QEX10

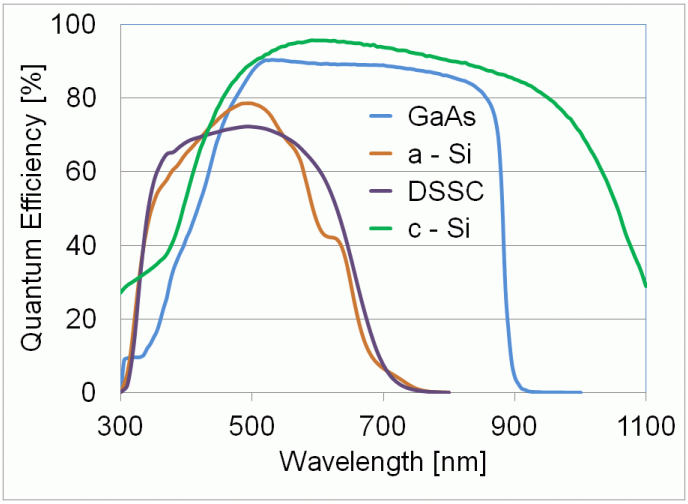
SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

QEX10 Solar Cell Quantum Efficiency Measurement System

The QEX10 Quantum Efficiency / Spectral Response / Incident Photon Conversion Efficiency Measurement System is the culmination of over 15 years of photovoltaics measurements and system design by a team dedicated to the advancement of photovoltaic device characterization.

General Description

The QEX10 uses a xenon arc lamp source, monochromator, filters and reflective optics to provide stable monochromatic light 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 for solar cell development.



- ☑ Turn-key solution for solar cell analysis
- ☑ System of choice by national laboratories
- ☑ Mature product - over 200 QE systems in the field
- ☑ Fast and easy installation
- ☑ Excellent repeatability
- ☑ Accurate measurements
- ☑ Light bias current capability up to 150 mA
- ☑ ASTM E 1021-06 and IEC 60904-8 compliant
- ☑ DC mode measurement capability (optional)
- ☑ Measures reflectance and IQE (optional)
- ☑ Glove box accessory (optional)

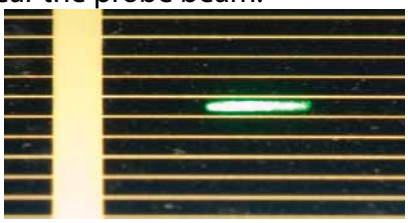
PV MEASUREMENTS
INSTRUMENTATION FOR PHOTOVOLTAICS INDUSTRY AND RESEARCH

www.pvmeasurements.com T: +1.303.386.3950 F: +1.303.648.6026 pvmsales@pvmeasurements.com

SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

Reflective Optical Path

There are no refractive focusing optics in the main beam path of the QEX10. This avoids chromatic aberrations, enabling the probe beam size to be uniform at all wavelengths. This ensures that 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.



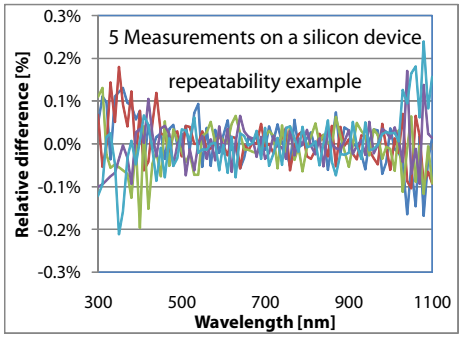
Focused beam size is about 1 mm x 5 mm independent of wavelength

Variable beam size

The standard beam size for the QEX10 is about 1 mm x 5 mm at focus. For small devices, other beam sizes are available. User facilities and laboratories that work with multiple device types and sizes can easily optimize the beam size for each device size at the time of measurement using the variable slit wheel.

High repeatability

The intensity of any light source will vary with time. The QEX10 performs simultaneous measurements of the device signal strength and the probe light intensity, minimizing the chance for noise from lamp intensity variations from appearing in measurement results.



Low QE device measurements

The QEX10 accurately measures devices with quantum efficiencies of 10 % without any additional accessories. With additional amplification, the QEX10 can measure devices as low as 0.1 %.

