1 IPCE (Incident photon-to-current efficiency) measurement apparatus (PEC-S20)

Summary

- PEC-S20 is equipment for measuring action spectra or incident photon-to-current efficiency of solar cells, especially for dye-sensitized solar cells with an active area of less than 1 cm^2.
- All-in-one type main body needs only a very setting area (D 60 cm and W 80 cm), which means that it is possible to be set on a usual laboratory desk.
- PEC-S20 has a 150-W Xe lamp as a light source. Monochromatic lights from a monochromator are irradiated to a sample through an optical fiber with an irradiation area of 3 mm in diameter.
- The irradiance at 480 nm is higher than 2 mW. This comparably high irradiance is suitable for measuring IPCE spectra of dye-sensitized solar cells.
- The software, PEC-Pro, can show a corrected spectrum on real-time when measuring. The photocurrent density of solar cells under the standard solar spectrum (AM1.5G – 100 mW cm^{-2}) is automatically calculated from IPCE spectra and showed.

Components & Specific

Main unit

Dimension : W355 x D408 x H441 mm
Measurement mode : DC mode (default)
Certifiable wavelength range : 400 nm - 800 nm (default)
Available wavelength range : 300 nm - 1000 nm
Intensity of monochromatic light : ca. 2 mW at 480 nm (default)
Wavelength purity : ca. 30 nm (default)
Light source : 150 W Xe lamp (ozone less type)
Monochromator
Optics system : modified asymmetric Czerny-Turner design
Focal length : 100 mm Focal ratio : F=3.0
Diffraction grating : 600 lines/mm, Blaze Wavelength 500nm (default)
Incident slit : W2×H3.5 mm, fixed slit
Interface : USB

Optical fiber

Optical fiber : bundled fiber (SUS) Fiber length : 1 m
Exit diameter : ID 3 mm, ED 5 mm Folder : detachable folder

Sample chamber

Dimension : W300×H218×D200 mm
IV amp : selectable (x1, x10, x100, x1k) Output voltage : 10 V

Calibrated reference photodiode

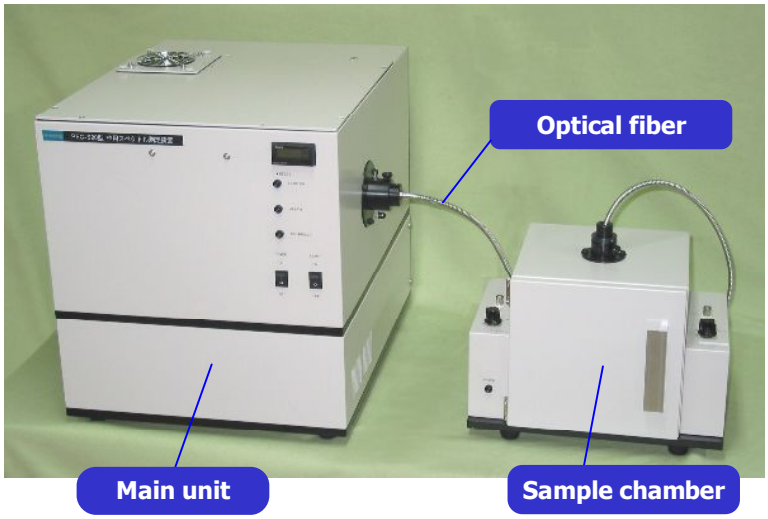
Si photodiode : S1337-1010BQ (with calibrated spectral sensitivity data)

Software for operation and analysis

Software : PEC-PRO
Wavelength control : step scanning Filter control : auto
Data analyzing : conversion to spectral sensitivity, quantum efficiency and Jsc, spectral calculation

- AC mode measurement is optionally available
- PC with Windows XP and USB port is optionally needed

Appearance



■Needed setting space is depth 60 cm and width 80 cm.
■PC with Windows XP and USB port is optionally needed

