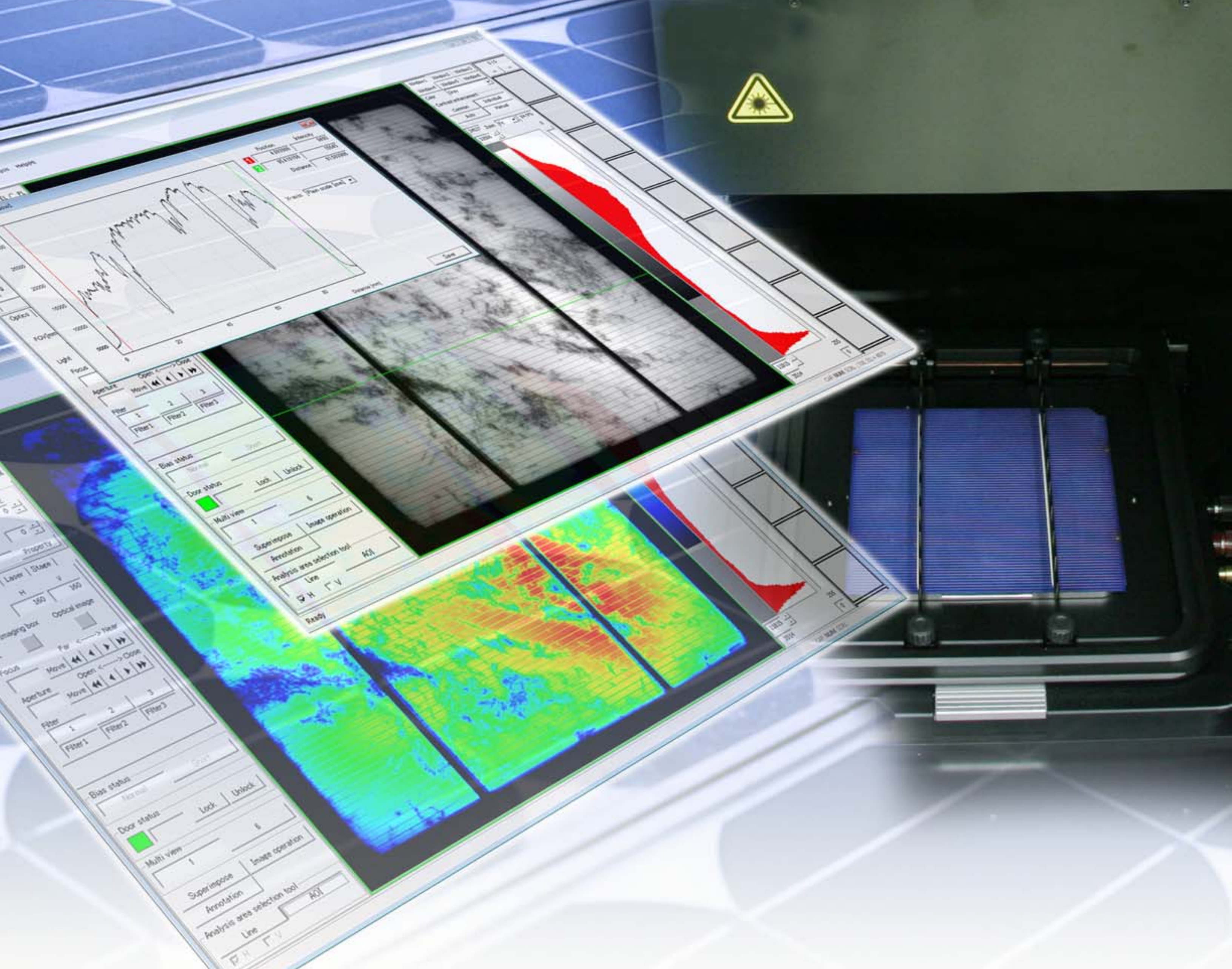
Product line for solar device evaluation

A measurement system lineup ideal for the evaluation and the analysis of solar devices! Hamamatsu's advanced detection technology provides solutions to various needs of the solar power industry.



