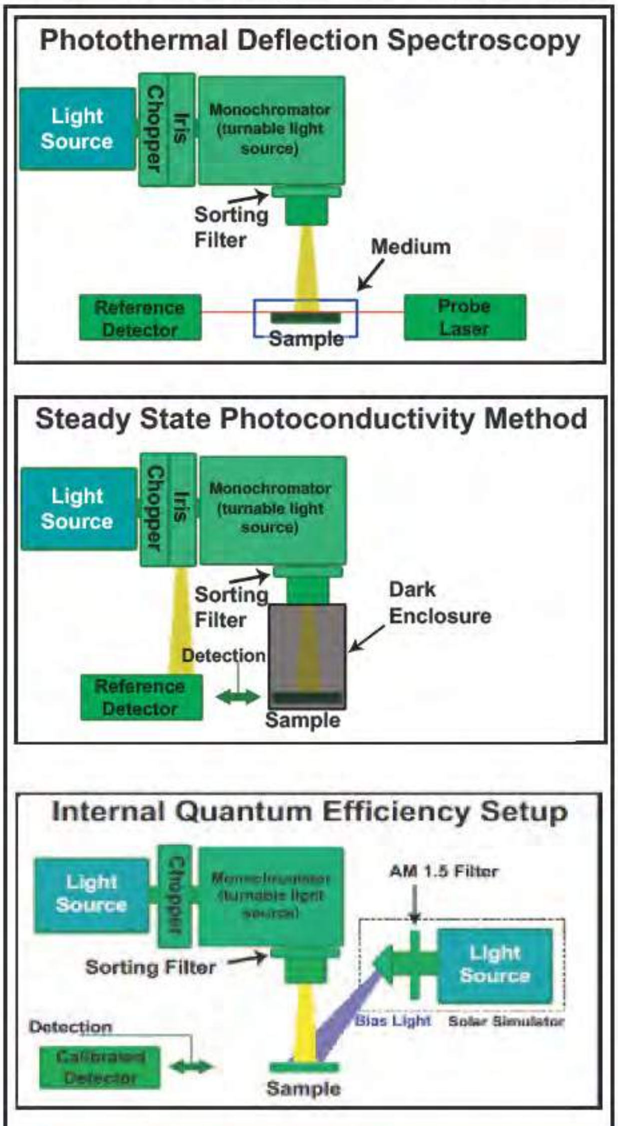


PTS Screenshot



PTS System Layouts

The PDS system can measure additional transitions not observed in photoconductivity measurements, since it is not dependent on the Fermi level position. This technique is sensitive to surface, interface and bulk states. The modulated, monochromatic light periodically heats the medium in which the sample is embedded. This in turn modulates the index of refraction near the film surface. The laser probe grazing the sample surface subsequently experiences a periodic deflection synchronized with the modulation of the intensity. The amplitude and phase of the deflection are measured and fed into a lock-in amplifier and thus, as the wavelength is varied, the deflection of the probe laser is a measure of the optical absorption spectrum of the sample.



PTS System Layouts (Continued)

The PTS-3 comes with a fully integrated software package, capable of controlling every aspect of the system. Graphical and data output can be in a wide range of file types, and as Sciencetech may supply source code to customers that wish to further modify the system or integrate it into existing computer framework.

The PTS-4 provides the same capabilities of the PTS-1, PTS-2, and PTS-3-CPM systems for IV, SR, QE, and CPM measurements, and adds the Steady State Photoconductivity (SSP) method. The steady state photoconductivity measurements give information about the nature of defects, mobility-lifetime products, and the transport and recombination kinetics of photogenerated carriers. Since the states between quasi-Fermi levels act predominantly as recombination centres, steady state photoconductivity is sensitive to both the density and the nature of these states.

The addition of the SSP method to the PTS-3 requires an upgrade to the existing software, as well as several modifications to the measurement components of the existing system. The iris, used in the PTS-3-CPM, combined with the beam-splitter for intensity control, allows tighter manipulation of the flux values. A calibration photodiode is used to regulate the incident white light for the respective photon energies.

PTS Dual Chuck Target Table

Key Features

- Monochromator with automated order sorting filters
- Monochromatic probe light area adjustable from 2mm to 5mm diameter with an option to concentrate in a 1mm x 4mm rectangle for rectangular samples.
- Monochromatic probe light power of 125 mW total (white light).
- Low noise bias light source with 1.5G Air Mass filter is included for QE and I-V measurements.
- Complete SR, QE and I-V measurement system with software is included.
- Keithley 2400 Series Source meter
- Bias voltage range from 0 to 200 Volts.
- Calibrated Reference Detector
- (PTS-3 and up) Control of Iris and stabilization of photocurrent via lock-in amplifier.
- (PTS-3 and up) Illumination intensity (and therefore photocurrent) is maintained constant within 5% over a range of 10,000:1 absorption or conversion efficiency.
- (PTS-3 and up) Monitoring of illumination throughput of Iris with 18 bit resolution.
- Optical chopper and drive
- Stanford SR800 series lock-in amplifier
- Photocurrents measurable resolution ranges from 10 picoampere to 10 microampere.
- Automated switching of lock-in input signals from reference detector to sample current measurement.
- All components assembled on Sciencetech's integrated optical and electronic mounting system with a 54x92 cm desktop footprint, not including light tight sample enclosure.
- Sample enclosure with adjustable dual cell holder
- Target table with dual cell holder has 150 mm height adjustment.

Design Specifications	
Monochromatic Light Source	- 150 W Xe arc lamp or 200W QTH Tuneable sources (SR or QE) - 250W QTH Tuneable source (CPM) - < 0.5% Stability - Adjustable Spot Size - Full spectrum coverage 300-2500 nm
Bias Light	- 75W Ultra-stabilized Xe arc lamp <0.1% instability - Adjustable Spot Size - Low-power lamp greatly increases signal to noise ratio
Monochromator	- Motorized triple grating - 250 - 2500 nm range - Czerny-Turner design
Reference Detector	- 5mm diameter - Broadband pyroelectric - Calibrated
Data Acquisition	- Stanford Lock-in Amplifier - MS Windows based software
System Dimensions	- 36" x 20" x 22" - 91.5cm x 50.8cm x 55.9cm
Standards	- ASTM 927-05 standard for Photovoltaic cell testing - Will meet IEC and JIS standards on request

Version/Model	Description
PTS-1	Spectral Response (SR) System
PTS-2	Quantum Efficiency (QE) system
PTS-3-CPM	Constant Photocurrent Method (CPM) System
PTS-3-DBPM	Dual Beam Photoconductivity (DBPM) Method
PTS-3-PDS	Phototermal Deflection Spectroscopy (PDS)
PTS-4-SSP	Steady State Photo-conductivity (SSP) Method
PTS-IQE	Upgrade to Internal Quantum Efficiency (IQE)