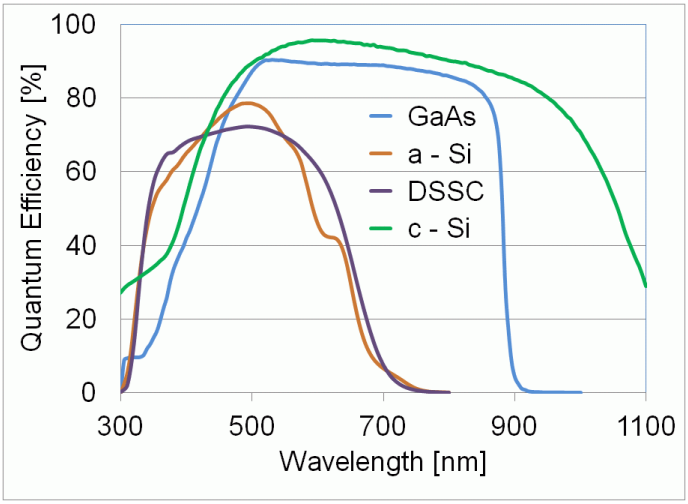
QEX10 Solar Cell Quantum Efficiency Measurement System

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.



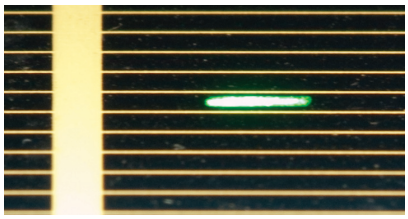
- ☑ Turn-key solution for solar cell analysis
- ☑ System of choice by national laboratories
- ☑ Mature product - over 200 QE systems in the field
- ☑ Fast and easy installation
- ☑ Excellent repeatability
- ☑ Accurate measurements
- ☑ Light bias current capability up to 150 mA
- ☑ ASTM E 1021-06 and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

PV MEASUREMENTS, INC.
Instrumentation for Photovoltaics Industry and Research

www.pvmeasurements.com Tel: +1.303.386.3950 Fax: +1.303.648.6026 pvmsales@pvmeasurements.com

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

Monitor Photodiode

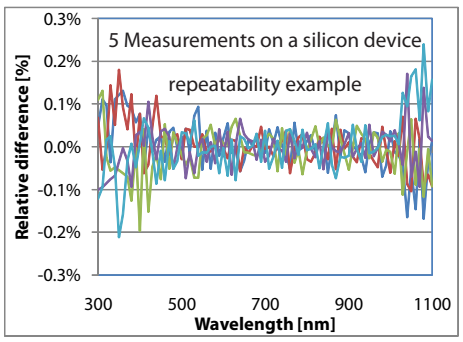
The intensity of any light source will vary with time. The QEX10 performs simultaneous measurements of the device signal strength and the probe light intensity, minimizing the chance for noise from lamp intensity variations from appearing in measurement results.

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.

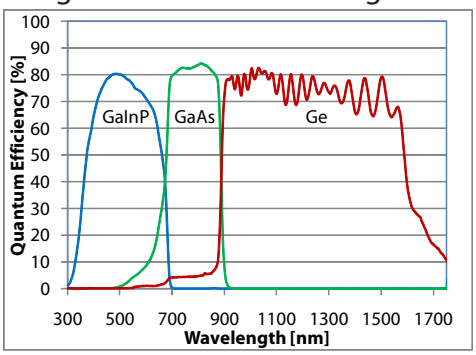
Wavelength Range & Uncertainty

The basic system wavelength range is 300 nm to 1100 nm. Typical repeatability for 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.



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



QE of a triple junction III-V device

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. PV Measurements also offers accessories to facilitate application of spectrally-selective bias light for multi-junction solar cell measurements, including multi-colored LED bias lights.

Monochromatic Light Modulation

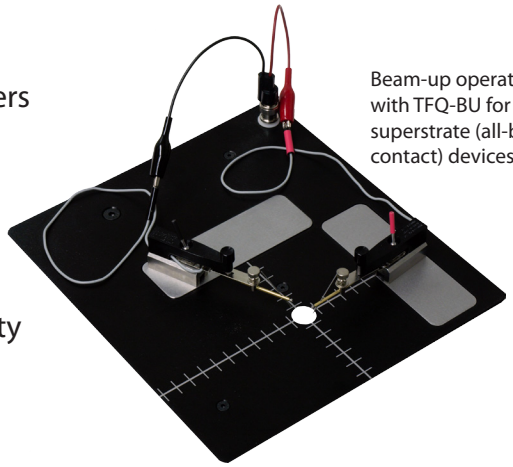
The QEX10 spectral response measurement system uses an adjustable mechanical chopper to modulate the light at rates between 4 Hz and 200 Hz (1.3 Hz to 50 Hz range optional). Solar cells with long response times require slower chopping speeds for accurate measurements, whereas faster devices can be measured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

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 %.