HAMAMATSU

PHOTON IS OUR BUSINESS

Various EL/PL imaging-based analysis methods

EL and PL imaging from wafer to module

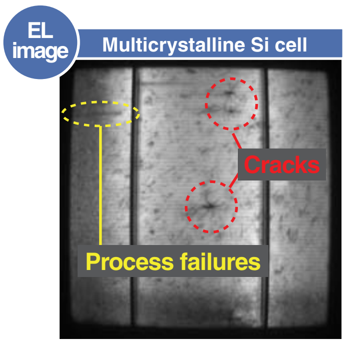
PV Imaging System EPLi

Si a-Si CIGS Organic

The EPLi is an EL/PL imaging system for PV, which evaluates the intensity and distribution of EL (electroluminescence) and PL (photoluminescence) images by using various high-sensitivity cameras and measurement software.

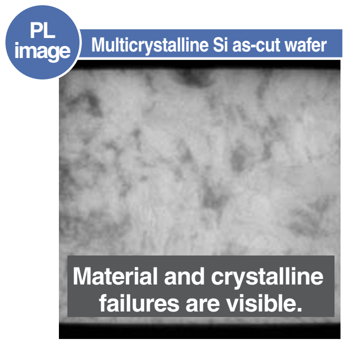
EL method

- **Process failure**
- **Grid/finger failure**
- **Cracks**



PL method

- **Material /crystalline failure**
- **Obstacles**
- **Thin-film defect**



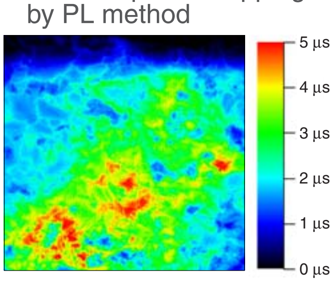
Development

Si carrier lifetime mapping

Si

Carrier lifetime mapping can be calculated from a PL image. As compared with the conventional technique (μPCD method), it's much faster and delivers high-resolution measurements.

■ An example of mapping by PL method



	Carrier lifetime mapping	Conventional method (μPSD)	
Resolution (pixels)	512 × 512	39 × 39	156 × 156
Measurement time	Approx. 2 seconds	Approx. 40 minutes	Approx. 11 hours

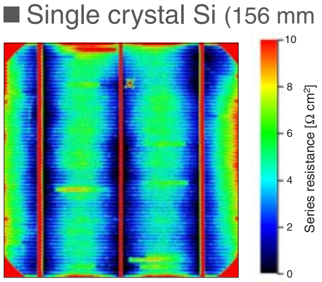
Development

Series resistance (Rs) mapping

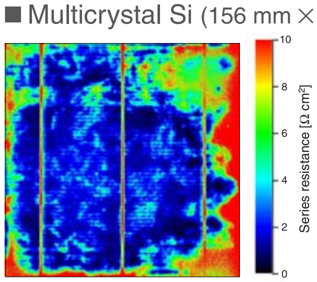
Si a-Si CIGS Organic

Series resistance mapping can be calculated from an EL/PL image. A high-resistivity area inducing decay in the fill factor can be detected with ease.

■ Single crystal Si (156 mm × 156 mm)



■ Multicrystal Si (156 mm × 156 mm)

