KOPEL

SHORT FORM CATALOGUE

Solar PV Test Systems 2016.9

Innovative
PV Test Systems

KOPEL's Way

3 main factors in measurement

KOPEL emphasizes the three main factors for product developments to do accurate and stable measurement. These are “Light” (light stability), “Electric (I-V measurement response), and “Temperature” (control of measurement temperature).

光 Light

Stable Light Source

The light instability is minimized to +/-0.1% by newly developed proprietary power supply and control circuitry. As shown in Fig.1, the light source is accurately controlled. Commonly used continuous xenon short-arc lamps have fluctuations of +/-0.5% because of arc flickering and power supply ripple noises. KOPEL’s KSX series minimize the light instability to +/-0.1% to avoid affecting measurement data. In production line classification, in particular, about 0.2% accuracy is often needed. In such cases, the light stability is very important.

The new system can create one single 50ms pulse, or two staged or three staged pulse. Therefore, it can measure Rs (internal resistance) as specified in IEC/JIS standards.

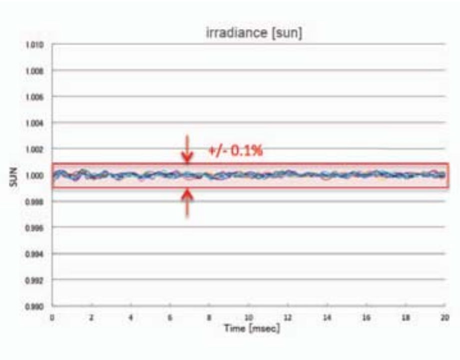


Fig. 1 Stable Light

IEC 60904-9 vs measured results

	Item	Class: KOPEL A++A+A++	Class: AAA
1	Spectral Match	<±6%	< ±25%
2	Spatial Non-uniformity	<±1.5%	< ±2%
3	Temporal Instability	<±0.2%	< ±2%

Fig. 2 Class A++ A+ A++

電 Electric

Accurate Electric Measurement and Optimum Probing

I-V measurement system is equipped with a high-speed bipolar power supply that can work in 4-quadrant operation and can measure solar cell characteristics precisely. Using 4-wire method, the system can measure the voltage and the current at the same time, and can draw accurate I-V curve during a very short light pulse. The measurement can be very precise by sweeping from Isc to Voc, and Voc to Isc, and can provide accurate data of Isc, Jsc, Voc, Pmax, FF, Rs, Rsh, Iv, Vi, Eff, and temperature. KOPEL’s jig uses very thin and strong probe bars to avoid making unwanted shadow to the solar simulator light, and the probe pins’ high durability and low contact resistance are also very important for accurate I-V measurement.

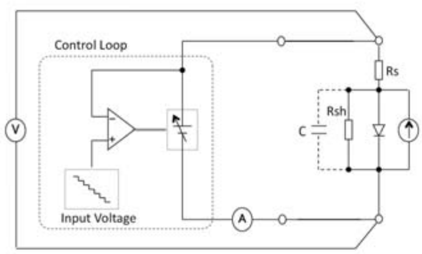


Fig. 3 Dynamic I-V Measurement

The I-V tester can be separately sold and used with other solar simulator. Refer to P6-7 for details.

The measurement Jig that has realized high data repeatability is shown here: Refer to P8-9 for details.

温 Temp.

Tight Control of Cell Temperature and Measurement Environment

Temperature is controlled by monitoring the cell and the sample plate, and kept at 25℃ as specified in the international standard. It is difficult to suppress the temperature rise using continuous light or a long pulse (300ms – 1000ms), and short pulse is normally preferred other than Japan. KOPEL uses 10ms – 50ms short pulse, and minimizes the temperature rise.

I-V Measurement of PV Cell and Module

I-V Measurement of common c-Si PV

Fig. K-1 shows the I-V measurement of common c-Si cell.

c-Si responds to the light very quickly, and can be measured sweeping the voltage from Isc to Voc during a short light exposure of several milliseconds.

Generally, a short pulse light of 1 – 10ms has been used for the measurement.

It does not rise the temperature, and has been widely used overseas.