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
- ☑ 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 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

Common Device Types

☑ Recommended
☐ Suggested

Options

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							☑					☑	☑
Reflectance and IQE measurement capability or SIQE	☑	☑	☐	☐	☐				☐				
1.3 Hz to 50 Hz chopping speed										☑			
DC mode measurement capability										☑			
Quick – swap filter assembly			☐								☑		
LED bias lights			☑								☑	☐	☐
Dual white bias lights											☐	☑	☐
Triple white bias lights												☐	☑
Beam-up operation			☑	☑									
Setup and training at customer's site													

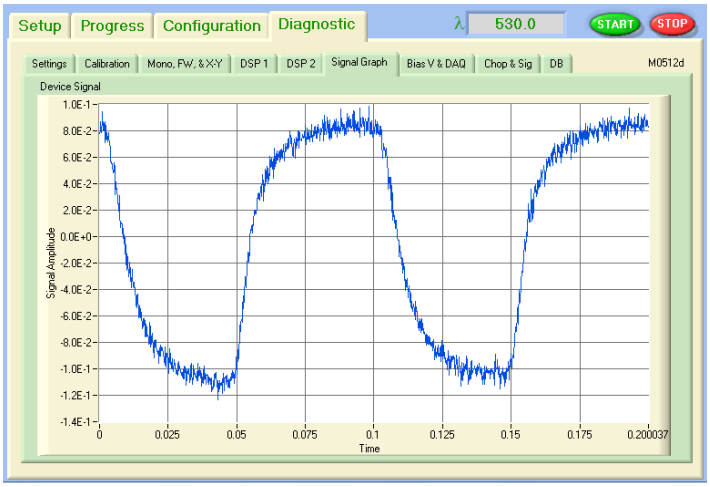
Accessories

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						☐	☐	☐	☐	☐	☐	☐	☐

SOLAR CELL QUANTUM EFFICIENCY MEASUREMENT SYSTEM

Reflectance & IQE

The Reflectance and IQE option includes the unique PV Measurements integrating sphere, optimized for solar cell measurements. The sphere is designed to more accurately account for both diffuse and specular reflections. This is a very important consideration for devices with surface texture, haze, or granular film structure. This results in more accurate Internal Quantum Efficiency (IQE) data. 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.

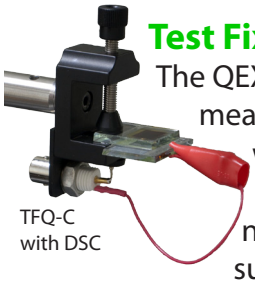


Oscilloscope function shows if the device is responding fast enough to the chopped probe light.

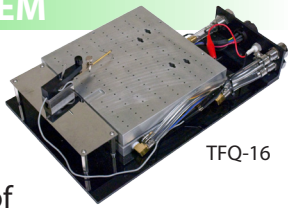
DC & Low Frequency Measurement Modes

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.

Test Fixtures



TFQ-C with DSC

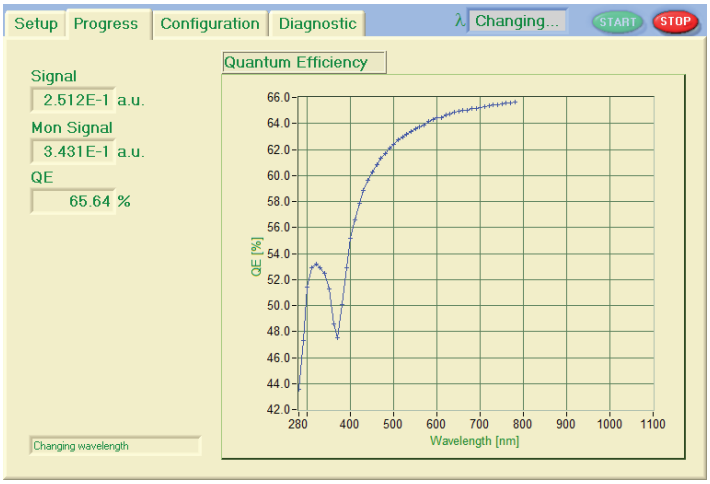


TFQ-16

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.

Computer & Software

The system operates automatically under the control of a computer with a Microsoft Windows™ Operating System and custom software written with National Instruments' LabVIEW™. 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.



QE scan progress is shown during the scan.

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.

www.pvmeasurements.com Tel: +1.303.386.3950 Fax: +1.303.648.6026 pvmsales@pvmeasurements.com