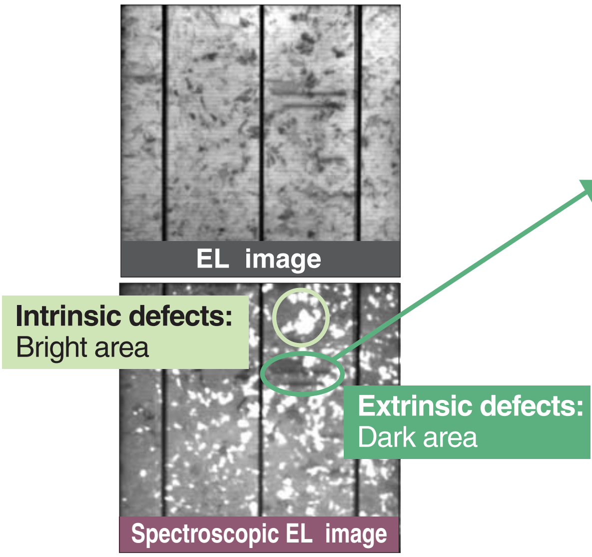


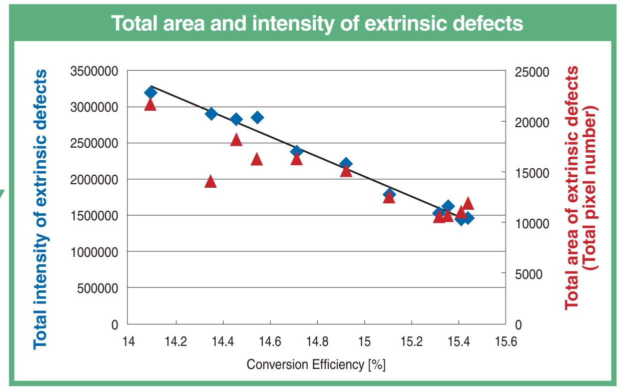
Development

Spectroscopic EL method / Correlation between defects and conversion efficiency

Si

The intrinsic deficiencies like lattice defects and the extrinsic deficiencies like cracks can be distinguished clearly at a glance.



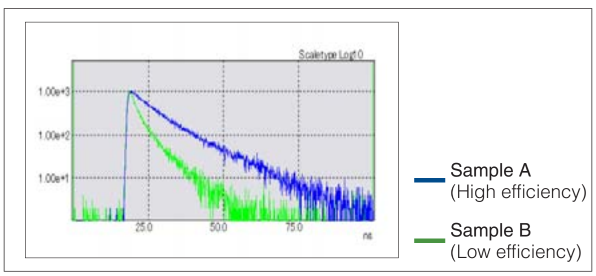


This method can extract extrinsic deficiencies that correlate to conversion efficiency as shown in the graph above.

CIGS PL lifetime measurement

CIGS

- **Multipoint measurement with motorized stage**



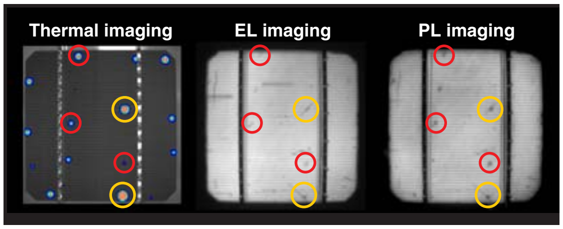
▲ PL lifetime of CIGS test piece

Measuring PL lifetime related to conversion efficiency

Thermal imaging analysis

Si a-Si CIGS Organic

- **Localization of wiring fault, shunts, abnormal resistance**
- **Corresponds to macroimaging (for cell and panel) and microimaging**



