

IQE-200 Quantum Efficiency Measurement Systems



- Fast, accurate and repeatable EQE and IQE measurements
- Patent pending optical design eliminates the need to reposition detector and sample
- Spectral responsivity, diffuse reflectance and J_{sc} measurements also supported
- AC and DC mode measurement systems cover all cell types
- Compliant to ASTM E1021-12 standard test method
- All new software application acquires data from all channels in a single pass
- Full complement of accessories include TE cooled vacuum chucks, light bias tools and X-Y motion stages
- Custom system requirements supported

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Oriel Instrument's IQE-200 Series Systems are turn-key quantum efficiency measurement instruments used to measure the External Quantum Efficiency (EQE) and Internal Quantum Efficiency (IQE) of solar cells, detectors, or other photon-current devices. These systems meet the ASTM E1021-12 standard test method for spectral responsivity measurements of photovoltaic devices.

Wavelength accuracy is an impressive 0.5 nm, repeatability is $\pm 0.2\%$ from 400 – 1000 nm, and spectral resolution is 10 nm (for systems with resolution down to 5 nm, please contact an Oriel Sales Engineer). We offer systems to cover the spectral ranges of 300 – 1100 nm and 300 – 1800 nm, for both AC-only and AC and DC operation. The all new IQE200 software commands the system's components and acquires and displays both EQE and IQE results. A unique feature of the IQE200 is the patent pending optical design which removes the need to reposition the detector and sample, thereby eliminating positional errors. The software is intuitive, fast and accurate, yet flexible enough to support all cell types and measurement modes. The IQE200 is a true research instrument for solar cell analysis – supporting the changing needs of Researchers.

WHAT ARE EQE AND IQE?

External Quantum Efficiency (EQE) is the ratio of the number of photons incident on a solar cell to the number of generated charge carriers. Internal Quantum Efficiency (IQE) also considers the internal efficiency - that is, the losses associated with the photons reflected back from the surface of the cell. In an IQE measurement, these losses are measured in order to calculate a net quantum efficiency – a much truer efficiency measurement. The patent-pending Oriel IQE200 calculates both measurements simultaneously, ensuring the highest measurement accuracy.

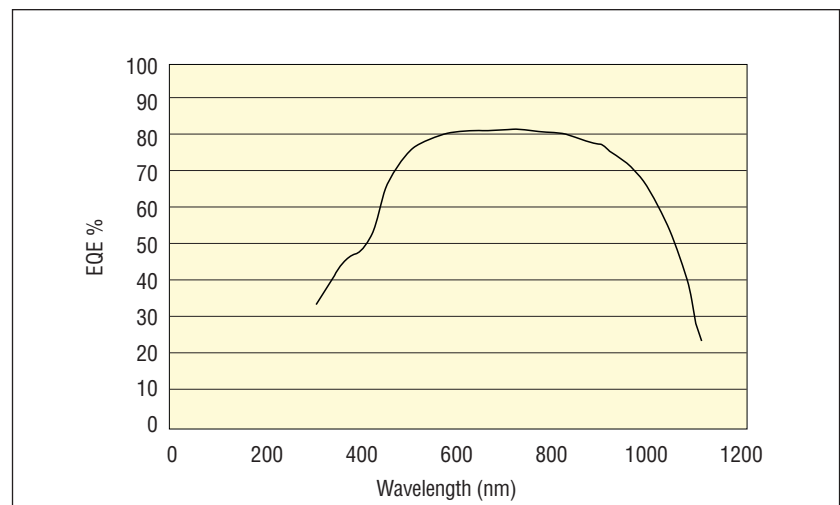


Fig. 1 Silicon Cell.