Measurement Example

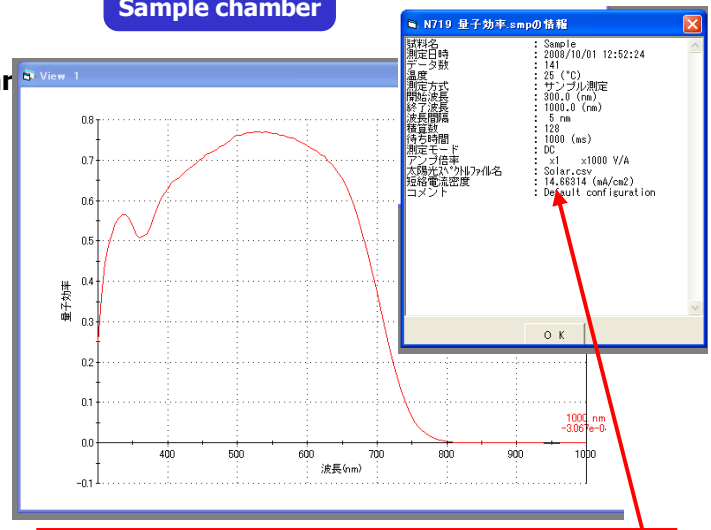
Measurement and Analyzing softwar「PEC-Pro」

■ **Reference Measurement Mode**
This mode measures data of a reference Si cell. From the measured data and the IPCE spectrum stored in your computer, the software calculates the irradiance at each wavelength.

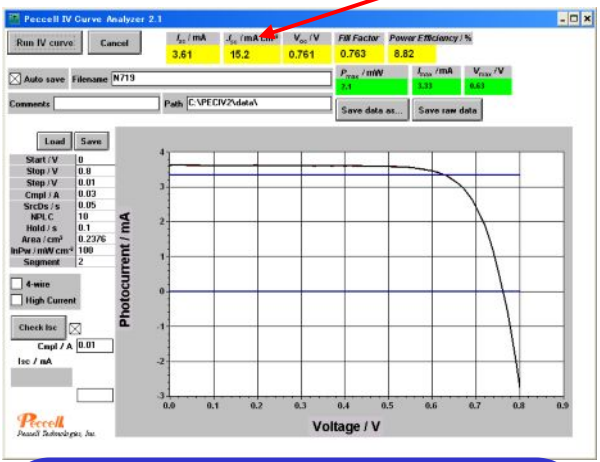
■ **Sample Measurement Mode**
This mode measures data of samples, and corrected spectra are showed in real-time on measuring.

■ **Automatic calculation of photocurrent density**
The photocurrent density of solar cells under the standard solar spectrum (AM1.5G – 100 mW cm^{-2}) is automatically calculated from IPCE spectra and showed.

■ **Save and load data**
Measurement data are easily converted to files in text format, which is loaded by Microsoft Excel and etc. In addition, PEC-Pro software can load text files and process the data.



Each photocurrent density measured by an I-V curve (below) and an IPCE spectrum (top) is compared for discussion.



Example of measurement of a dye-sensitized solar cell using N719 dye.
(top) IPCE spectra measured by PEC-Pro
(bottom) I-V curve measured by PEC-IV2 (sold separately)

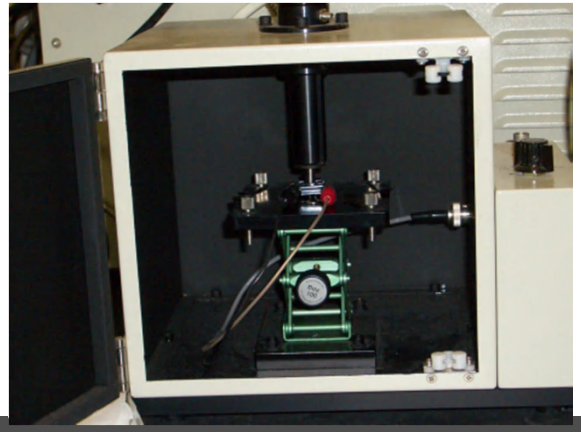
Introduction of PEC-S20 IPCE Measurement System

Peccell Technologies, Inc.
Yokohama, Japan

Concept of PEC-S20 IPCE Measurement System

- **Measuring IPCE of solar cell without a shading mask**
  A solar cell area is determined not by a shading mask but by number of photons.
- Lamp house, power supply, monochomater are compacted in **a unit body**, which is easily placed on a desktop.