○ Si material defects depend on crystal growth condition and quality

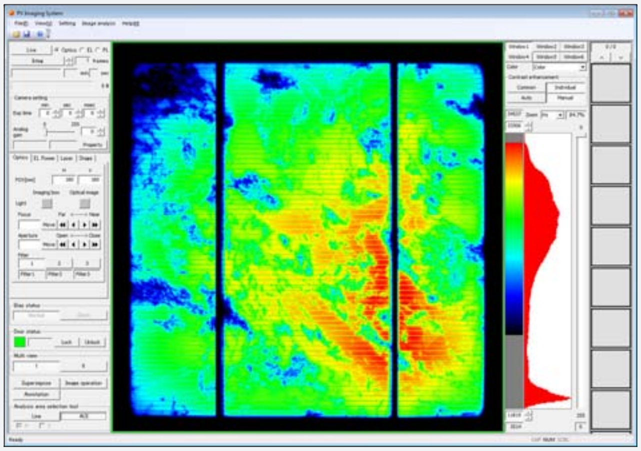
○ Physical defects like a crack

Hot spots correspond to shunt points on the EL/PL image

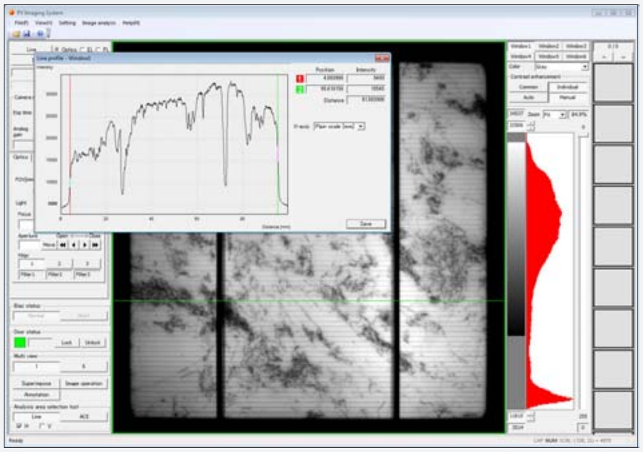
In the case of a good cell,
thermal image reflects contact status of PN junction

Software, cameras, options

Measurement software



▲ Imaging window



▲ Analysis window

- **EL/PL intensity distribution image**
- **EL/PL image operation (four arithmetic operations)**
- **Measurement protocol management**
- **Analysis functions (intensity profile, histogram, calculation, etc.)**

Specifications

			EM-CCD camera	Cooled InGaAs camera
Imaging station	Wavelength range		400 nm to 1100 nm	900 nm to 1550 nm
	Pixel number		1024 (H) × 1024 (V)	640 (H) × 512 (V)
	Field of view	EL imaging	50 mm × 50 mm to 200 mm × 200 mm	50 mm × 63 mm to 210 mm × 168 mm
		PL imaging	170 mm × 170 mm to 200 mm × 200 mm	210 mm × 168 mm
System control	Power supply for EL detection		0 V to 20 V / 0 A to 18 A*	
	Detector control		Exposure time, focus, filter, etc.	
	Power supply control		Bias control for EL measurement	
	Switching forward/reverse bias		Capable of control	
	Excitation light source		Excitation light source control for PL measurement (The number of light sources: 2 max.)	
	PL measurement		Enables open/short PL imaging	
	Laser class		Class 1 (as system: laser safety circuit integrated)	

*Please consult us about other model of power supply options.

▲ EM-CCD camera

▲ Cooled InGaAs camera

Options

Probing unit (For crystalline Si cell)	Cell size*	125 mm × 125 mm, 156 mm × 156 mm
	Probing bar	3 busbars max. (position adjustable)
Sample stage for temperature control	Temperature range	+15 °C to +100 °C
Marking function	Method	Ink method (manual operation)

* Please consult us about other cell sizes that the probing unit can accommodate.

▲ Probing unit

PV photoemission and PV thermal analysis

Localize leakage points by photoemission analysis

PV Emission Microscope System

Si | a-Si | CIGS | Organic

Capture electroluminescence and leak emissions caused by defects in solar cells using a cooled CCD camera (Si-CCD camera and cooled InGaAs camera are optional.), and localize the precise failure point by superimposing a microscope image onto the emission image.

- Si-CCD camera: It is more sensitive than standard cooled-CCD cameras to detect low-light emission in a short time.
- Cooled InGaAs camera (Peltier-cooling type): It is the best camera for analyzing compound solar cells with emission wavelength longer than 1100 nm.

*The product in above image is designed for 450 mm × 450 mm sample size. The system size can be customized depending on sample size and stage size.

Features

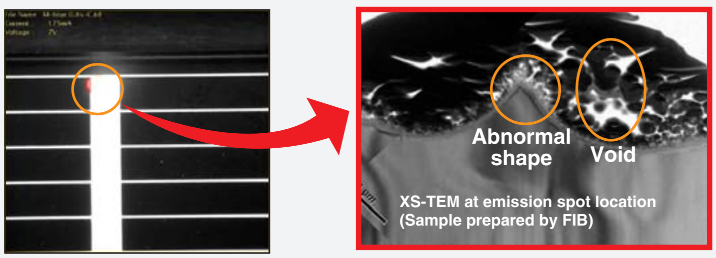
- **Crack/physical defect detection**
- **Leak and wiring fault detection**

Lens specifications

Lens	Field of view (mm)
Micro lens 0.8×	16.64 × 16.64
M plan NIR 5×	2.6 × 2.6
M plan NIR 20×	0.65 × 0.65
M plan NIR 50×	0.26 × 0.26
M plan NIR 100× Option	0.13 × 0.13

Detection of junction leakage emissions from multicrystalline Si solar cells (with reverse bias)

Leak position near wiring is detected by finding leakage emission at high magnification.