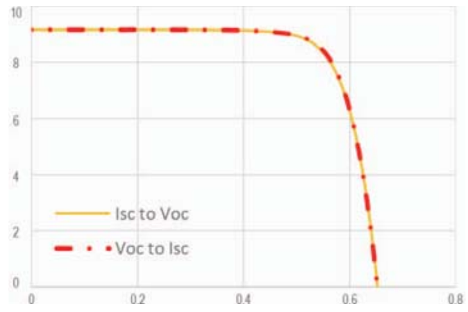


Fig. K-1 I-V Measurement of c-Si Cell

High-Efficiency PV Measurement

Generally, high-efficiency PV has complicated structure, and high capacitance. It is not possible to measure using a short pulse (less than 100ms), because unlike conventional c-Si types, its reaction to voltage sweep is very slow.

High-efficiency PV, therefore, has been generally measured using continuous light or a long pulse (600-800ms). In that case, temperature rise and light stability must be seriously considered. If a short pulse is used, because of the PV capacitance, the IV curve is strongly distorted. In the sweep direction from Isc to Voc, the PV capacitance is not fully charged during the short pulse, Pmax is measured low. In the reverse direction, from Voc to Isc, Pmax is measured high. Anyway, accurate evaluation is not possible because of this IV curve distortion.

Fig.K-2 shows the test result of HIT ®, sweeping from Isc to Voc and from Voc to Isc, in 20ms respectively.

Because of the high capacitance, HIT ® and also IBC, does not respond to the voltage change. If the sweep time is 300ms, instead of 20ms, the distortion disappears, and the two curves in the both directions will overlap on the real I-V curve (black line).

During the long sweep time, however, the PV must be exposed to a stable light. That increases the temperature of the cell or module, and it's also a heavy burden to the light source. For instance, a 800ms exposure to 1 SUN will increase the temperature by 1 degree, and Voc and Pmax are both measured low.

Fig.K-3 shows HIT ® module measurement data. With 200ms to 300ms, there is not much difference, but with 100ms, Pmax error is as much as +/-1%. With a shorter light, deviation becomes asymmetry and bigger.

PV manufacturers are aiming higher efficiency, and that means PV has higher capacitance.

Using our new PDA technology (KOPEL Method), even high-capacitance cells or modules can be measured accurately and quickly.

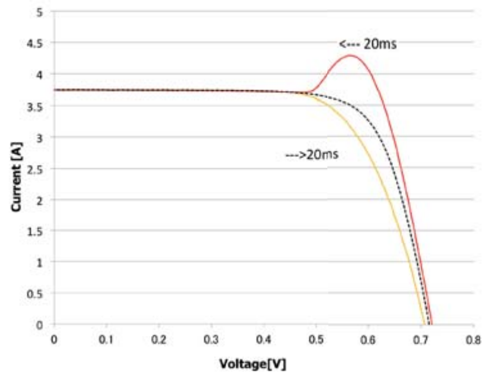


Fig. K-2 I-V Curves of High-efficiency Cell by Quick Sweeps

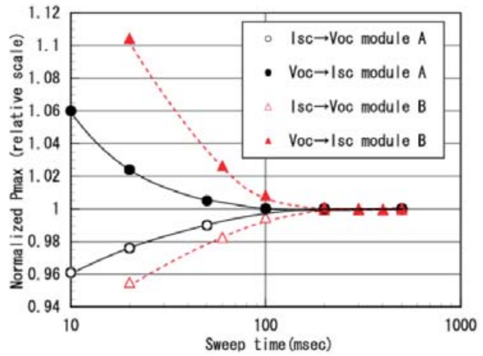


Fig. K-3 Effect of Sweep Time (HIT®)

KOPEL Method

KOPEL Method has realized the new PDA(Photo and Dark Analysis) technology and can measure high-capacitance cells and modules, fast and accurate.