Calibration

The system includes a reference photodiode that is calibrated for spectral response and traceable to NIST. A simple scan of the reference photodiode calibrates the QEX10 Quantum Efficiency System's optical path and measurement electronics.

Wavelength Range & Uncertainty

The basic system wavelength range is 300 nm to 1100 nm. Repeatability for stable p-n junction solar cells is better than ±0.3 % 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.

Broadband Bias Light

Bias light is an important feature in a QE system because some device types exhibit different characteristics when strongly illuminated than they do when in the dark. The QEX10 illuminates a region on the sample approximately 1.5 cm in diameter with stable, broad-band bias light adjustable from 0 to 1.5 sun intensity to simulate intended end-use operating conditions. The bias light includes additional focusing optics that can provide bias illumination up to 5 suns intensity over a central 7 mm diameter region. The included holder for 25 mm diameter optics enables the use of optical filters to customize the bias light spectrum.

Monochromatic Light Modulation

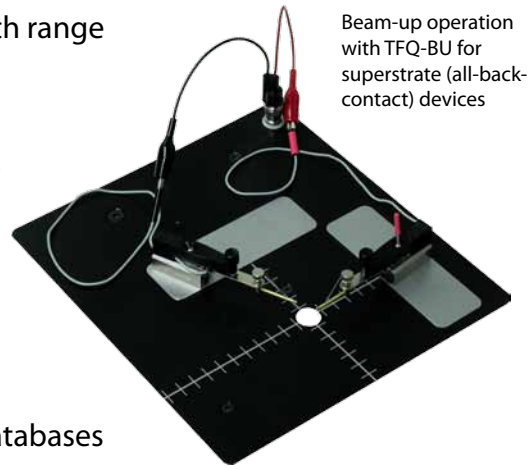
The QEX10 spectral response measurement system uses an adjustable mechanical chopper to modulate the light at rates between 4 Hz and 200 Hz (1.3 Hz to 50 Hz range optional). Solar cells with long response times require slower chopping speeds for accurate measurements, whereas faster devices can be measured with higher chopping speeds. Overall measurement speed is proportional to the beam modulation frequency. The DC Mode Option adds the capability to measure with non-modulated light.

QEX10

SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

Basic System Features

- ☑ User changeable monochromatic light 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 ± 3.0 V
- ☑ Transmission measurement capability
- ☑ Computer system with easy-to-use graphical user interface
- ☑ Data saved in text files for easy import into spreadsheets and databases
- ☑ Simultaneous measurement of device signal and light intensity
- ☑ White bias light source (up to 5 suns) with filter options
- ☑ Chopping speed 4 Hz to 200 Hz (1.3 Hz optional)
- ☑ 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)
- ☑ Customer training at PV Measurements, Inc. headquarters in Boulder, Colorado, USA
- ☑ Instruction manual
- ☑ Spare Lamps

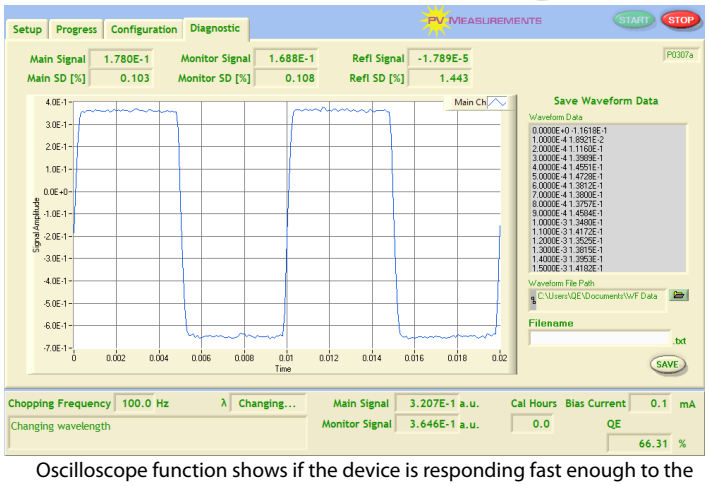


Beam-up operation with TFQ-BU for superstrate (all-back-contact) devices

TFQ-C with DSC

DC & Low Frequency Measurement Modes

Some device types, including Dye Sensitized Solar Cells (DSSC or DSC), respond slowly to modulated light. For some devices, even the standard minimum 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 optional slower modulated light at 1.3 Hz or DC light. 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. QEX10 systems containing the DC Mode Option enable the scientist to quickly switch between AC and DC modes to gather the maximum amount of information from their IPCE/QE scans.