IQE-200 Quantum Efficiency Measurement Systems

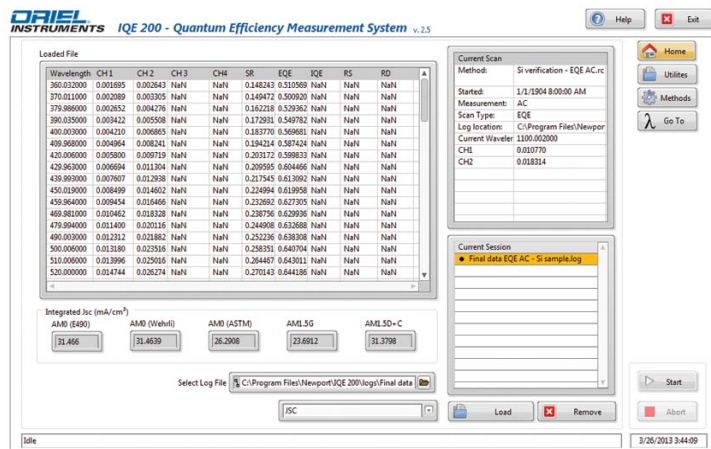


Fig. 2 IQE200 Software showing the Junction Current Calculator.

OTHER MEASUREMENTS SUPPORTED

Other measurements possible with the IQE200 are:

- Specular Reflectance
- Spectral Responsivity
- Junction Current
- Diffuse Reflectance (systems with integrating sphere)

CHOOSING THE SYSTEM TO MATCH YOUR CELL TYPE(S)

Your cell type will determine the spectral range, method of measurement and additional accessories needed for accurate IQE and EQE measurements. Table 1 shows the features that best support common cell types. We offer IQE200 systems that meet all of these requirements; contact a Sales Engineer for guidance in configuring a system for your cell type(s).

Table 1 Measurement Requirements for Common Cell Types

Features	Common Cell Types						
	Mono Crystalline Si	Multi Crystalline Si	Organic	DSSC	Quantum Dot	InGaAs	III-V Multi-Junction
300 - 1100 nm Spectral Range	X	X					
300 - 1800 nm Spectral Range					X	X	X
IQE with Specular Reflectance	X	X	X				
IQE with Specular Reflectance and Diffuse Reflectance (requires system with integrating sphere)	X	X					X
DC mode				X			
White light bias		X					X
Triple light bias							X

HOW DOES THE SYSTEM WORK?

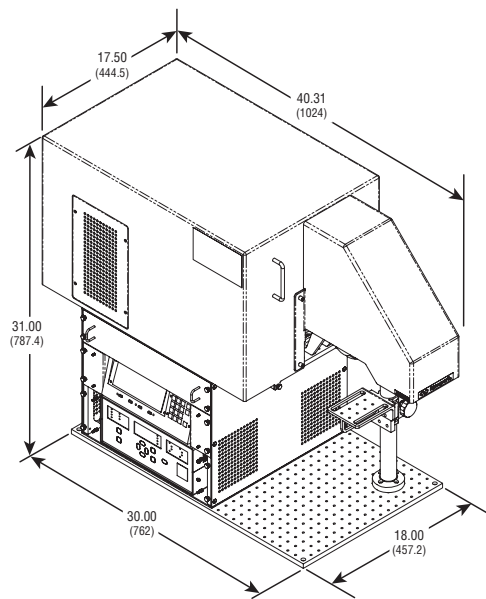
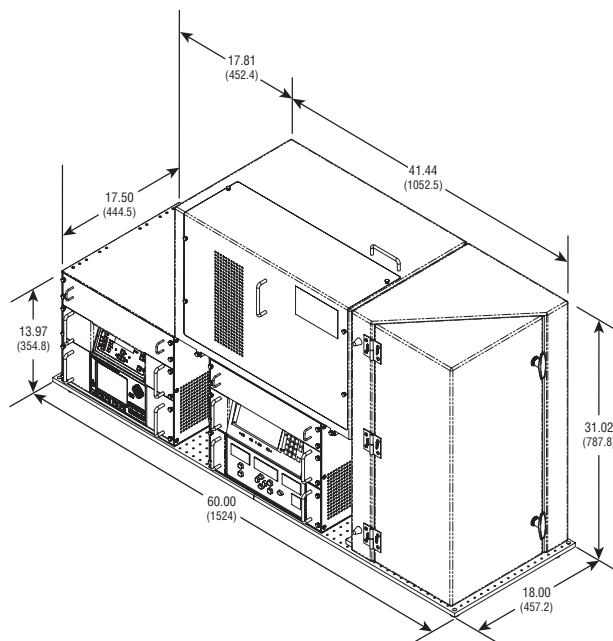


Fig. 3 Dimensional diagrams of AC and DC IQE200 System (top) and AC - only IQE200 System (bottom).