Kyoshin Electric has developed a completely new measurement method in cooperation with AIST (National Institute of Advanced Industrial Science and Technology). The method is called PDA (Photo and Dark Analysis) technology. To realize the method, Kyoshin has developed a high-speed and accurate bipolar power supply, its control system, and software.
The system is called KOPEL Method. (International patent pending)

KOPEL Method – Theory

As shown in Fig.K-2 (refer to P3), high-capacitance PV does not respond to the quick voltage change. The delay is purely caused by electrical capacitance, and has nothing to do with photochemical properties of PV. That is the basic idea we started with KOPEL Method.

If PV responds in the same manner to the voltage sweep with of without light, it is possible to estimate the right I-V curve, from slow sweep data in the dark state, quick sweep data also in the dark state, and quick sweep data in the lighted (photo) state.

Fig.K-4 shows HIT ® cell measurement in photo and dark states. If there is correlation between them, we can use it to estimate the data we want.

Fig.K-5 is the graph that two sets of I-V curves, dark and photo, are overlapped. They are very different. That means we cannot get the right I-V curve using the similarity.

We have found, however, the reason why they are different. It's internal resistance that causes the difference. The currents of the photo and the dark states are very different. At 0V, the maximum current (Isc) flows in the photo state, and in the dark state, current does not flow at all. The voltage drop caused by the current must be removed from the measurement before comparing two sets of data.

Fig.K-6 (refer to P5) shows the measurement sequence of KOPEL Method. KOPEL Method measures the voltage and current in the dark state. And then measure the voltage and current in the photo state of 50ms. *Refer to "Dark State" below.

Fig.K-7 shows a diagram to show the process of KOPEL Method without removing the effect of the internal resistance. The red line above and the shaded blue line are the same voltage if the effect of the internal resistance is removed, and become a vertical single line. As the photo state and the dark state exhibit the same characteristics if the effect of the internal resistance is removed, the correct I-V curve can be measured. This is the theory of KOPEL Method.

Fig.K-8 shows a comparison data of HIT ® cell between AIST (1000ms long pulse) and KOPEL Method (KSX-3000H, 50ms). The difference is less than 0.2%. Also PV modules can be measured in the same manner (KSX-2015HM).

Patented (USA No.US 9,176,182 B2)

Patent Pending (Japan, Germany, Switzerland, China Taiwan, Korea)