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

www.pvmeasurements.com T: +1.303.386.3950 F: +1.303.648.6026 pvmsales@pvmeasurements.com

SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

Reflectance & IQE

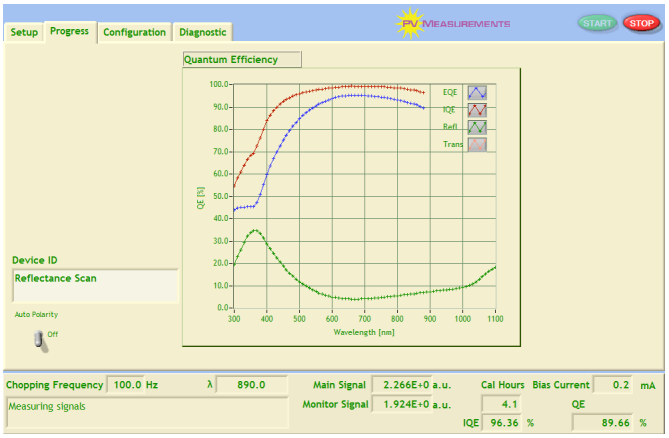
The Reflectance and IQE option includes the unique PV Measurements integrating sphere, optimized for hemispherical reflectance measurements of solar cells. This is a very important consideration for devices with surface texture, haze, or granular film structure, enabling it to provide more accurate Absorbed Photon Conversion Efficiency (APCE) or Internal Quantum Efficiency (IQE) data.

The optional QEX10 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.

The QEX10 Simultaneous IQE (SIQE) option allows for simultaneous measurement of specular reflection and EQE to deliver faster IQE data. This option is useful for smaller devices and those with specular surfaces.

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 QEX10 completes the measurement solution with the capability to make transmission measurements. The diffuse transmission option enables the QEX10 to perform high precision transmission measurements on samples with diffuse transmission.



IQE scan progress is shown during the scan.

Flipping the mirror on the right lets the probe beam enter the integrating sphere on the left.
The sphere is designed for maximum reflectance measurement accuracy on solar cells.