The Oriel IQE200 has a patent pending optical design. The light engine is comprised of a Xenon or Quartz Tungsten Halogen Light Source and Oriel Cornerstone 130 1/8 m Monochromator with adjustable slit wheels, two gratings, and order sorting filters. The monochromator's entrance and exit slits are factory set to 10 nm spectral resolution (for higher resolutions, contact an Oriel Sales Engineer). The systems' spot size is 1 x 1.5 mm; for smaller spot sizes, contact an Oriel Sales Engineer.

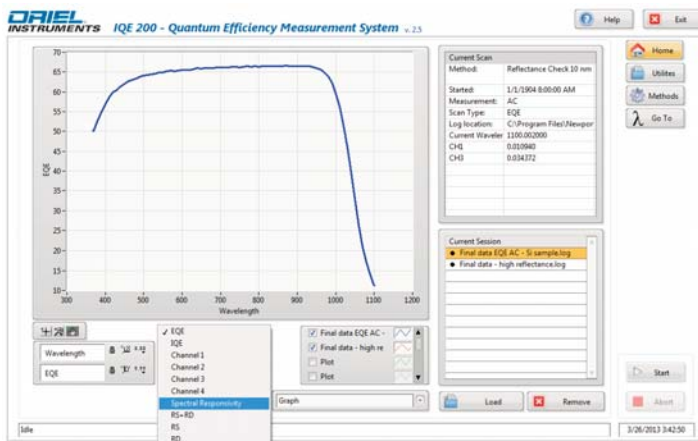


Fig. 4 IQE200 Software, showing the EQE curve of a silicon reference cell.

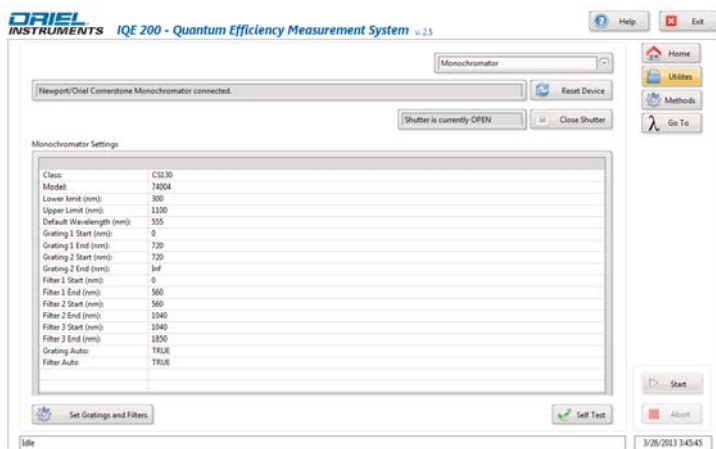


Fig. 5 Instrument utility panel of the IQE200 Software, showing the monochromator's settings.

ALL NEW IQE200 SOFTWARE

All IQE200 systems include a laptop computer with the IQE200 software pre-installed. Also loaded are all of the necessary calibration and reference files. The software controls all of the basic system components, including the Monochromator, order sorting filter wheel, and lock-in amplifier and chopper or power meter. The software acquires data from all channels in a single pass and generates the IQE and EQE curves in real time without the need to reposition detectors or sample. All data is automatically saved with a date and time stamp for easy identification.

One of the IQE200 software's unique features is the Methods Editor – this utility lets users save unique scan parameter settings specific to their cell type(s). This ensures measurement consistency across multiple batches. It is particularly useful for multi-user sites and/or for users researching various cell sizes and types.

Other improved software functionality includes: improved graphing features, tabular data view for easy measurement datum inspection, a diagnostics utility for the system's components, and ability to vary the wavelength intervals over a single scan.

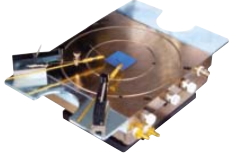
HOLDING YOUR SAMPLE

Our IQE200 Systems include a 5 x 4 inch sample platform on a vertical translation rod; the platform has 1/4 - 20 tapped holes spaced 1 inch apart. Two optional vacuum chuck assemblies are available, one with temperature control and one without. We detail these on the next page.

