QEXL

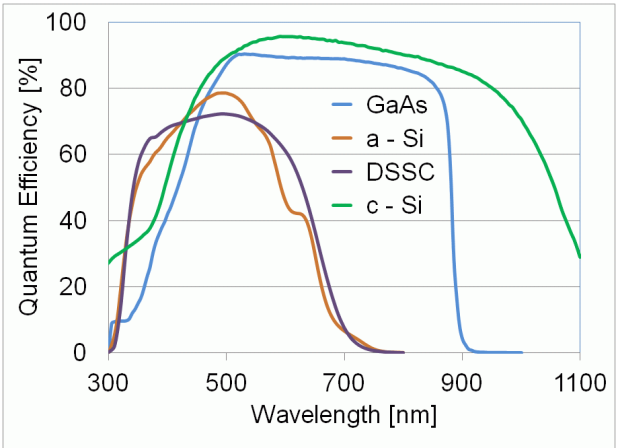
SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

QEXL Solar Cell Quantum Efficiency Measurement System

The QEXL Quantum Efficiency / Spectral Response / Incident Photon Conversion Efficiency Measurement System brings over 15 years of photovoltaics measurements and system design by a team dedicated to the advancement of photovoltaic device characterization.

General Description

The QEXL uses a tunable monochromatic light source based on a xenon arc lamp, dual grating monochromator, filters and reflective optics to provide stable monochromatic light free of chromatic aberrations to a photovoltaic test device. A broadband bias light also illuminates the test device to simulate end-use conditions. The system uses a detection circuit designed to maximize measurement speed and accuracy.



- ☑ Turn-key solution for solar cell analysis
- ☑ Fast and easy installation
- ☑ Excellent repeatability
- ☑ Accurate measurements
- ☑ Light bias current capability up to 150 mA
- ☑ ASTM E 1021-06 compliant
- ☑ Automatic AC/DC mode switching
- ☑ Measures reflectance and IQE (optional)
- ☑ Glove box accessory (optional)

PV MEASUREMENTS
INSTRUMENTATION FOR PHOTOVOLTAICS INDUSTRY AND RESEARCH

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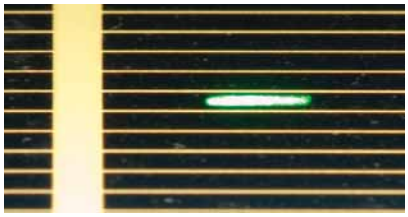
Reflective Optical Path

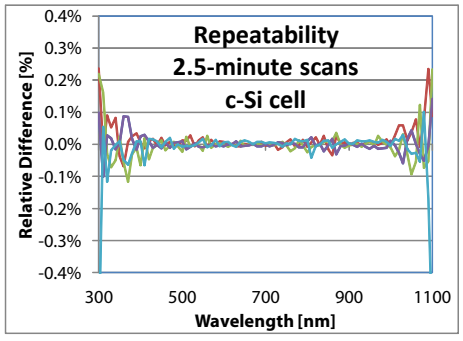
The QEXL system design eliminates chromatic aberrations through the absence of refractive focusing optics. This gives the researcher total confidence the beam will retain the size and shape of the green alignment beam throughout the whole scan. Uniform probe beam size ensures any measured features are due to material characteristics of the device - as opposed to grid lines, device boundaries or other non-uniformities in the device near the probe beam.
The system includes the option to focus the beam down to 1 mm x 1 mm on a test device or to narrow the spectral bandwidth down to 3 nm.



Focused beam size is about 1 mm x 5 mm independent of wavelength. The beam size is reconfigurable down to 1 mm x 1 mm.

Monitor Photodiode

The intensity of any light source will vary with time. The QEXL performs simultaneous measurements of the device signal strength and the probe light intensity, producing measurement results which minimize the appearance of noise from lamp intensity variations.



Calibration

The system includes a reference photodiode calibrated for spectral response and traceable to NIST. A semi-automated and simple scan of the reference photodiode calibrates the QEXL Quantum Efficiency System's optical path and measurement electronics.