- **Contact Irradiation through an optical fiber**
  It is easy to calculate a current density without considering actual cell area.
  Option: An achromatic lens makes 2mm or 1mm irradiation spot, which is suitable for Small solar cells such as Organic Solar Cells.



Purposes of Measurement of IPCE

- Measure spectral response of photoelectric conversion device

- <u>Estimate a Current density under a standard solar spectrum</u>
  In the case of a small cell, difficult to determine an actual cell area, which should be needed in current density calculations.

IPCE spectrum is a plot of a ratio of number of output electrons (current) and input photons (irradiance) against wavelengths.

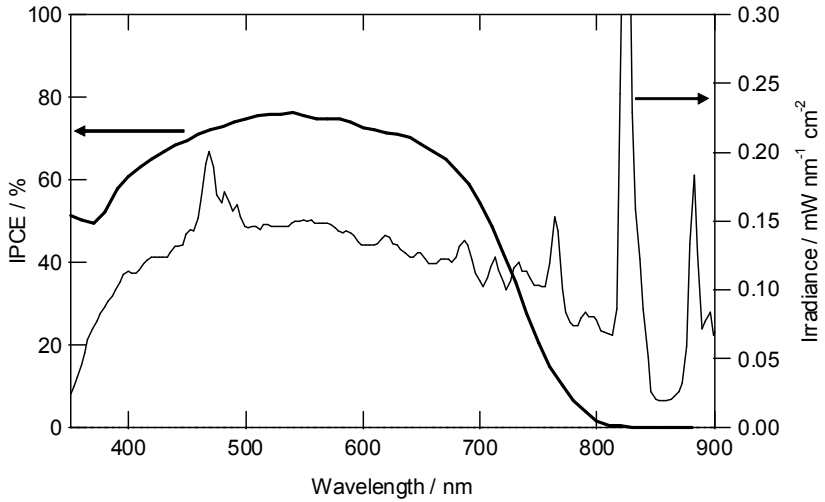
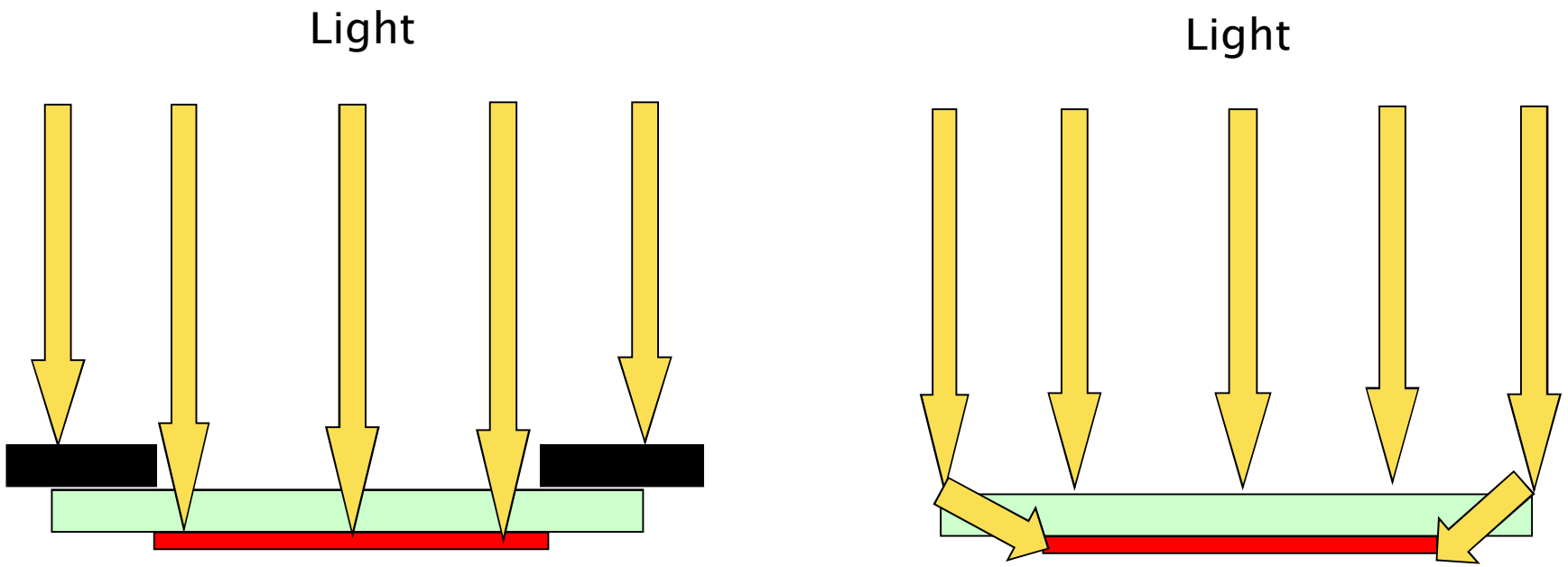