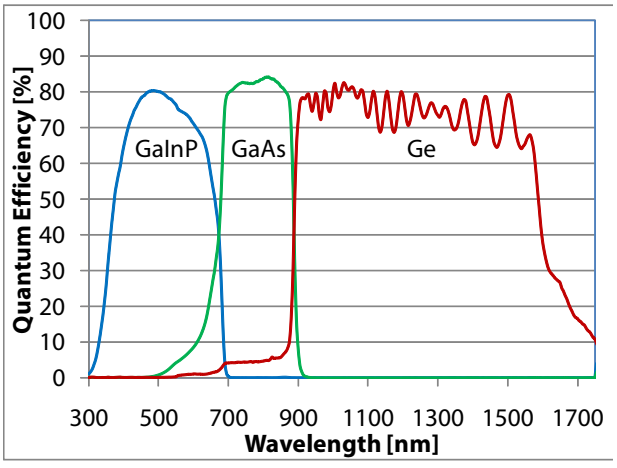
QEX10

SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

☑ Recommended
☐ Suggested

Common Device Types

Options	c – Si	mc – Si	a – Si / μ c- Si	CdTe	CIGS	GaAs	InGaAs	InGaP	Organic	DSSC	III-V Dual – Junction	Triple Junction	4 – junction
300 nm to 1400 nm spectral range	☑	☑			☑							☐	
300 nm to 1800 nm spectral range							☑					☑	☑
1.3 Hz to 50 Hz chopping speed										☑			
DC mode measurement capability										☑			
LED bias lights			☑								☑	☐	☐
Dual broadband bias lights											☐	☑	☐
Triple broadband bias lights												☐	☑
Quick – swap filter assembly			☐								☑		
Beam-up operation			☑	☑									
Automated measurements			☐							☐	☐	☐	☐
Reflectance and IQE measurement capability or SIQE	☑	☑	☐	☐	☐				☐				
Discrete, variable slit size													
Diffuse transmission measurements													
Setup and training at customer's site													
Accessories													
Glove box interface									☐	☐			
Clamp test fixture										☑			
Vacuum test fixture	☑	☑	☐		☑	☑	☐	☐	☐	☐	☑	☑	☑
Test fixture temperature control													
X – Y scanning for response mapping at any wavelength (coarse LBIC)	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Custom test fixture						☐	☐	☐	☐	☐	☐	☐	☐



QE of a triple junction III-V device

Multiple Bias Lights

Measurement of multi-junction solar cells requires the application of bias lights to ensure that the cell to be measured is current limiting and the current generated by the probe light is able to pass through those cells. The QEX10 is capable of delivering a 3 V bias voltage of 3 V and any number for bias lights required for your device measurements. Systems with two or more bias lights include a filter set designed for measurements of common triple junction III-V based devices.

www.pvmeasurements.com T: +1.303.386.3950 F: +1.303.648.6026 pvmsales@pvmeasurements.com

SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

LED Bias Light

LEDs provide a narrow band illumination that is well suited for measurements on various test device types. The computer controlled, LED bias light option for the QEX10 includes two wavelengths designed for dual junction amorphous silicon solar cells. Other wavelengths are available upon request.

Computer & Software

The system operates automatically under the control of a 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. It provides a graphical user interface, allowing the operator to easily and quickly specify tests to be performed, monitor test progress, and produce clear and informative test reports. The software saves the data in tab-delimited text format for simple import to graphing or other data analysis software.

X-Y Scanning

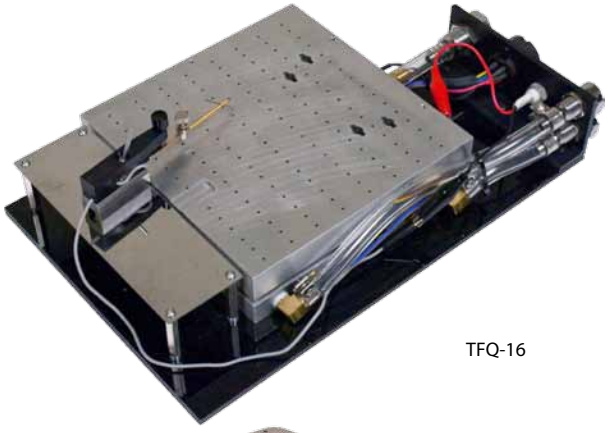
Using the X-Y Scanning accessory, one can scan the entire surface of a solar cell up to 150 mm x 150 mm dimensions (customization for larger scanning areas is available). This accessory reveals spatial variations in the response of solar cells as a function of wavelength. Using this accessory, the user can scan the QE of the test device at any wavelength or at a set of wavelengths in the system's range. After locating regions of concern, the user can perform more-resolved spatial and QE measurements to help diagnose device responsivity issues.

Test Fixtures

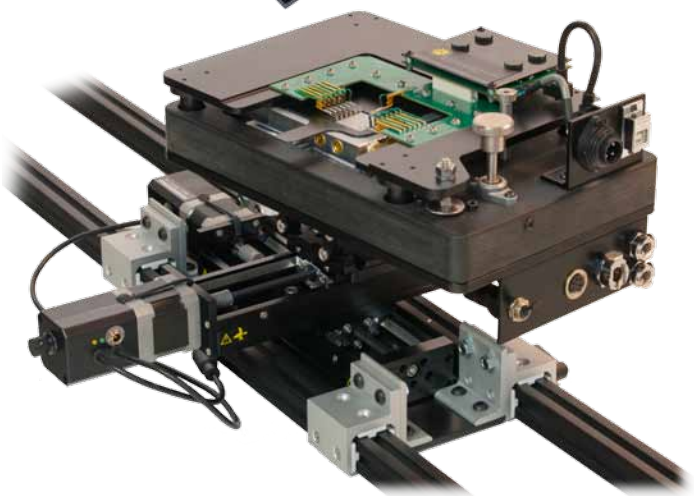
The QEX10 can measure such a wide variety of different types of solar cells that no single test fixture design is suitable for all of them. Therefore, a test fixture is not included although ordering one is recommended. PV Measurements offers a variety of vacuum and clamp test fixtures to hold and contact test devices. Temperature control capability up to 125 °C is an option for some test fixtures.