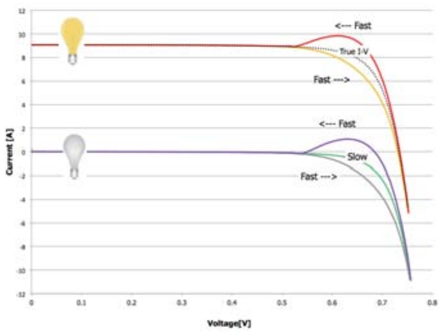


Fig. K-4 Photo and Dark I-V Curves

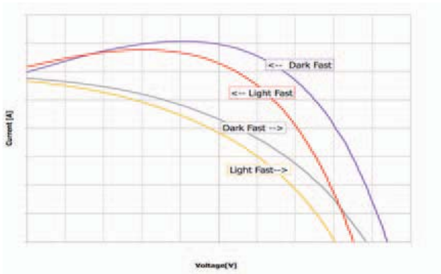


Fig. K-5 Two Sets of Curves Overlapped

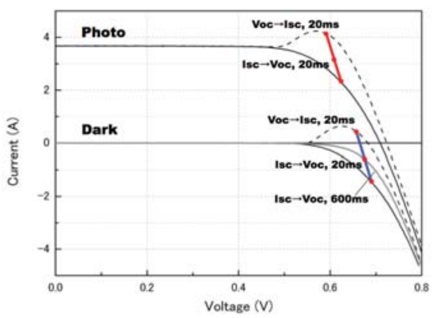


Fig.K-7 Compared with Dark and Photo

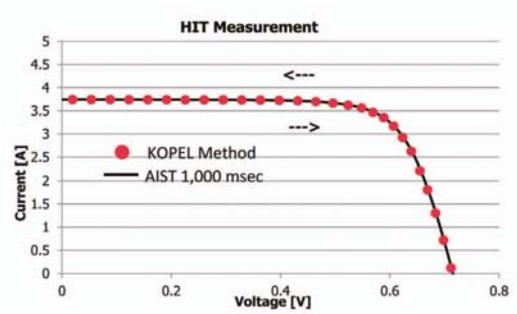


Fig. K-8 KOPEL Method Measurement Results

Dark State

The dark state measurement is done in a state extremely dark compared with 1 SUN. The indoor environment is normally less than 1000LUX, as 1 SUN=100,000LUX. PV cells and modules are normally measured in 100-1000LUX. It is very dark compared with 1 SUN, and darkroom is not necessary for the measurement. (According to our measurement, 1000LUX affects 0.1% to 1 SUN Isc measurement, 100LUX affects 0.075%, and the darkroom affects 0.04%.)

Measurement Time of High-Efficiency PV Cell

The actual measurement sequence needs Isc to Voc sweep (200-600ms) in the dark state,
which is almost same as the long pulse measurement, sweeps (20-50ms) in both directions in the dark state, and another sweeps (20-50ms) in the photo state. The total measurement time, including gaps between measurements and data calculation/transfer, is less than **1.0sec**.

In the production line, cell handling time must be added, which can be as short as 1.0-1.5sec per cell. Not only for accurate measurement in R&D usage, KOPEL Method is also usable in the PRODUCTION LINE because of its speed.

High-Efficiency PV Module Measurement (KOPEL Method NEW FUNCTION)

PV modules are normally measured using short pulse type solar simulators, but for high-efficiency modules have hysteresis for voltage sweeps, conventional Isc to Voc measurement exhibits undershoot in I-V curve, and Pmax is measured low. For that reason, long pulse type solar simulators have been used. As alternatives, two-time I-V measurement, averaging method, or various other methods have been proposed. As the module efficiency goes even higher (along with its capacitance), most of these methods cannot measure accurately.

KOPEL Method NEW FUNCTION can use existing short pulse solar simulator, and measure accurate I-V curve with two light exposures. Its actual measurement sequence is basically the same as cell measurement already explained. It separates Isc to Voc and Voc to Isc measurements in the photo state, and measures the modules during two separate short 10ms (or less) pulses. Therefore, any solar simulator that can create 10ms short pulses twice in a short interval can be used for high-efficiency PV module measurement with our I-V tester (KST-P80).

[Measurement Sequence For PRODUCTION LINE]

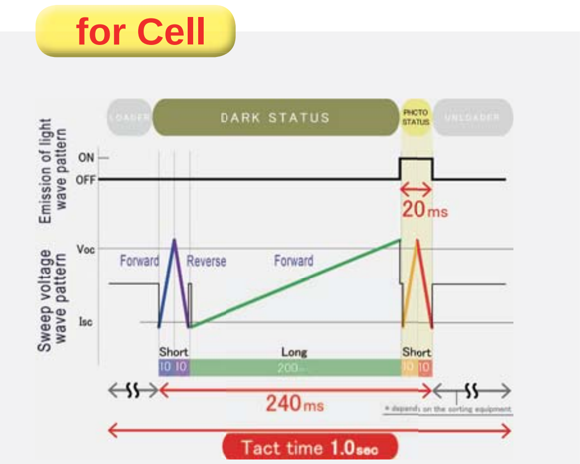


Fig. K-6 KOPEL Method Sequence for Cell

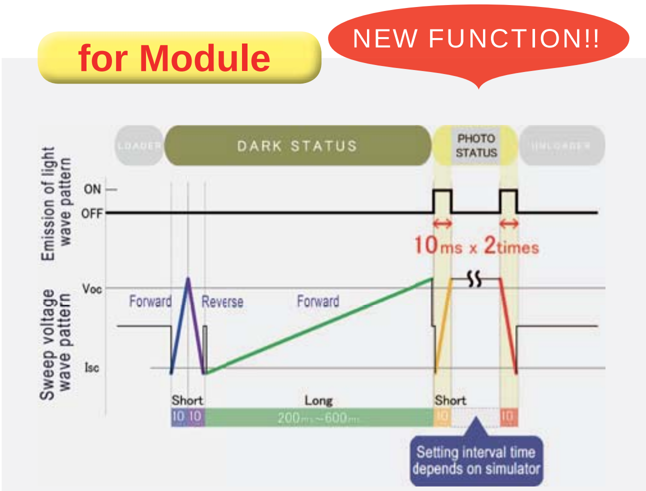


Fig. K-6-1 KOPEL Method Sequence for Module

[Submitted papers]