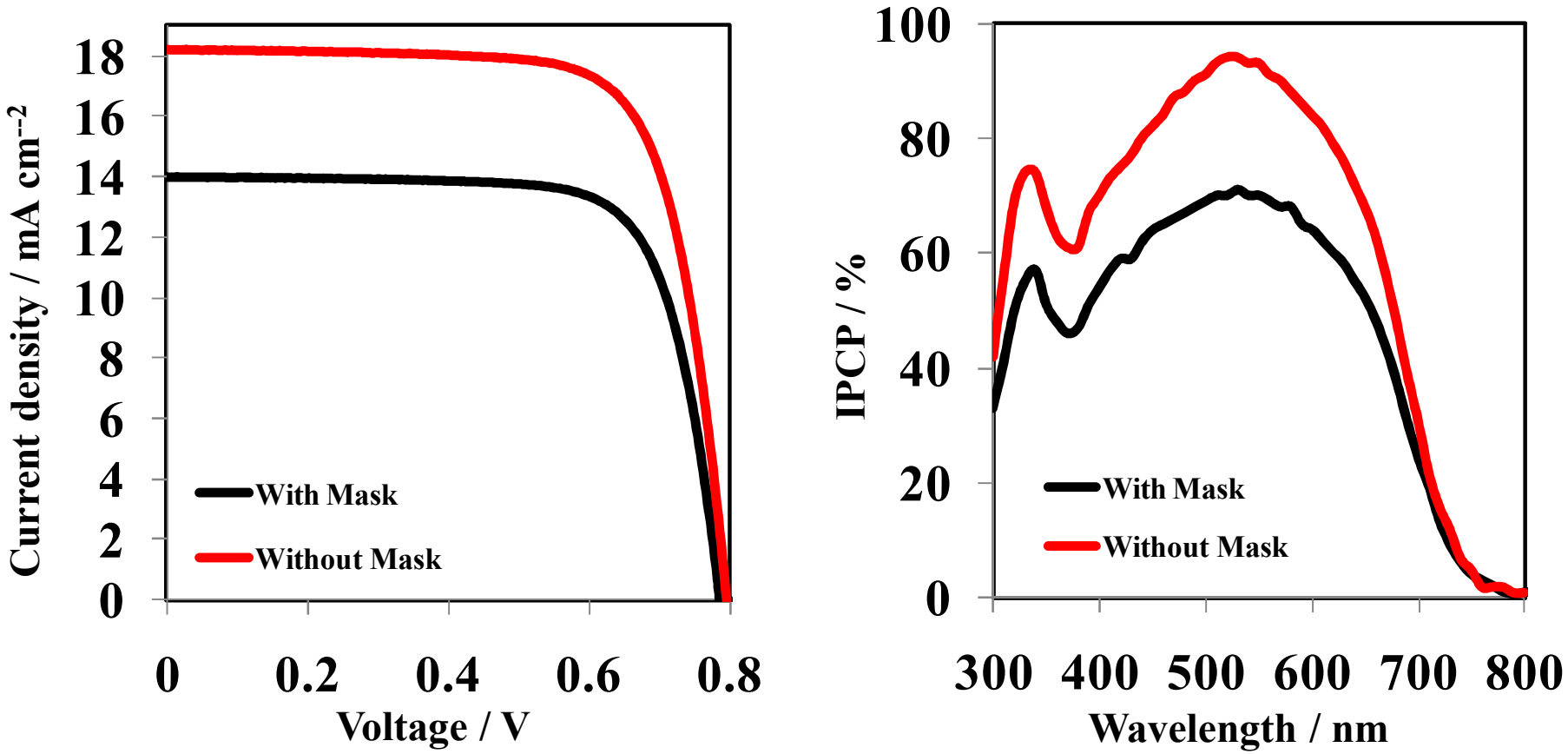
Figure Examples of IPCE spectrum and solar simulator spectrum