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IQE200 ACCESSORIES

Vacuum Chuck Assemblies and Probe Kits



The model IQE-TC-VAC is a temperature controlled vacuum plate with a 1.0 inch (25 mm) travel X-Y stage; it holds samples from 2x2 to 6x6 inches (51x51 to 152x152 mm) and mounts directly to the sample plate on the IQE200 system. Temperature measurement range is $-40\text{ }^{\circ}\text{C}$ to $125\text{ }^{\circ}\text{C}$, $\pm 1\text{ }^{\circ}\text{C}$ (chiller, dependent).

The IQE-VAC is an economical alternative to the IQE-TC-VAC for samples not requiring cooling. It also includes a 1.0 inch (25 mm) travel X-Y stage and holds samples from 2x2 to 6x6 inches (51x51 to 152x152 mm).

The PVIV-PROBE-KIT provides an electrical contact probe, for use with the vacuum chuck assemblies. A convenient adapter plate allows the probe to be mounted to the vacuum chuck. A magnetic base holds the probe kit on the adapter plate at any location and angle. One probe tip is included with the kit; the length of the tip that extends to the sample can be adjusted. The probe kit offers excellent accuracy in positioning and measurement; a micropositioner joystick precisely places the probe exactly where it is needed. The number of probes needed is based on factors including, but not limited to, probing method, current capacity and electrical biasing requirements.

Vacuum Pump



We offer a quiet, lightweight and compact 1/8 HP vacuum pump as an accessory for our vacuum chuck assemblies. Choose between model PVIV-VAC-PUMP and PVIV-VAC-PUMP-220 based on your line voltage.

Temperature Controlled Chiller



The model PVIV-CHILLER is a thermoelectric temperature control system with full PID control of both heating and cooling. Temperature set point range is $2\text{ }^{\circ}\text{C}$ to $45\text{ }^{\circ}\text{C}$; control accuracy is $\pm 0.1\text{ }^{\circ}\text{C}$.

Light Bias Kit



The Oriel IQE-LIGHT-BIAS kit is made up of a quartz tungsten halogen source with a 3-position, 1.0 inch (25.4 mm) diameter filter holder and a bifurcated fiber optic cable. Choose various filters to deliver filtered bias light to a multi-junction cell under test, or deliver white (unfiltered) light bias to a cell requiring pre-soaking with white light. Note, filters are not included with the Light Bias Kit – please order these separately. Filters can be stacked up to 0.28 inch (7.11 mm) thick, in each filter holder.

Modifying the spectral distribution of the light bias is the key to ensuring accurate Quantum Efficiency (QE) measurements of multi-junction cells. Optically chopped monochromatic light will cause an additional alternating current if its wavelength lies in the response band of more than one subcell. This spectral artifact, which is the result of a subcell not under test contributing to the QE measurement of a subcell under test, can be eliminated by isolating the bandpass regions of the individual subcells.

This measurement artifact can be observed when measuring the quantum efficiency of GaInP/Ga(In)As/Ge, a common triple-junction cell. In the figures below we show the effect of using spectral selection filters with the IQE-LIGHT-BIAS. To measure the GaInP top cell of the GaInP/Ga(In)As/Ge triple-junction cell, the bias light has to have less effective irradiance in the blue than in the red and infrared, as is shown in Fig. 6. A 695 nm long pass filter (model 10CGA-695) is used. To measure the Ga(In)As middle layer, a 650nm short wave pass filter (model 10SWF-650-B) and 900 nm long pass filter (model 10LWF-900-B) are used. Fig. 7 shows the light bias condition for GaA (middle cell). Lastly, to measure the Ge bottom layer, a 900 nm short pass filter (model 10SWF-900-B) and heat absorbing KG1 filter (model FSR-KG1) are used. Fig. 8 shows the light bias condition for the bottom (Ge) layer. The heat absorbing filter is used to protect the 900 nm short pass filter. These filters are listed in Table 2.

Table 2 Recommended Filter Combinations for GaInP/Ga(In)As/Ge Cells

Filter Model	Filter Description	For this M-J Layer
10CGA-695	695 nm Cut-on LP Filter	Top Layer
10LWF-900-B + 10SWF-650-B	920 nm Cut-on LP Filter 650 nm Cut-on SP Filter	Middle Layer
10SWF-900-B + FSR-KG1*	900 nm Cut-on SP Filter Heat Absorbing KG1 Filter	Bottom Layer

* Note, the FSR-KG1 Heat Absorbing Filter is used to protect the 900 nm Short Pass Filter. These two filters must be stacked together in the filter holder, with the SP Filter being inserted first (furthest away from the light source).