Localize shorts by temperature characteristic analysis

PV Thermal Imaging System

Si | a-Si | CIGS | Organic

Use a high-sensitivity infrared detector (InSb) to analyze temperature characteristics of solar cells/modules and localize failure points indicating abnormal temperature. The thermal lock-in function is valuable to reduce ambient noise so that even small temperature variations can be detected.

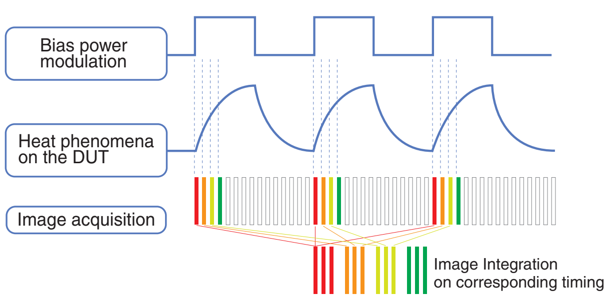
▲ For cell observation ▲ With microscope

*The product in above image is designed for 290 mm × 250 mm sample size. The system size can be customized depending on sample size and stage size.

Features

- **Pinpoints wiring short, shunts and dislocation failure points**
- **Measurement of temperature distribution on solar cells**

Principle of thermal lock-in



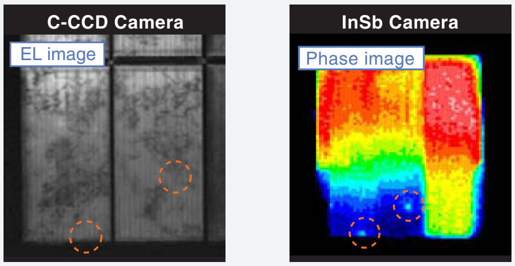
Lock-in measurements are performed while modulated bias voltage is applied to the device under test (DUT).
By detecting the signals only in that modulation frequency, a high S/N measurement is obtained while eliminating noise components.

Detector specifications

Detector	InSb
Spectral response range	3.7 µm to 5.2 µm
Effective number of pixels	320 × 240
Cooling method	Stirling cycle cooling
Noise equivalent temperature difference (NETD)	< 25 mK (30 °C [typ.] /hour)

Detection example of defect positions by thermal emission

Detects thermal defect points that cannot be detected by EL imaging technique.



Spectral photometry systems for solar devices and materials

Chemical compound thin-film evaluation

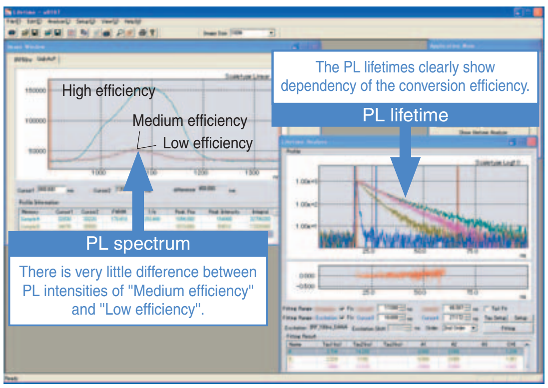
Compact Near Infrared Fluorescence Lifetime Measurement System

CIGS Organic

Features

- **Wavelength: 650 nm to 1400 nm**
- **Enable the measurement of multiple points and of integrating a microscope** (Option)

Compact Near Infrared Fluorescence Lifetime Measurement System C12132



▲ Fluorescence spectrum and PL lifetime measurement data of CIGS thin film.