Error of current density calculation without a shading mask (1)



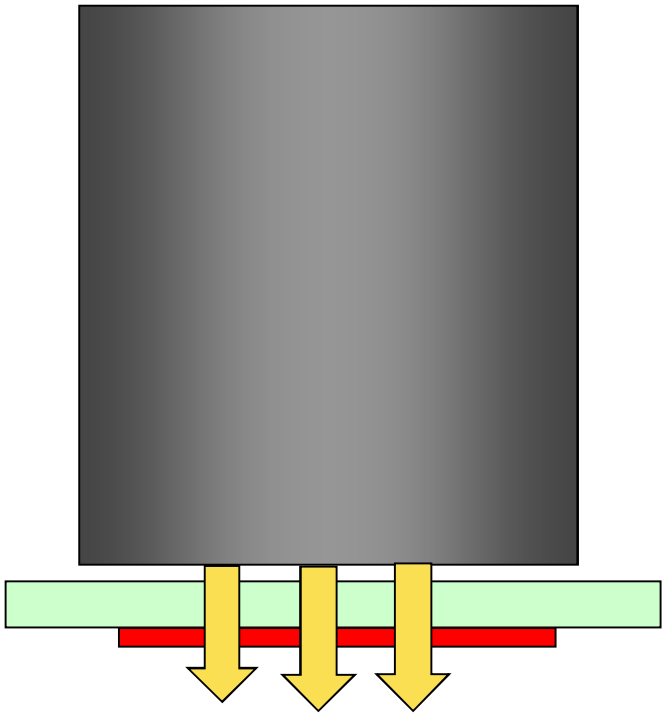
It is very important to consider an actual cell area in current density calculation.
Without a shading mask, calculation of current density is affected by photons from outside of the cell.
Often overestimate the current density, Jsc.

Error of Current density without a shading mask (2)
TiO_2 area 5mm x 5mm Dye-sensitized solar cell



	J_{sc} / mA cm^{-2}	V_{oc} / V	*FF*	*Effi* . / %
With mask	14.0	0.79	0.74	8.20
Without mask	18.2	0.80	0.74	10.67