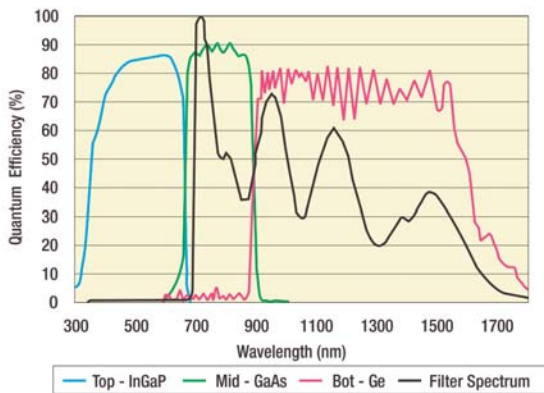


Fig. 6 Light bias condition for GaInP (top layer of GaInP/Ga(In)As/Ge triple-junction cell).

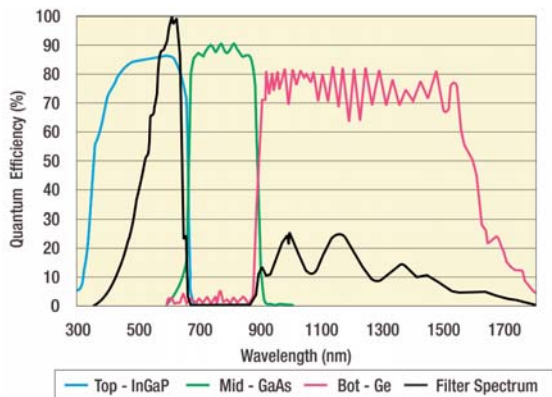


Fig. 7 Light bias condition for GaAs (middle layer of GaInP/Ga(In)As/Ge triple-junction cell).

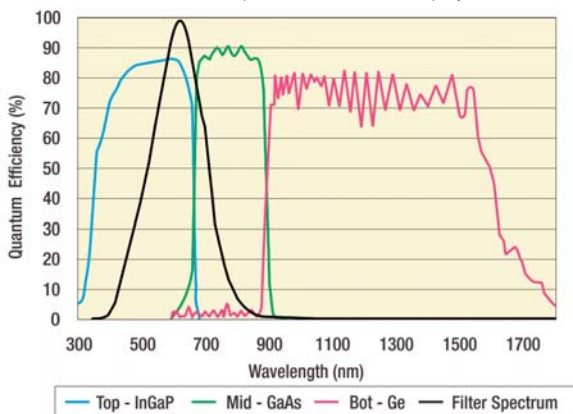


Fig. 8. Light bias condition for Ge (bottom layer of GaInP/Ga(In)As/Ge triple-junction cell).

WHEN DO I NEED TO APPLY A VOLTAGE BIAS?

The external voltage of a multi-junction (MJ) cell (V_{MJ}) and the operating voltage V_i of the individual subcells i needs to be distinguished in the case of multi-junction (MJ) cells.

The voltage of the MJ cell is the sum of the subcells' voltages ($V_{MJ} = \sum V_i$) since a MJ cell is in series. The bias light generates photocurrent for a particular subcell j , which causes a mismatch to the current – the operating voltage V_i of the subcell to be measured is shifted. A subcell j with excess photocurrent is operating at a lower current level than its photocurrent and consequently closer to its open-circuit voltage V_{OCj} . With respect to a spectral responsivity measurement, this means that, if the external voltage equals zero ($V_{OCj} \approx 0V$), the voltage V_i of the subcell to be measured is $V_i = - \sum V_{OCj}$ ($j \neq i$). Therefore, the external voltage has to be set to $V_{MJ} = \sum V_{OCj}$ ($j \neq i$) in order to short-circuit the subcell to be measured.

In the case of our GaInP/Ga(In)As/Ge M-J cell, to measure the V_{OC} of the bottom cell (Ge), following the light bias condition is required.