2014.6 : "Accurate and Rapid Measurement of High-Capacitance PV Cells and Modules Using a Single Short Pulse Light", to be published in the Proceedings of the 40th IEEE PVSC, Denver (2014)
2014.7 : GRE2014 O-PV-10-5 IV 20140810B (Tokyo, Japan)
2014.11 : 7TuPo 10 7 WCPEC-6 -Kyoto 2014 11 25

I-V Tester

KST Series

Can Work with Any Types of Solar Simulators
For Research, Quality Control, and Production Line
Replacement as well as New Installation

KST Series I-V testers have been developed for solar cell/module testing. They can measure electric characteristics such as I-V and P-V curves of solar cells and modules for R&D and production lines. The I-V testers can work with continuous, long pulse or short pulse solar simulators.

The I-V testers are designed for I-V characteristic measurement of solar cells and modules, and can measure electric characteristics as specified in JIS C8914（IEC 60891）standards.

The I-V testers can be used for common c-Si PV measurement as well as high-efficiency PV such as hetero-junction types, using a short (20ms—50ms) light, fast and accurate.

High-efficiency PV (hetero-junction) normally has high capacitance, and needed a longer light exposure for I-V measurement. The new I-V testers can install an innovative technology that KOPEL and AIST (National Institute of Advanced Industrial Science and Technology) have jointly developed. We call the technology as KOPEL Method.

Actual characteristic values (Isc, Voc, Pmax, - etc) of high-efficiency PV can be accurately and quickly measured using KOPEL Method.

KST Series are an all-in-one, compact design that consists of direct current power supply, electric load unit, high precision measurement unit, control unit, and communication unit.

The measurement software has graphical user interface. It can set measurement conditions, do measurement and display characteristic values of solar cells and modules, and also has dark current measurement capability and data collection function. It can create CSV text files to be used in excel, and the data can be stored in PC or transferred to an external equipment (such as host PC).

The newly developed high-speed I-V tester, KST-5Ce-LC can measure concentration type PV up to 1000 SUN, fast and accurate.

Features

- IEC 60904-1 / JIS C 8913 Compliant
- All-in-one compact design
- Proprietary Software that comes as standard with the I-V tester.
- High-speed sampling with better than +/-0.2% FS accuracy.
- High-speed sweep at 20us/point up to 1024 points.
  Sweep direction selectable by the setting, from Isc to Voc or Voc to Isc.
- Dark current measurement
- KOPEL Method (PDA: Photo and Dark Analysis) function can be installed.
  High-speed I-V measurement of high-efficiency PV cell/module using 50ms light or less.
  Can be used with existing pulse type solar simulators = Please contact us about the requirements of the light conditions.
- Can be used with common continuous or pulse type solar simulators.
- For R&D, quality control, and mass-production.
- Classification function for mass-production is equipped as standard.
  Up to 16 ranks. Above 16 ranks is available as an option.
- Can work with concentration PV solar simulator – KST-5Ce-LC
  50 point measurement in 1ms

New functions for module measurement

- Work with any kind of solar simulator: long pulse, middle pulse, or short pulse.
  Optical trigger, optical fluctuation feedback, manual measurement.
  = No electrical connection necessary with the solar simulator to do the measurement.
  High-efficiency PV can be measured simply by replacing with the existing IV tester.
- One 20ms pulse is enough to measure high-efficiency PV modules precisely with KOPEL Method, not affected by hysteresis or capacitance.
- High-speed measurement (20us/point, maximum 1024 points)
- KOPEL Method can make precise measurement with 2 x 10ms pulse / 2 sweep measurement.