Glove Box Accessory

The glove box interface accessory couples the probe light from the QEX10 into a customer's glovebox for measurements of devices with short lifetime in air and are fabricated and should be measured in an inert atmosphere. Also included are focusing optics, text fixture mounting plate and bias light for measurements inside the glovebox.



TFQ-16



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.

SOLAR CELL QE / IPCE / SR MEASUREMENT SYSTEM

Installation

The QEX10 can be uncrated and installed in one morning by a trained person with an assistant. Note that it is important that the installers be able to lift objects with a mass of up to 70 kg.

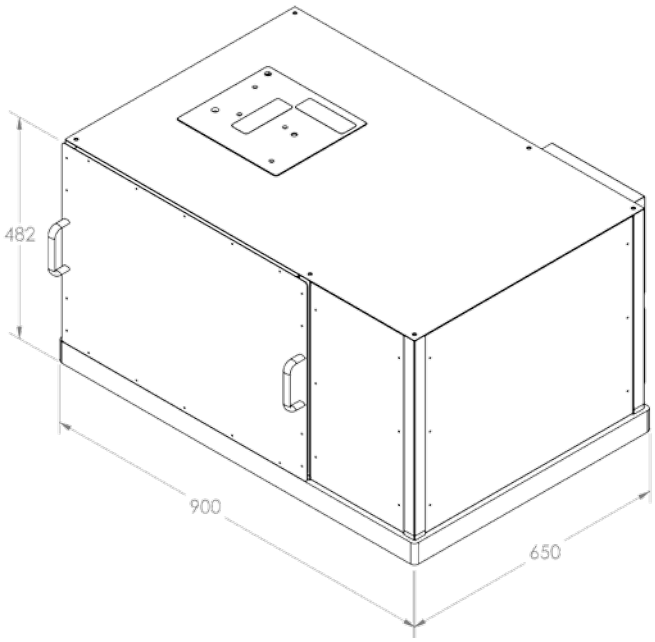
Training

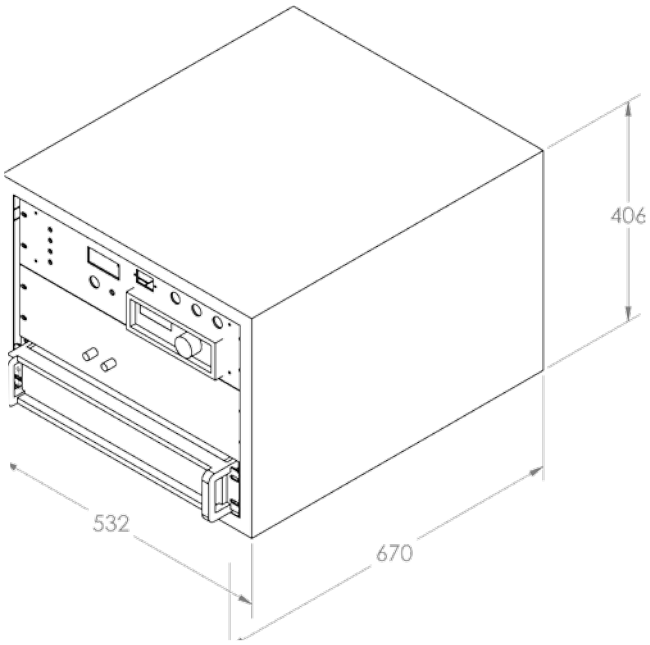
The QEX10 is simple to use and we invite you to come to PV Measurements headquarters in Boulder, Colorado, USA to learn how to install the system, use it and perform routine maintenance. The training takes one day and is included in the price of the system.