Wavelength Range & Uncertainty

Measurement repeatability for stable p-n junction solar cells is better than ±0.15 % in the 400 nm to 1000 nm range and better than ±0.6 % in the 300 nm to 400 nm and 1000 nm to 1100 nm ranges. The default beam spectral bandwidth is approximately 5 nm; narrower or wider bandwidths can be obtained by adjusting the monochromator slits. The measurement interval is selectable with a default of 10 nm and minimum step size of 0.1 nm. The basic system wavelength range is 300 nm to 1100 nm. The 1400 nm wavelength range extension enables measurements through the whole device sensitivity range for technologies such as CIGS.

Bias Light

Bias light is an important feature in a QE system because some device types exhibit different characteristics when strongly illuminated versus when in the dark. The high power of the QEXL computer controlled, broad band bias light enables light biasing of devices with illumination density from 0 to 1.5 suns on a circle of 15 mm diameter. The bias light includes additional focusing optics that can provide illumination up to 5 suns intensity over a central 7 mm diameter region. The included 25 mm diameter optics holder enables the use of optical filters to customize the bias light spectrum. Please inquire for available filters for your application.

Monochromatic Light Modulation

The QEXL spectral response measurement system uses a computer controlled, continuously adjustable mechanical chopper to modulate light at rates between 1 Hz and 120 Hz. DC measurement mode is also available. Solar cells with long response times require slower chopping speeds for accurate measurements, while faster devices can be measured with higher chopping speeds. Overall measurement speed is correlated to beam modulation frequency. The PV Measurements Signal Conditioning and Voltage Bias Circuit automatically adapts to the light modulation for both AC and DC measurements.

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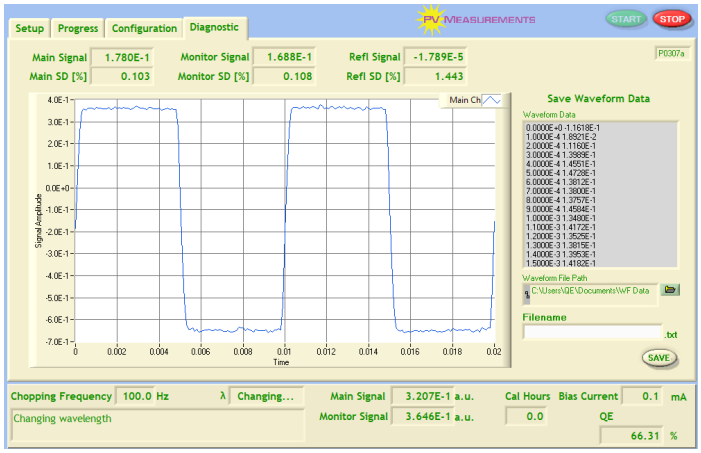
Basic System Features

- ☑ User-changeable spectral bandwidth
- ☑ Monochromatic probe light with 300 nm to 1100 nm wavelength range
- ☑ Selectable wavelength interval (default 10 nm)
- ☑ Dual grating monochromator with computer control
- ☑ Filter wheel with order-sorting and stray light attenuation filters
- ☑ Calibrated reference photodiode, NIST traceable (one step)
- ☑ Line filter for wavelength calibration verification
- ☑ Voltage bias capability of ± 3.0 V
- ☑ Computer system with easy-to-use graphical user interface
- ☑ Data saved in text files for easy import into spreadsheets
- ☑ Simultaneous measurement of device signal and light intensity
- ☑ White bias light source (up to 5 suns) with filter options
- ☑ Chopping speed 1 Hz to 120 Hz
- ☑ DC measurement mode
- ☑ Transmission measurements capability
- ☑ Measures Si cells in less than 3 minutes at 10 nm interval
- ☑ Calculates Jsc estimate using reference spectrum AM1.5G or a spectrum of your choice
- ☑ Complete scan in less than 45 seconds for 12 wavelengths (minimum required for ASTM E 1021-06)
- ☑ Includes training at PV Measurements, Inc. headquarters in Boulder, Colorado, USA
- ☑ Instruction manual
- ☑ Spare Lamps

Oscilloscope Function

Some device types, including Dye (Sensitized) Solar Cells (DSC or DSSC), respond slowly to modulated light. For some devices, even a low modulation frequency of 4 Hz may not be slow enough to produce accurate measurement results. Therefore, it is often useful to measure these devices with the probe light modulated at 1 Hz or perhaps continuous, in a DC measurement. The built-in oscilloscope function can help the scientist determine the appropriate light modulation and bias light level for the desired test. This ensures accurate measurement of the spectral response and increases understanding of charge transport mechanisms. The QEXL system gives the scientist access to a continuously variable chopping speed from 1 to 120 Hz through a simple software input. No changes in connections are necessary. This makes it simple to gather the maximum amount of information from IPCE/QE scans of devices. Scientists can save waveform data for further analysis.