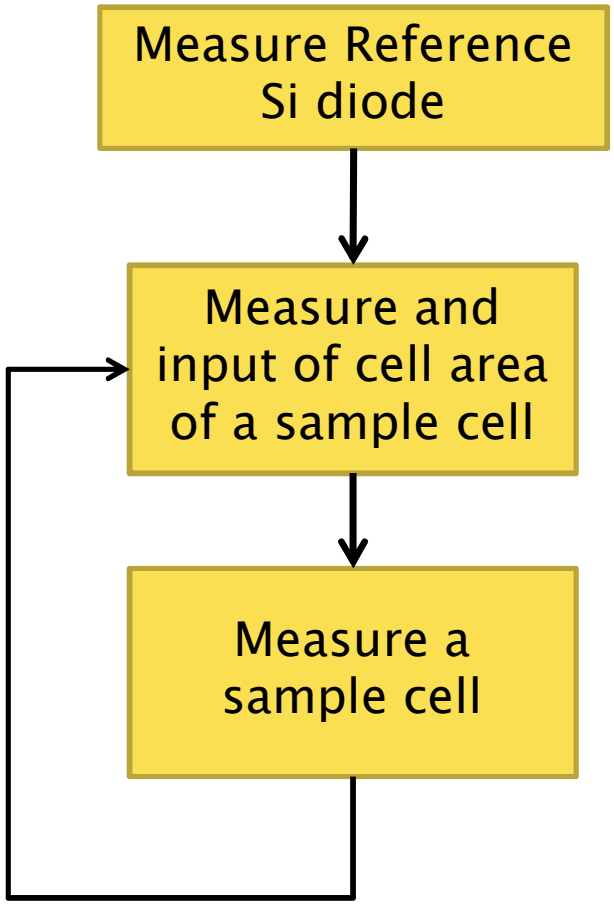
Contact irradiation through the optical fiber of PEC-S20



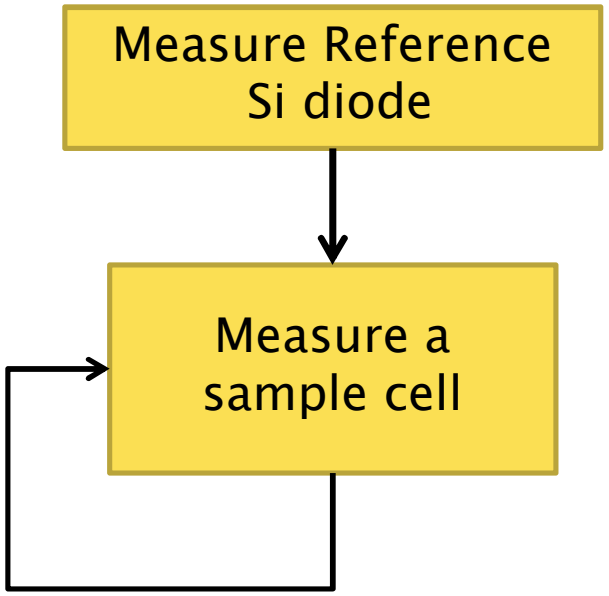
All the photons from an optical fiber go into a sample cell.
IPCE is simply calculated by number of photons (irradiance) and electrons (current) against wavelength.
No need to correct actual cell areas.