Specifications

Type number		C12132
Excitation light (YAG Laser)	Excitation light wavelength	532 nm
	Output	Approx. 30 mW (532 nm)
	Pulse width	< 1.3 ns
	Repetition rate	Approx. 15 kHz
Detectors (PMT)	Measurement wavelength range	650 nm to 1400 nm
Measurement time range		2.5 ns to 50 µs / full scale
Measurement lifetime		Approx. 200 ps to 5 µs
Time axis channel		512 ch, 1024 ch, 2048 ch, 4096 ch
Total time resolution		< 1.5 ns (Full width at half maximum)
Analysis function		Windows 7 or more

Thickness measurement of thin-films in solar cells

Optical NanoGauge Series

Si a-Si CIGS Organic

Features

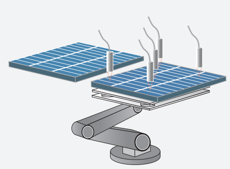
- **Thickness measurement of semiconductor films for thin-film solar cells, as well as thickness of organic films**
- **Real-time measurement and non-destructive measurement of thin films**

Optical NanoGauge C11627

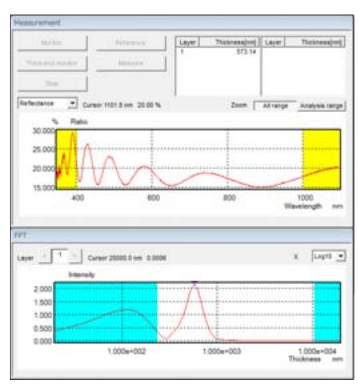
For multipoint measurement

Multipoint Nanogauge C11295

Real-time multipoint measurement allows simultaneous measurements in multiple chambers and multipoint measurements on the thin film surface.



Real-time simultaneous measurements of sample thickness to maximum of 15 points

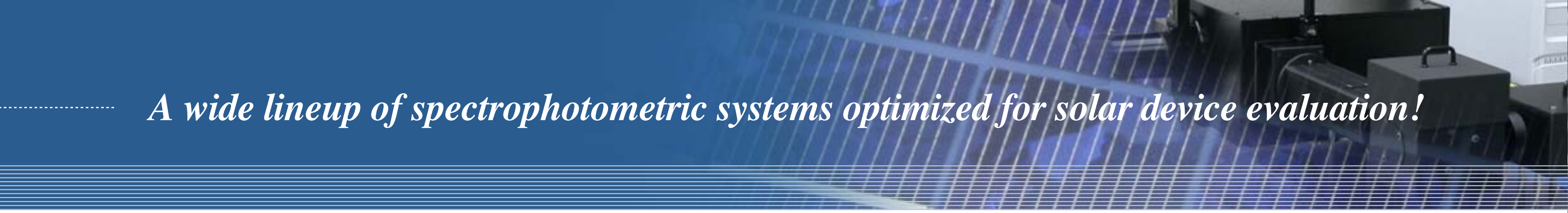


▲ Film thickness measurement of TiO_2 based transparent conductive film
Data courtesy of Prof. Takahiro Wada, Ryukoku University

Specifications

Type number	C11627	C11295
Measurement film thickness range*	20 nm to 50 µm	20 nm to 100 µm
Measurement accuracy**	± 0.4 %	
Reproducibility***	0.02 nm	

*In terms of SiO_2
**VLSI Standards-compliant
***Standard deviation when a 400 nm thick SiO_2 film is measured.