Oscilloscope function shows if the device is responding fast enough to the chopped probe light.

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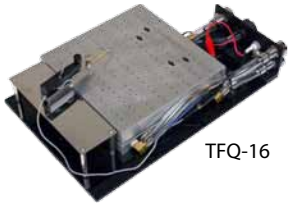
Lock-In Detection

The QEXL maximizes precision using lock-in detection. The dual-channel lock-in amplifier isolates the signal to be measured from other signals or sources of noise.

Test Fixtures

The QEXL can measure such a wide variety of different types of solar cells that no single test fixture design is suitable for all of them. Therefore, a test fixture is not included. Ordering one is recommended. PV Measurements offers a variety of vacuum and clamp test fixtures to hold and contact test devices. Thermoelectric temperature control capability up to 125 °C is an option for many test fixtures.



TFQ-16

TFQ-C
with DSC

☑ Recommended
☐ Suggested

Common Device Types

Options

Options	c – Si	mc – Si	a – Si / μ c- Si	CdTe	CIGS	CZTS	Organic	DSSC	Perovskite	III-V Dual – Junction	Multiple Devices on a Single Substrate
300 nm to 1400 nm spectral range	☑	☑			☑						
Reflectance and IQE measurement capability	☑	☑	☐	☐	☐		☐		☐		
Quick – swap filter assembly			☐							☑	
Setup and training at customer's site											
Beam-up test fixture			☑				☑				

Accessories

Accessories											
Glove box interface							☐	☐			
Clamp test fixture								☑	☐		
Vacuum test fixture	☑	☑	☐		☑	☑	☐	☐	☐	☑	
Test fixture thermoelectric temperature control	☐				☐	☐	☐				
X – Y scanning for response mapping at any wavelength (coarse LBIC)	☐	☑	☐	☐	☐	☐	☐	☐		☐	☑
Custom test fixture						☐	☐	☐		☐	
Automated measurement scripting			☐		☐		☐	☑	☑		☑
Integrated I-V measurements				☐	☐	☐	☐	☐			☑

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Reflectance & IQE

The Reflectance and IQE option includes the unique PV Measurements integrating sphere, optimized for hemispherical reflectance measurements of solar cells. This is a very important consideration for devices with surface texture, haze, or granular film structure, enabling it to provide more accurate Absorbed Photon Conversion Efficiency (APCE) or Internal Quantum Efficiency (IQE) data.
The optional QEXL Small Device IQE (SDIQE) reduces the minimum device size for reflectance measurements to 3 mm x 3 mm so you can measure the hemispherical reflectance of your smallest devices.

Transmission Measurements

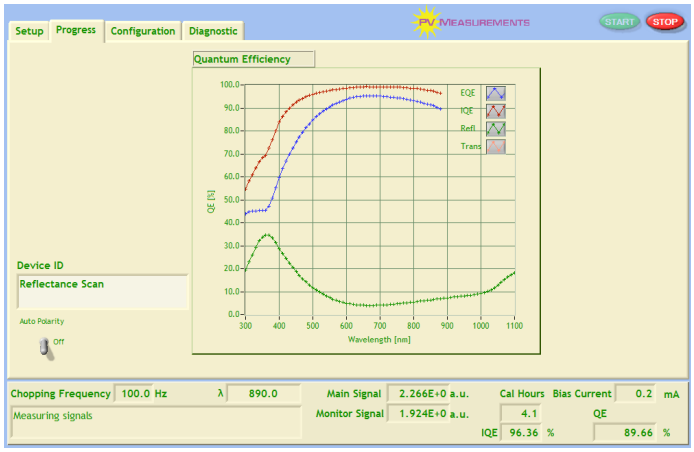
For accurate APCE or IQE measurements of partially transparent devices it is important to include the transmission characteristics in the measurements. Additionally, accurate transmission data for various layers of the solar cell is an important tool in the creation of an accurate model of the solar cell. The QEXL completes the measurement solution with the capability to make transmission measurements.