Measurement of IPCE by PEC-S20

Other system



PEC-S20

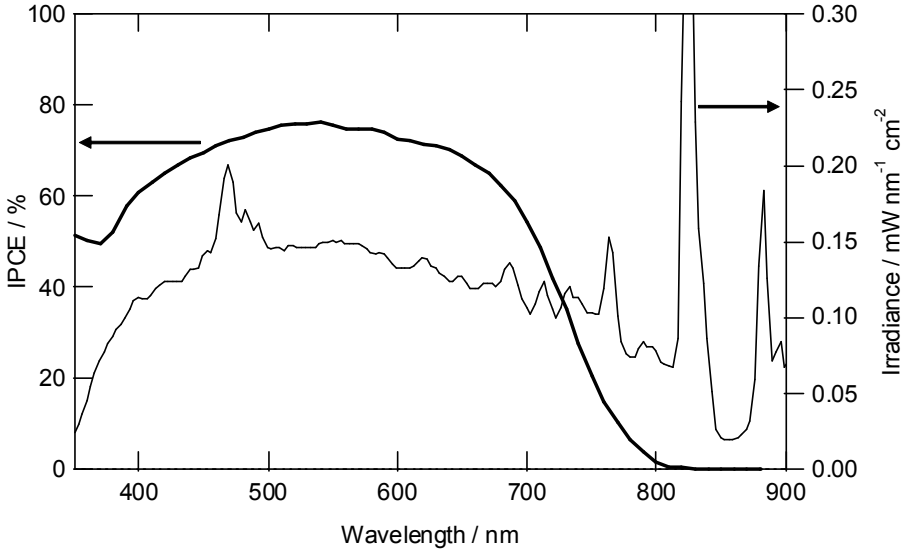


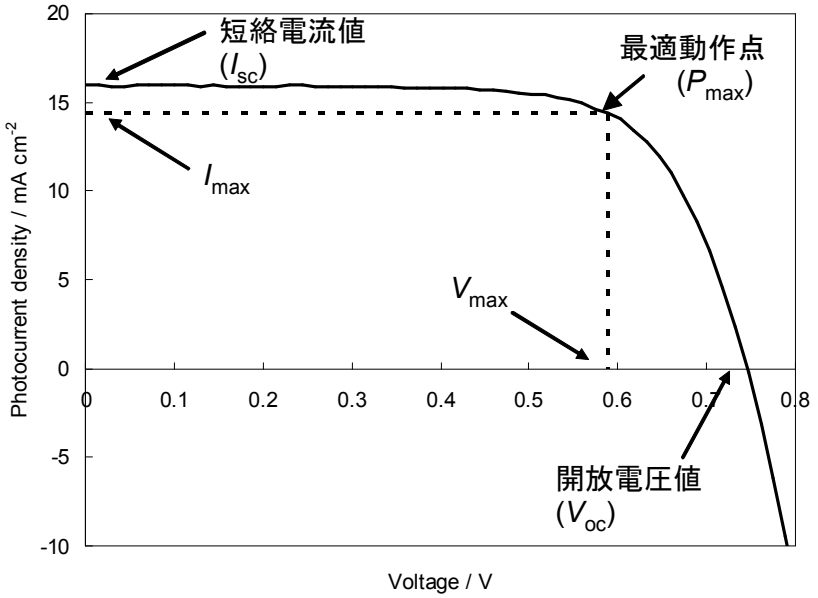
<u>PEC-S20</u>
No need to measure actual cell area of solar cells.

Comparison of J_{sc} calculated from IPCE spectrum with I-V curve

$$J_{sc} / mAcm^{-2} = \int \frac{P_{in\lambda} \times \lambda}{1.99 \times 10^{-16}} \times \frac{IPCE_{\lambda}}{100} \times \frac{1}{6.24 \times 10^{18}} d\lambda$$

J_{sc} = 15.2 mA cm^{-2} (N719)