With the excess light bias on the top and middle layers, the sum V_{MJ} will be:

$$V_{MJ} = V_{OCt} + V_{OCm} + V_b$$

Where:

V_{OCt} and V_{OCm} = open circuit voltage of top and middle layers, respectively.

The current of the triple cell is limited by the Ge bottom layer; the top and middle layers, with excess photocurrent as a result of proper light bias filtering, operate near V_{OC} . The bottom Ge layer would be working at a negative voltage if the external voltage of the triple cell were 0V. Therefore, an external bias voltage of $V_{BIAS} = V_{OCt} + V_{OCm}$ should be applied in order to accurately measure the EQE of the Ge subcell under short-circuit conditions

IQE-200 Quantum Efficiency Measurement Systems

CHOOSING THE CORRECT IQE SYSTEM

We offer a full series of IQE200 systems and an array of complementary accessories. Use Fig. 9 to guide you in choosing a system that is customized for your needs. The choice is based on the four selection criteria shown in the diagram below. Our Sales Engineers are available to help ensure the appropriate selection for your needs. Contact us for assistance.

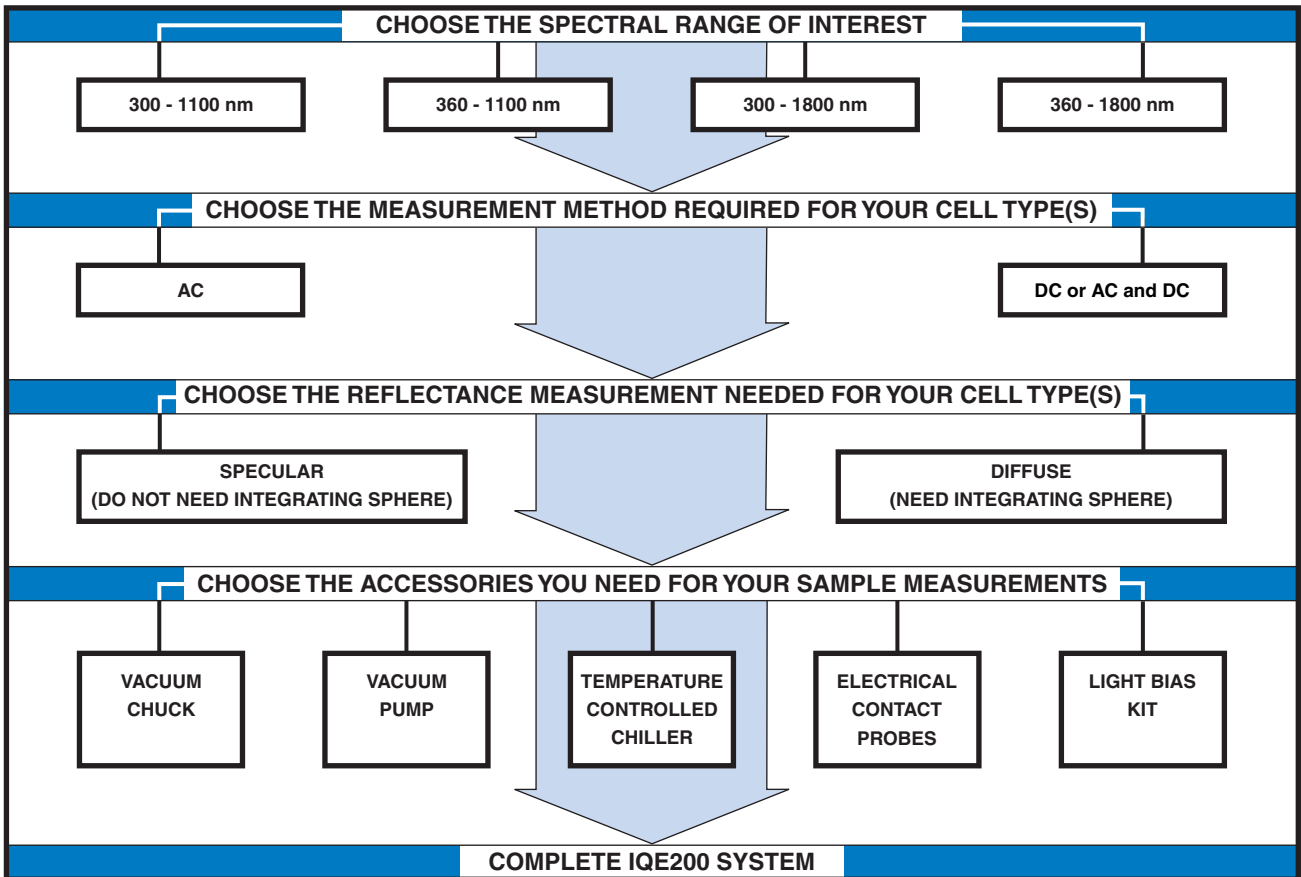


Fig. 9 The choice of IQE200 System depends upon the above four criteria. Contact a Sales Engineer to help validate your choice.

CUSTOM REQUIREMENTS WELCOME

The IQE200 systems we detail here support the majority of solar cell characterization requirements, but we recognize that they do not support them all. We welcome the opportunity to work with you to adapt a system to meet your unique needs. Whether you need a system with mapping capabilities, or a system that will couple to a glove box, or simply a different spot size, we will work with you to design, build and deliver a system that meets your needs, budget and timeline. Contact an Oriel Sales Engineer to discuss your requirements.



IQE200 System with upward facing beam for glove box integration. Contact a Sales Engineer for details.

SPECIFICATIONS

IQE System Specifications

Wavelength Range (s)	300 - 1100 nm 360 - 1100 nm 300 - 1800 nm 360 - 1800 nm