Data Output

PVM software saves the data in tab-delimited text format for simple import to graphing or other data analysis software.
The data include calculated Jsc values under a variety of spectra, such as AM1.5G, AM1.5D and AM0. Users can also supply their own spectra for the calculation of the Jsc for a more accurate representation of performance of the cell under their solar simulator and actual end use conditions.
You can dig deeper into your data using the Multiple QE Report application by plotting data from multiple scans on a single plot to quickly identify features of interest.

I-V Measurement Option

PV Measurements saves you time and money with the I-V Measurement Option. This enables the system to perform I-V Measurements on small devices, without changing any electrical connections or remounting the sample. For rough measurements, the built-in bias light can be used as the light source.

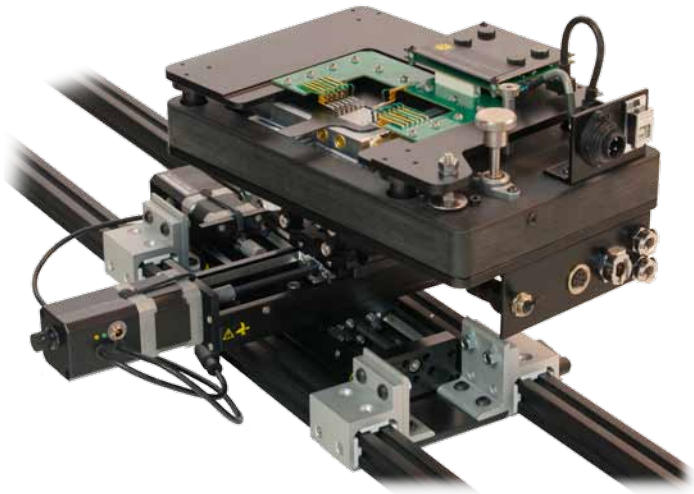


APCE / IQE scan progress is shown during the scan.

Higher accuracy measurements can be achieved using a separate solar simulator, available from PV Measurements. Maximum current is 200 mA.

Measurement Automation

The optional QEXL automation interface allows you to create measurement scripts to handle measurements of multiple devices under variable conditions as a single click operation. The interface enables seamless integration with PV Measurements I-V Measurement Systems and Test Fixtures to save you time in the lab. Please inquire about integration with third party hardware.



TFI-P12 Test Fixture and the QEXL IPCE/QE/SR System make a powerful combination for fast measurement on multiple devices on a single substrate.

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Computer & Software

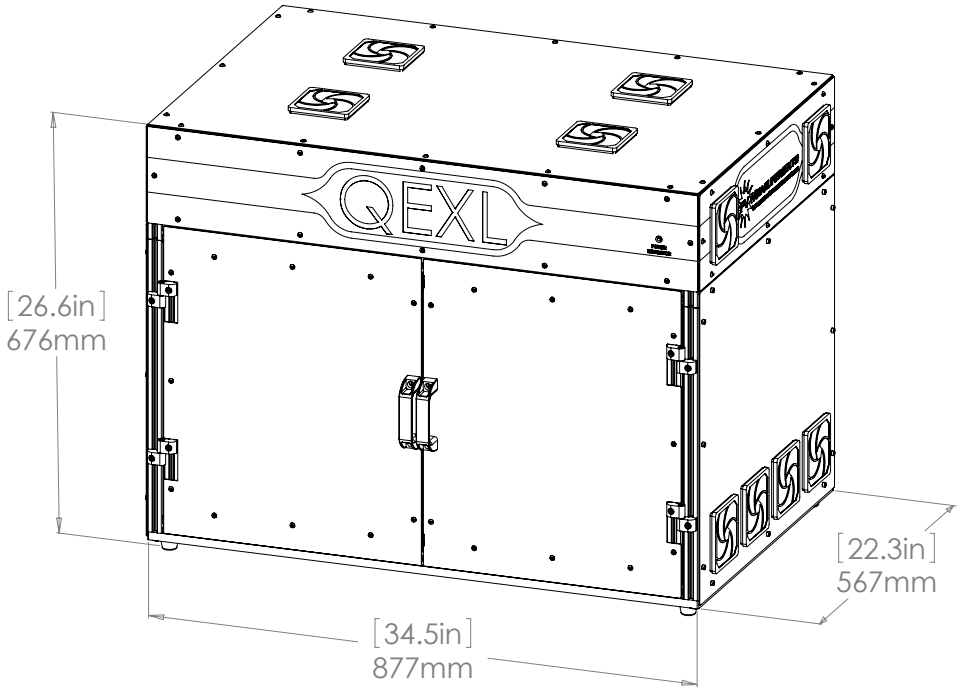
The system operates automatically under the control of the included laptop computer with a Microsoft Windows™ Operating System and custom software that facilitates quick configuration and measurement control. The system software controls the equipment, gathers the instrument readings, and maintains the calibration information. The graphical user interface allows the operator to easily and quickly specify tests to be performed, monitor test progress, and produce clear and informative test reports.