Absolute quantum yield measurement of organic solar cell materials

Absolute PL Quantum Yield Measurement System

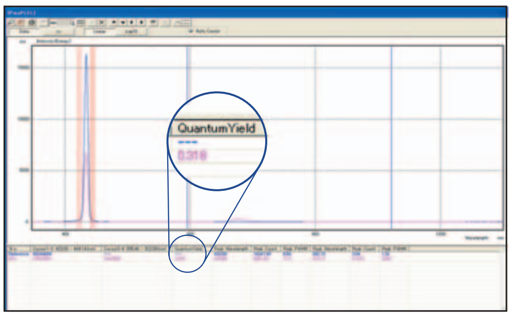
Organic

Features

- **Excitation wavelength dependency on quantum yield**
- **PL excitation spectrum**
- **Simple and intuitive handling**
- **Compact unit and quick measurement (Quantaurus-QY)**

Absolute PL Quantum Yield Measurement System C9920-02G, -03G

Absolute PL Quantum Yield Spectrometer Quantaurus-QY



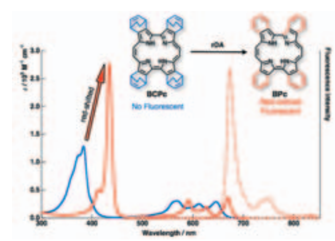
This figure shows fluorescence quantum yields for benzoporphycenes, which are promising materials for organic solar cells. Benzoporphycenes synthesized by the retro-Diels-Alder reactions show strong fluorescence, while the precursors are nonfluorescent.

Specifications

Type number	C9920-02	C9920-02G	C9920-03	C9920-03G
PL measurement wavelength range	300 nm to 950 nm		400 nm to 1100 nm	
Excitation wavelength	250 nm to 800 nm	250 nm to 950 nm	375 nm to 800 nm	375 nm to 1100 nm
Bandwidth	FWHM 10 nm or less	2 nm to 5 nm	FWHM 10 nm or less	2 nm to 5 nm
Excitation spot size	ϕ8 mm			
Sample holder	Thin film (16 mm × 10 mm × 1 mm, quartz substrate)			
	Solution (12.5 mm × 12.5 mm × 140 mm cuvette: option)			
	Powder (ϕ17 mm Petri dish: option)			
Connector tube diameter for nitrogen gas flow	Outer diameter 4 mm, inner diameter 2.5 mm (in integrating sphere)			

Benzoporphycenes (BPc) are constitutional isomers of benzoporphyrins.
They are promising materials for PDT, PVC applications, and so on. BPcs are prepared from their soluble precursors by retro-Diels-Alder reaction in solution or as a film. The fluorescence quantum yields drastically changed from 0 % to 40 % by the conversion from precursors to BPcs. They are also promising latent fluorescent materials.