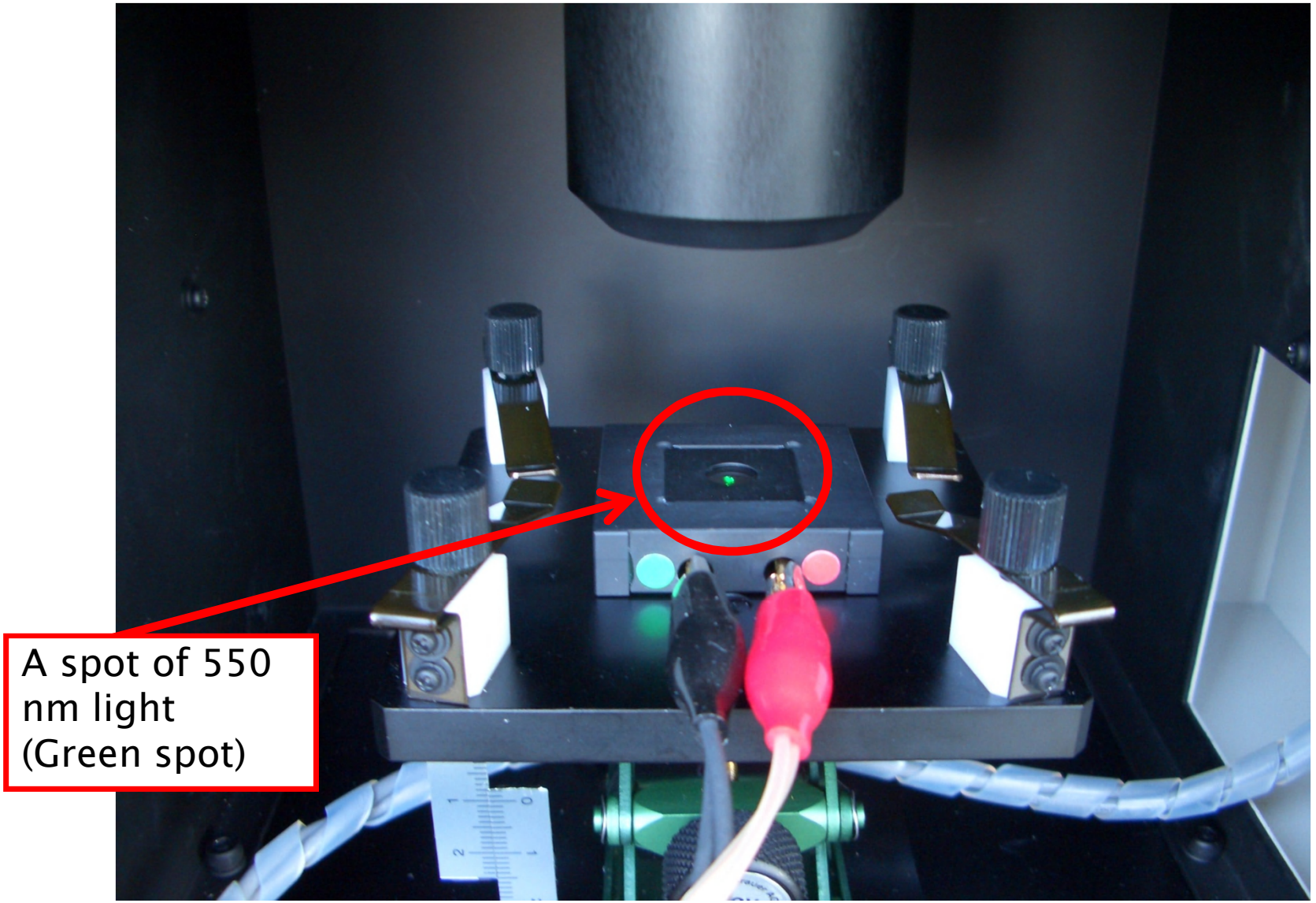


J_{sc} can be calculated with using IPCE spectra and standard solar spectrum or solar simulator spectrum.

Achromatic optics for measurement of IPCE of small solar cells

- For measuring small solar cells with 2 mm or 1 mm Especially for organic solar cells.
  - It is difficult to set appropriately a shading mask on small solar cells. It causes to often overestimate Jsc. Sometimes, the error reaches 2 or 3 times higher.
- A solar cell area is determined not by a shading mask but by number of photons. This method makes Jsc calculation very easily.

Irradiation to a reference silicon solar cell by the Achromatic optics



How to make shading masks by using an old floppy disk cover

- Shading masks are consumable goods.
  They are easily made dirty by electrolyte or something.
- A shading mask made by an metal plate is difficult to be prepared by user own.
- <u>A shading mask is possible to be made by what users have.
  Old black floppy disk drive cover and a stationery punch</u>

The radius of an optical fiber of PEC-S20 is 5.5 mm. Usual stationery punch size is 6 mm or 5.5 mm. A black floppy disk cover is used for mask, and to be a light guide as well as a shading mask

PEC-S20 Models

- **A. Standard**
  PEC-S20 (Standard DC measurement)
- **B. AC Measurement**
- + Chopper Unit
  + Lock-in-Amplifier
- **C. AC Measurement with White bias light**
  + Chopper Unit
  + Lock-in-Amplifier
  + White bias bianntenary optical fiber
- **D. DC measurement Keithley 2400 model**
  + Keithley 2400 sourcemeter
- **E. 1mm ϕ achromatic lens optics**
  + Achromatic lens optics
- **F. 1mm ϕ achromatic lens optics Keithley 2400**
  + Achromatic lens optics
  + Keithley2400