Spot Size	1 x 2.5 mm
Working Distance	
Systems with Integrating Sphere	100 mm
Systems without Integrating Sphere	50 mm
Spectral Resolution	10 nm
Step Size	10 nm
Wavelength Accuracy	0.5 nm
Repeatability, Spectral Response	±0.4%, 300 (360) - 400 nm ±0.2%, 400 - 1000 nm ±0.6%, 1000 - 1800 nm
Wavelength Precision	0.08 nm
Monochromator Path Length	1/8 meter
Measurements Supported	
AC-only Systems with Integrating Sphere	EQE, IQE, Spectral Responsivity, Specular Reflectance, Diffuse Reflectance, Jsc
AC-only Systems without Integrating Sphere	EQE, IQE, Spectral Responsivity, Specular Reflectance, Jsc
AC/DC Systems with Integrating Sphere	EQE, IQE (AC mode, only), Spectral Responsivity, Specular Reflectance, Diffuse Reflectance, Jsc
AC/DC Systems without Integrating Sphere	EQE, IQE (AC mode, only), Spectral Responsivity, Specular Reflectance, Jsc

ACCESSORY SPECIFICATIONS

Vacuum Chuck Assembly Specifications

Sample Size	2 x 2 to 6 x 6 inch (51 x 51 to 152 x 152 mm)
Temperature Measurement Range	-40 °C to 125 °C, ±0.1 °C
Temperature Holding	<0.5 °C/minute with Newport chiller P/N: PVIV-Chiller
Material	Nickel plated Aluminum
Vacuum Requirement	150 mm Hg, minimum
Weight	9.5 lb (4.3 kg)

Vacuum Pump Specifications

Discharge	Oil free
Max Vacuum (hg)	650
Free Air (cfm)	20
dB Rating	50
Horsepower	1/8 HP
VAC @ 60 Hz	115 (1)
Amps	0.7
Size	11 x 6 x 4.5 inches (279 x 150 x 114 mm)
Connection	Barbed for use 1/4 inch ID tubing, Conversion parts for 1/4 inch OD tubing included
Weight	4.1 lb (1.9 kg)

Temperature Controlled Chiller Specifications

Operating Range	10 °C to 40 °C
Cooling Capacity	160 W at 20 °C (20 °C ambient)
Modes	Cool, Heat, Cycle
Precision	<0.1 °C with a constant load
Operating Voltage	200 W, 12 VDC, 8 A maximum, universal AC adapter supplied
Pump	0.5 lpm gear pump at 10 psi, with a magnetically-coupled brushless DC motor (10,000 hr MTBF)
Tank Volume	75 ml, additional coolant needed to fill hoses and cold plate.
Size	7.5 x 5 x 7 inches (190 x 127 x 178 mm)
Weight	8 lb (3.7 kg)
Coolant Fluid Connections	1/8" CPC with shut-off valves
Noise	63 dBA at 3 feet