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.

Facility Requirements

The QEX10 requires 115 VAC, 10 A or 230 VAC, 5 A, 50 Hz to 60 Hz (please specify voltage and frequency with your order) and a sturdy table at least 1.5 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 %.





QEXL Order Information

Part Number	Description	Summary
QE-IR4 QE-IR4-PP QE-IR4-C	Wavelength range extension to 1400 nm.	Total wavelength range is 300 nm to 1400 nm. Ge calibration photodiode included.
QE-IR8 QE-IR8-PP QE-IR8-C	Wavelength range extension to 1800 nm.	Total wavelength range is 300 nm to 1800 nm. Ge calibration photodiodes included.
QE-IR30 QE-IR30-PP QE-IR30-C	Wavelength range extension to 3000 nm.	Total wavelength range is 300 nm to 3000 nm Ge photodiode and other appropriate calibration devices are included.
QE-IQE QE-IQE-PP QE-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 x 5 mm for opaque substrates and 10 mm for semi-transparent devices.
QE-SIQE QE-SIQE-PP QE-SIQE-C	Specular Reflectance Measurements	Measure the specular reflectance of a test device simultaneously with the EQE to get IQE, assuming that all reflectance is specular. For devices with patterned surfaces, use QE-IQE and QE-SDIQE for higher accuracy.
QE-DT QE-DT-PP QE-DT-C	Diffuse Transmission	Measure the transmission of a diffusive device with maximum accuracy using an integrating sphere to ensure good light collection.
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-XY TFQ-XY-PP TFQ-XY-C	X-Y Scanning Capability	Perform coarse LBIC measurements on a test device.

Part Number	Description	Summary
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.
QE-MJ3 QE-MJ3-PP QE-MJ3-C	Additional Bias Light	Additional broadband bias light for measurements of multi-junction devices. Systems with two or more bias lights include a filter set designed for measurements of typical III-V triple junction devices.
QE-MJ3A QE-MJ3A-PP QE-MJ3A-C	Automated measurement capability.	Program the system to run a batch of measurements on your devices unattended.
QE-LBL2 QE-LBL2-PP QE-LBL2-C	Dual Wavelength LED Bias Light	Dual color LED bias light designed for a-Si/uc-Si tandem device measurements.
QE-LBLC QE-LBLC-PP QE-LBLC-C	Custom Wavelength LED Bias Light	LED bias light at a custom wavelength specified by the customer. Please inquire with your sales engineer for available wavelengths.
QE-PVS QE-PVS-PP QE-PVS-C	Photovoltage Spectroscopy	The QEX10 can be configured to be able to measure the surface photovoltage of a test device.
QE-DC QE-DC-PP QE-DC-C	DC Mode Measurements	Capability to measure the response of a test device in DC mode. This option is very useful for DSSC/DSC.
QE-LF QE-LF-PP QE-LF-C	Low Frequency Measurements	Measure the response of a test device with a slow response at a lower chopping frequency. With this option, the chopping frequency range is 1.4 Hz to 50 Hz.

Notes

Due to our practice of continuous product improvement, specifications and appearance are subject to change. Quantum Efficiency Measurement Systems carry a limited warranty. Please contact PV Measurements, Inc. or your local representative for details.

Revision 140618, © 2014 PV Measurements, Inc. All rights reserved

For additional and up to date product information, visit our web site at www.pvmeasurements.com

Technical Support: techsupport@pvmeasurements.com
Sales: pvmsales@pvmeasurements.com

Tel: +1.303.386.3950
Fax: +1.303.648.6026

Address:
5757 Central Ave, Ste. B
Boulder, CO 80301
USA

Notes

Due to our practice of continuous product improvement, specifications and appearance are subject to change. Quantum Efficiency Measurement Systems carry a limited warranty. Please contact PV Measurements, Inc. or your local representative for details.
Revision 140618,
© 2014 PV Measurements, Inc. All rights reserved

PV MEASUREMENTS
INSTRUMENTATION FOR PHOTOVOLTAICS INDUSTRY AND RESEARCH