Facility Requirements

The QEXL requires 115 VAC, 10 A or 230 VAC, 5 A, 50 Hz to 60 Hz (please specify voltage, frequency and power plug type with your order) and a sturdy table at least 1.3 m wide and 0.7 m deep (optical table not needed). The equipment is expected to operate in an environment with little dust, temperature between 20 °C and 27 °C, no organic vapors or corrosive fumes, and relative humidity < 60 %.
Please inform us of the local voltage and the plug type used in your laboratory so we can include the correct connector.

Installation and Training

The QEXL is simple to use and we invite you to come to PV Measurements headquarters in Boulder, Colorado, USA to learn how to install the system, use it and perform routine maintenance. The training takes one day and is included in the price of the system.
If you prefer, a PV Measurements engineer can be hired to visit your facility and install the system and train you on its use. Please be prepared for one or two people to receive an uninterrupted day of training. Additional training is available upon request.



QEXL Order Information

The table below gives a quick overview of various QEXL features.

Part Number	Description	Details
QE-IR4 QE-IR4-PP QE-IR4-C	Wavelength extension to 1400 nm.	Total wavelength range is 300 nm to 1400 nm. Ge calibration photodiode included.
QEXL-IQE QEXL-IQE-PP QEXL-IQE-C	Hemispherical Reflectance Measurements.	Single beam hemispherical reflectance measurements using a custom designed integrating sphere with a reference port for maximum accuracy. Minimum device size is 20 mm x 20 mm and minimum substrate size is 30 mm diameter.
QE-SDIQE QE-SDIQE-PP QE-SDIQE-C	Small Device Hemispherical Reflectance Measurements	Adaptation of the integrating sphere to be able to measure devices down to 3 mm x 3 mm with minimum substrate size of 5 mm for opaque substrates and 10 mm for semi-transparent devices.
QE-PDSi QE-PDSi-PP QE-PDSi-C	Additional Si Calibration Photodiode	Spare Si photodiode to ensure no down time when the primary photodiode is at the factory for calibration.
QE-PDGe QE-PDGe-PP QE-PDGe-C	Additional Ge Calibration Photodiode	Spare Ge photodiode to ensure no down time when the primary photodiode is at the factory for calibration.
QE-IV QE-IV-PP QE-IV-C	I-V Measurement Capability	Capability to measure the I-V characteristics of small devices with Isc of up to 200 mA. Use the bias light as a simple solar simulator or use an external solar simulator.
QE-GB QE-GB-PP QE-GB-C	Glove Box QE Measurement Capability	Measure the QE of unstable devices in the inert atmosphere of a glove box. Includes bias light and all connections for KF-40 connection.
TFQ-XYL TFQ-XYL-PP TFQ-XYL-C	X-Y Scanning Capability	Perform coarse LBIC measurements on a test device.
QE-BLF QE-BLF-PP QE-BLF-C	Bias Light Filter Set	A pair of filters designed for measurements of a-Si / uc-Si tandem solar cells.

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