D. Kuzuhara *et al. Chem. Eur. J.*, **15**,10060 (2009)



Data courtesy of NARA INSTITUTE of SCIENCE and TECHNOLOGY, Dr. H. Yamada

Peak wavelengths measurement EL, PL spectrum

Photonic Multichannel Analyzer

PMA-12 Series

Si a-Si CIGS Organic

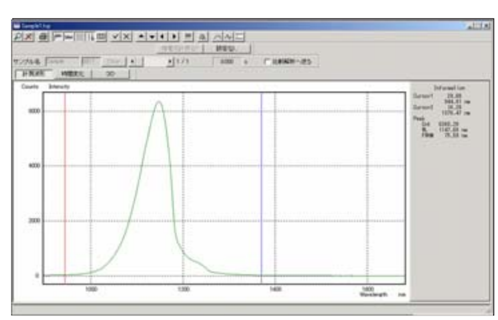
Photonic Multichannel Analyzer PMA-12

Features

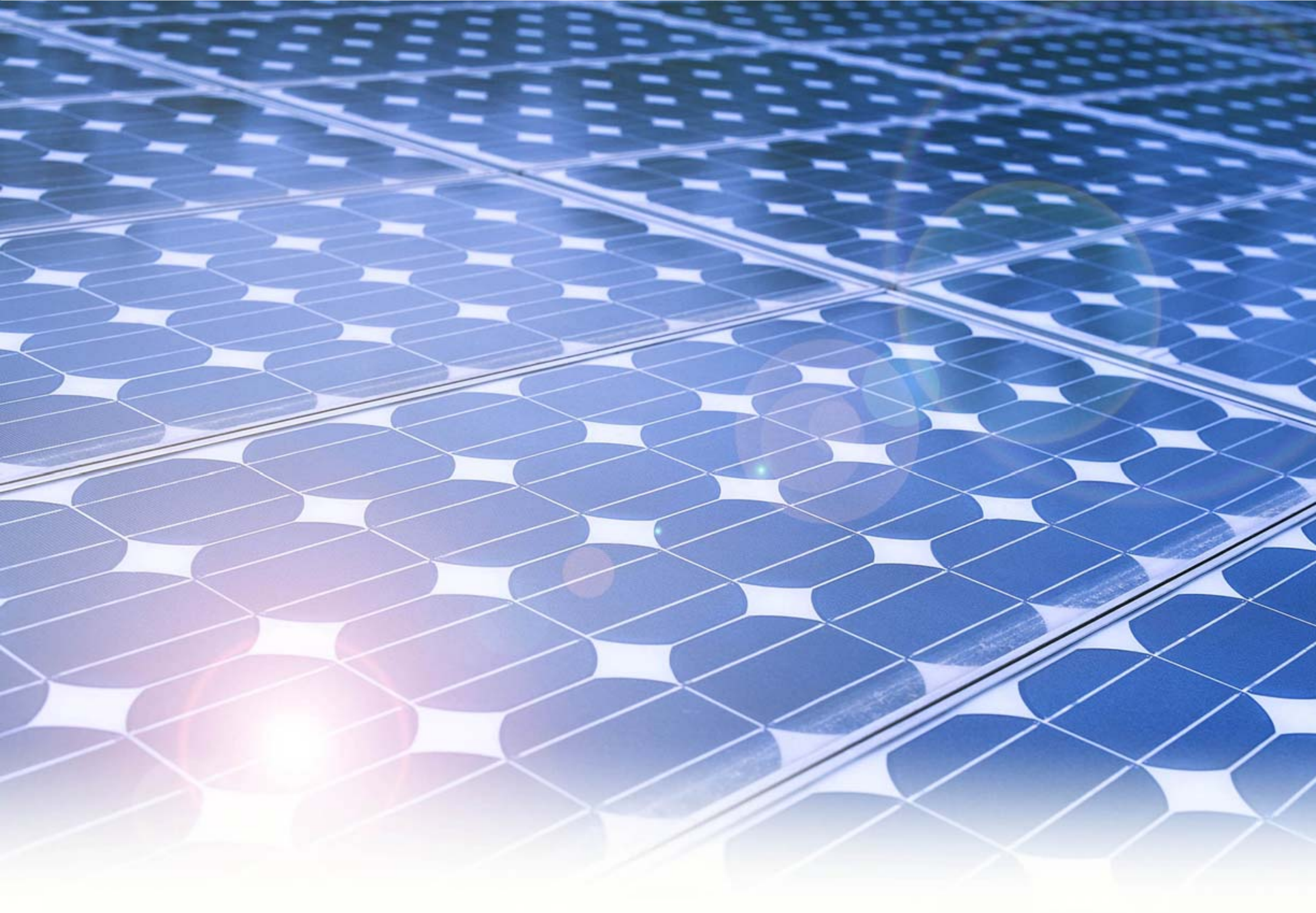
- **Reflectance and transmittance of amorphous silicon**
- **Real-time measurement of PL spectrum of solar devices**

Specifications

Type number	C10027-01	C10027-02	C10028-01	C10028-02
Photodetector	Back-thinned CCD linear image sensor		InGaAs linear image sensor	
Measurement wavelength range (nm)	200 nm to 950 nm	350 nm to 1100 nm	900 nm to1650 nm	1600 nm to 2350 nm
Spectral resolution (FWHM)	< 2 nm	< 2.5 nm	< 9 nm	
Exposure time	19 ms to 64 s		5 ms to 64 s	5 ms to 50 ms
Number of sensor channels	1024 ch		256 ch	



▲ EL spectrum data of multicrystalline Si solar cell



LASER SAFETY

Hamamatsu Photonics classifies laser diodes, and provides appropriate safety measures and labels according to the classification as required for manufacturers according to IEC 60825-1. When using this product, follow all safety measures according to the IEC.

CLASS Ⅰ LASER PRODUCT

Description Label (Sample)

Caution Label

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