Please ask us for necessary light conditions {NEW FUNCTION} (Patent Pending) ⇒ REFER to P5

KST-C Series

I-V Tester for Cell -Specifications-

Cell I-V Testers		
Product Model	KST-P15HC2	KST-5Ce-LC2
Software	KSW-001	KSW-01LC
Target Cell	c-Si type, Heterojunction type, Multijunction type Cells	Concentrated Solar Power (CSP)
Corresponding Solar Simulator	Continuous Type, Long pulse, Middle pulse, Short pulse	Continuous Type
Standards	IEC60904-1,JIS C8913 Compliant	-
Sweep Bias Voltage	±3V	±10V
Sweep Direction	**Isc to Voc , Voc to Isc , Both direction is able to sweep sequentially.**	
Measurement Voltage	±3V	±10V
Measurement Current	±15A	-2A～+5A
Current Ranges	15A , 1.5A , 0.15A , 0.015A	5A , 0.5A , 0.05A , 0.005A
Sampling Points	32～512 Points（Both directions） 32～1024 Points（One direction）	
Measurement Speed	20us～100ms/Points	
Measurement Accuracy	0.2%FS	
Measurement Items	**I-V Curve, P-V Curve（Light/Dark）, Max. Power (Pmax), Open-circuit Voltage (Voc), Short-circuit Current (Isc), Fill Factor (FF), Efficiency (η), Voltage at Max. Power (Vpm), Current at Max. Power (Ipm), Series Resistance (Rs), Shunt Resistance (Rsh)**	
Temperature Sensors	Selectable: Thermo couple, IR, Pt-100 *without sensors	
Input Voltage	Single-phase 100V～240V、50/60Hz、200VA	
Dimensions	W430 x D430 x H225 mm	
Weight	16 kg (36 lb)	
Measurement Resolution	**18bit (Super High Speed)**	
OS	Windows 7 , 8.1 (32/64-bit)	
Data Output	LAN	
Data Format	CSV	
Options	Monitor Cell	

KST-M Series

I-V Tester for Module -Specifications-

Module I-V Testers			
Product Model	KST-P80MO	KST-P250MC	KST-P250MO
Software	KSW-01M	KSW-03M	KSW-02M
Target Module	c-Si type, Heterojunction type, Multijunction type Modules	c-Si type,Heterojunction type, Multijunction type, **Thin Film type Modules**	**Thin Film Modules**
Corresponding Solar Simulator	Continuous Type, Long pulse, Middle pulse, Short pulse		
Standards	IEC60891,JIS C8914 Compliant		
Sweep Bias Voltage	±8V/±80V	±8V/±80V -10～+250V	-10～+250V
Sweep Direction	**Isc to Voc , Voc to Isc , Both direction is able to sweep sequentially.**		
Measurement Voltage	±8V/±80V	±8V/±80V -10～+250V	-10～+250V
Measurement Current	±15A	-15A～+15A (@±8V/±80V) ±1A (for short period ±3A) (@±250V)	±1A (for short period ±3A)
Current Ranges	15A , 1.5A , 0.15A , 0.015A	15A,1.5A,0.15A,0.015A (@±8V/±80V) 3A , 0.3A , 0.03A (@±250V)	3A , 0.3A , 0.03A
Sampling Points	32～512 Points（Both directions） 32～1024 Points（One direction）		
Measurement Speed	20us～1s/Point		
Measurement Accuracy	±0.2%FS		
Measurement Items	**I-V Curve, P-V Curve（Light/Dark）, Max. Power (Pmax), Open-circuit Voltage (Voc), Short-circuit Current (Isc), Fill Factor (FF), Efficiency (η), Voltage at Max. Power (Vpm), Current at Max. Power (Ipm), Series Resistance (Rs), Shunt Resistance (Rsh)**		
Input Voltage	Single-phase 200V, 50/60Hz, Max1700VA		Single-phase 200V, 50/60Hz, Max1400VA
Dimensions	W570 x D630 x H1078 mm	* Twin rack systems W570 x D630 x H1078 mm x 2pieces	W570 x D630 x H1078 mm
Weight	150 kg (330 lb)	300 kg (660 lb)	150 kg (330 lb)
Measurement Resolution	**18bit (Super High Speed)**		
OS	Windows 7 , 8.1 (32/64-bit)		
Data Output	LAN		
Data Format	CSV		
Options	Monitor Cell		

Solar Module Test System

KSX-2014HM

High-efficiency solar module Test System

The system can measure high-efficiency (high-capacitance) solar modules such as HIT® or IBC accurately using a 50ms or shorter pulse. KSX-2014HM consists of an accurate I-V tester and a stable light source, is an advanced PV test system for high efficiency modules.