Light Bias System

Source	QTH
Light Delivery	Fiber
Number of Fibers	1 Bifurcated to dual output
Filter Holder (slide mount)	3 filter slots; holds 1.0 inch (25.4 mm) diameter filters, up to 0.28 inch (7.11 mm) thick
Intensity	Variable
Weight	11.0 lb (5 kg)

IQE-200 Quantum Efficiency Measurement Systems

Ordering Information

IQE200 Systems

Measurement Mode	Spectral Range (nm)	Lamp Type	Includes Integrating Sphere	Model	
				110V Versions	220V Versions
AC-Only	360 - 1100	250 W QTH	No	IQE-AC-QTH-SI	IQE-AC-QTH-SI-220
	300 - 1100	300 W Xenon	No	IQE-AC-XEN-SI	IQE-AC-XEN-SI-22
	360 - 1800	250 W QTH	No	IQE-AC-QTH-EXT1	IQE-AC-QTH-EXT1-22
	300 - 1800	300 W Xenon	No	IQE-AC-XEN-EXT1	IQE-AC-XEN-EXT1-22
	360 - 1100	250 W QTH	Yes	IQE-AC-Q-SI-IS	IQE-AC-Q-SI-IS-22
	300 - 1100	300 W Xenon	Yes	IQE-AC-X-SI-IS	IQE-AC-X-SI-IS-22
	360 - 1800	250 W QTH	Yes	IQE-AC-Q-EX-IS	IQE-AC-Q-EX-IS-22
	300 - 1800	300 W Xenon	Yes	IQE-AC-X-EX-IS	IQE-AC-X-EX-IS-22
AC and DC	360 - 1100	250 W QTH	No	IQE-ACDC-QTH-SI	IQE-ACDC-QTH-SI-22
	300 - 1100	300 W Xenon	No	IQE-ACDC-XEN-SI	IQE-ACDC-XEN-SI-22
	360 - 1800	250 W QTH	No	IQE-ACDC-QTH-EXT1	IQE-ACDC-QTH-EXT22
	300 - 1800	300 W Xenon	No	IQE-ACDC-XEN-EXT1	IQE-ACDC-XEN-EXT22
	360 - 1100	250 W QTH	Yes	IQE-ACDC-Q-SI-IS	IQE-ACDC-Q-SI-IS22
	300 - 1100	300 W Xenon	Yes	IQE-ACDC-X-SI-IS	IQE-ACDC-X-SI-IS22
	360 - 1800	250 W QTH	Yes	IQE-ACDC-Q-EX-IS	IQE-ACDC-Q-EX-IS22
	300 - 1800	300 W Xenon	Yes	IQE-ACDC-X-EX-IS	IQE-ACDC-X-EX-IS22

IQE200 Accessories

Model	Description
IQE-TC-VAC	Temperature controlled Vacuum Chuck Assembly
IQE-VAC	Vacuum Chuck Assembly
PVIV-PROBE-KIT	Electrical Contact Probe Kit
PVIV-VAC-PUMP	PVIV Vacuum Pump, Oil Free, Cool Air Output, 110 VAC
PVIV-VAC-PUMP-220	PVIV Vacuum Pump, Oil Free, Cool Air Output, 220 VAC
PVIV-CHILLER	Circulating Water Bath Chiller
IQE-LIGHT-BIAS	Light Biasing Kit (Includes External QTH Source, mounting flange and bifurcated fiber optic cable) Note: filters must be ordered separately
10CGA-695	Filter, Colored-Glass Alternative, Longwave pass cut-on λ 695 nm, 1 in. dia.
10LWF-900-B	Long Wave Pass Filter, 25.4 mm Diameter, 900 ± 7 nm Cut-On, 990 to 2200 nm
10SWF-650-B	Short-Pass Filter, 25.4mm Diameter, 650 ± 5 nm Cut-On, 415-640nm Transmittance
10SWF-900-B	Short-Pass Filter, 25.4mm Diameter, 900 ± 7 nm Cut-On, 475-880nm Transmittance
FSR-KG1	Colored Glass Filter, 25.4 mm Diameter, Heat Absorbing, KG.1



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DS-061501