The innovative KOPEL Method has made the accurate measurement possible using a short pulse light. The deviation from the data using a 1000ms sweep under the continuous light is only 0.2 to 0.3%. The continuous or a long pulse (>100 ms) system is huge and needs a long distance (about 10m) from the light source to the module to be tested, and needs a wide space(darkroom) .
By using KOPEL Method, the system can use upward lighting, needs a small space, and a perfect system for in-line use, because it does not require reversing the modules.

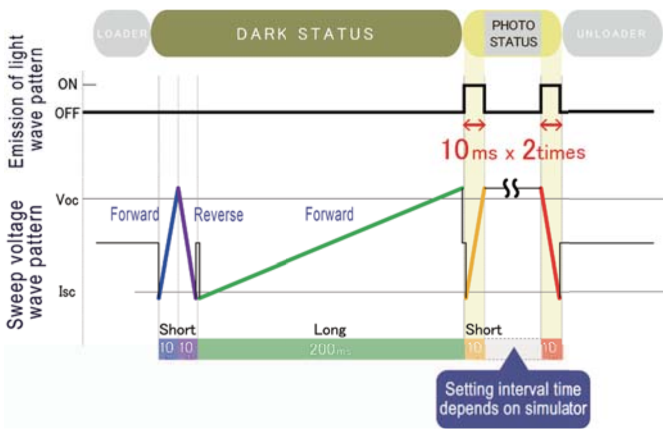
Accurate and Stable Test Results

High-efficiency (high-capacitance) solar modules can be accurately measured by a 50ms pulse
Stable test results by innovative KOPEL Method
Spectral match: +/- 20% from AM-1.5G
Class AAA, JIS C8912, C8933, IEC/EN.60904-9, ASTM-E927 compliant
Non-uniformity: +/-2% using a single lamp and original adjustment technology
Very small spectral non-uniformity using patented AM filter.
Upward lighting structure – no need to reverse the module, perfect for in-line use.
No darkroom needed.
Easy to replace the single lamp, and no optical adjustment after the replacement.
A very short downtime for the lamp replacement
No specialist dispatch for the replacement and adjustment (no engineer dispatch fee)

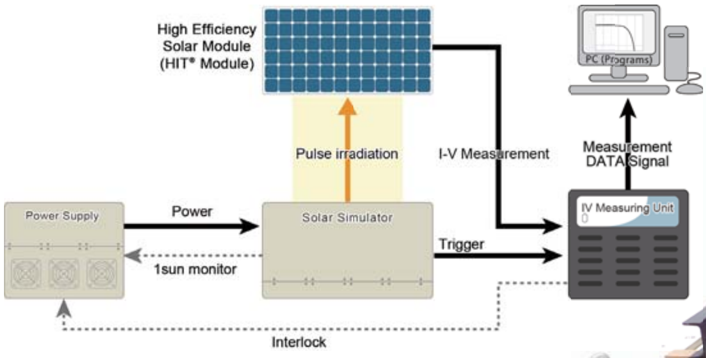
High-speed operation with15 second charge time

Any solar simulator can be used for high-efficiency PV module measurement with our KOPEL Method.

KOPEL Method NEW FUNCTION can use existing short pulse solar simulator, and measure accurate I-V curve with two light exposures. Its actual measurement sequence is basically the same as cell measurement already explained. It separates Isc to Voc and Voc to Isc measurements in the photo state, and measures the modules during two separate short 10ms (or less) pulses. Therefore, any solar simulator that can create 10ms short pulses twice in a short interval can be used for high-efficiency PV module measurement with our I-V tester (KST-P80).



System Configuration



Specifications

(1) KSX-2012HM Pulse Type Solar Simulator - Light Source

Items	Specifications
Effective Irradiated Area	2000 mm×1200 mm (Maximum: 2000m×1500 mm)
Performance	**Class** AAA **(JIS C8912,C8933,IEC60904-9)**
Irradiance	200～1000W/㎡ (0.2～1SUN) variable
Spectral Distribution	AM1.5G
Spectral Match	Within ±20% (JIS C8912, C8933, IEC60904-9) **ClassA** ※Measured at 9 points in the effective irradiated area.
Irradiation Non-uniformity	Within ±2% **ClassA** ※Measured at the full irradiated area using 6-inch cell.
Temporal Instability	Within ±1% **ClassA**
Spectral Non-uniformity	Within ±3%
Pulse Width	Effective 60ms (Extendable up to 100ms: Custom Order)
Lamp	Straight-tube Xenon Flash Lamp 1 unit
Lamp Life	1M pulses (average), 500k pulsed (guaranteed)
Cooling	Forced Air Cooling
Dimensions	Approx. W2600 x D1800～2200 x H1000 mm (1900 mm×1200 mm effective area system)
Weight	Approx. 1250 kg (2,800 lb)

(2) KSX-2012HM Pulse Type Solar Simulator - Power Supply

Items	Specifications
Pulse Interval	Min. 15 seconds
Manual Operation	Power ON/OFF, Output Adjustment, Manual Emission Test
Safety Devices	Power Input Breaker, Panel Cover Interlock, Overheat Protection
Connection	Power Input, Output to Power Supply, Trigger Signal Input from Measuring Unit, Trigger Signal Output to Power Supply
Input Power	3-phase 200V、50/60Hz、9kVA
Dimensions	1200 x 1000 x 1500 mm
Weight	Approx. 1000 kg (2,200 lb)

(3) KST-P80MO I-V Tester (Refer to P11 " I-V Tester" for details.)

(4) KSW-01F Measurement Software (Refer to P11 "I-V Tester" for details)

(5) Other Components

Items	Specifications
Module Guide Rails	Manual or Automatic
Module Temp. Measurement System	Up to 6 measurement locations
Auto Irradiance Measurement System	Comes with the software that can measure non-uniformity of the effective area for calibration.

KOPEL Tokyo Technical Center

Solar Cell/ Module "Free" Testing Services using New and High-performance Test Systems

Kyoshin Electric (KOPEL) is offering free testing services at our Tokyo Technical Center (Sagamihara Incubation Center, Kanagawa, Japan) to introduce our new I-V measurement systems. Bring your own samples, and you can touch and feel the speed and accuracy of our systems by doing the actual measurements by our staff or even by yourself. (Appointment required).

Tokyo Technical Center has the following systems for the free testing:

1. Pulse Solar Simulator (Cell) + KOPEL Method I-V Tester

Cell Size : 156mm x 156mm（Effective Irradiated Area: 200 x 200 mm）

Target Cells : c-Si and High-efficiency cells (HIT, IBC, and others)

Pulse Width : Max. 50ms

Sample Plate, Tem. Control Chiller, Vacuum Pump

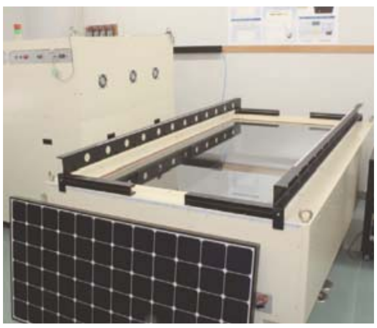
2. Continuous Solar Simulator (Cell) + I-V Tester

Cell Size : 156mm x 156mm

Target Cells : c-Si and any kind of cells (HIT, IBC, CIGS, and others)

Light Source : Xenon Lamp 1kW

Sample Plate, Tem. Control Chiller, Vacuum Pump



3. Pulse Solar Simulator (Module) + KOPEL Method I-V Tester

Module Size : 1900mm x 1200mm

Target Modules : c-Si and High-efficiency cells (HIT, IBC, and others)

Pulse Width : Max. 100ms