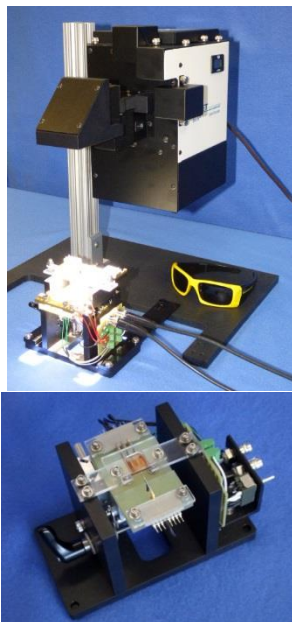


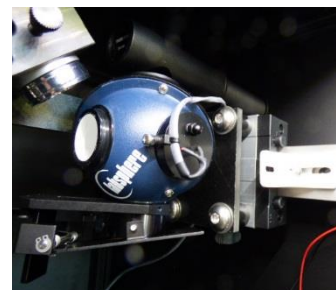
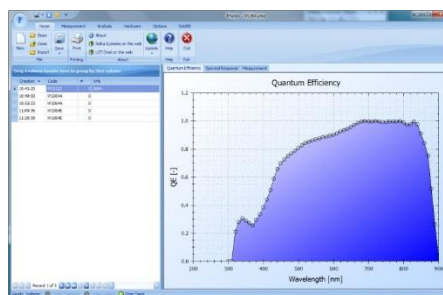
Function Focused Innovation™

2019 PRODUCT LINE CATALOG

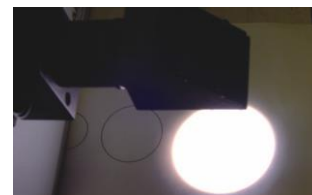
SOLAR SIMULATORS and PV IV MEASUREMENT TOOLS



QE AND IQE SYSTEMS



UV-VIS-IR LIGHT SOURCES AND LITHOGRAPHY



Systems and components for
Photovoltaic Research and Industry
Spectroscopy
Life Sciences
Material Sciences

Letter from Abet

Incorporated in 2006 bringing a now patented compact 150 W Xenon arc lamp source to the market Abet has evolved to become a major provider of solar simulators and PV IV measurement systems, standard and custom, delivering over 800 instruments since its inception.

Our product line includes a wide range of illuminated area solar simulators from 35 mm diameter to over 350x350 mm. The very popular Class AAA offerings are complemented by the less expensive Class B uniformity instruments when test needs are less stringent.

In addition to our line of solar simulators we offer a wide range of test solutions for just about any cell material or contact geometry from traditional top-bottom contacts solar cells to multi-device cells on a single substrate, glass sandwich geometries or bottom-bottom contact. Calibrated reference cells allow absolute metrology.

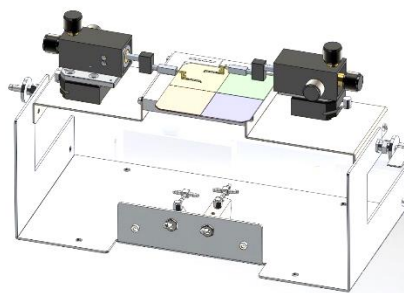
A recent upgrade of integrated quantum efficiency metrology systems with a custom designed 250 mm monochromator further enhances the solar cell characterization tool set offered by Abet.

Many of our standard measurement tools started as a custom solution for a particular customer. Many times we were able to provide such solutions at near standard system prices and delivery times. If you do not find a solution for your particular test requirements among our standard offerings please contact us.

The PV market has been the biggest driver of the fast growth of Abet Technologies. Life and material sciences and MEMS lithography have also contributed to our success story. A short description of our UV-VIS-IR light sources and lithography systems can also be found in this catalog.

We would like to thank our existing customers and representatives for placing their trust in us. We hope to become your supplier, too, with our standard or custom test solutions. Please let us know your needs.

Thank you from team Abet.



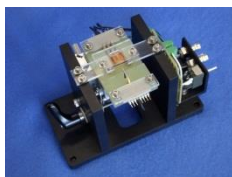
PV IV SOLUTIONS FOR CELLS LARGE:



MEDIUM:



AND SMALL: CRYSTALLINE THIN FILM ITO/CTO DSSC



SINGLE DEVICE AND MULTIPLEXER SYSTEMS



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PV IV System

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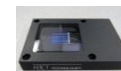
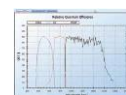
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45

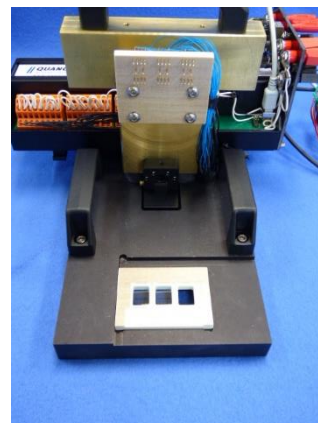
Arc Lamp Light Sources

Including optics and accessories

46-47



ASTM
IEC JIS



Equipment and Test Standards

Why use standards

Following common practices on manufacturing, calibrating and using test equipment, as specified by national and international Standards Organizations allows easier intercomparison of measurement results performed in different laboratories. Abet Technologies' systems are constructed to allow standards compliant metrology.

The following is a sampling of the standards, current as of the publication date of this catalog. These are the standards we refer to when specifying that our products are standards compliant:

ASTM E927-19(2019) Standard Specification for Solar Simulation for Photovoltaic Testing

ASTM E948-16 Standard Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells Under Simulated Sunlight

ASTM E973-16 Standard Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell

ASTM E1021-15 Standard Test Method for Spectral Responsivity Measurements of Photovoltaic Devices

ASTM E1143-05 (2019) Standard Test Method for Determining the Linearity of a Photovoltaic Device Parameter with Respect To a Test Parameter

ASTM E1362-15 Standard Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells

ASTM G138-12 Standard Test Method for Calibration of a Spectroradiometer Using a Standard Source of Irradiance

ASTM G177-03 (2012) Standard Tables for Reference Solar Ultraviolet Spectral Distributions: Hemispherical on 37° Tilted Surface

IEC 60891 Ed. 2.0 (2009-12) Standard Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics

IEC 60904-1-1:2017 Measurement of photovoltaic current-voltage characteristics

IEC 60904-2:2015 Requirements for reference solar devices

IEC 60904-3:2016 Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

IEC 60904-4:2009 Reference solar devices - Procedures for establishing calibration traceability

IEC 60904-7 Ed. 3.0 (2008-11) Computation of the spectral mismatch correction for measurements of photovoltaic devices

IEC 60904-8:2014 Measurement of spectral response of a photovoltaic (PV) device

IEC 60904-9 Ed. 2.0 (2007-10) Solar simulator performance requirements

JIS C 8912 (1998) through Amendment 2 (2011) Solar simulators for crystalline solar cells and modules

JIS C 8913 (1998) Measuring method of output power for crystalline solar cells

Solar Simulator standards

The currently applicable standards are quite similar but not identical. The ASTM, IEC and JIS requirements for different solar simulator classifications are as follows:

Spectral match				Stability			
	ASTM	IEC	JIS		ASTM	IEC	IEC
nm	%	%	%		%	LTI	STI
400-500	18.4	18.4	18.5	A	2	2	0.5
500-600	19.9	19.9	20.1	B	5	5	2
600-700	18.4	18.4	18.3	C	10	10	10
700-800	14.9	14.9	14.8				
800-900	12.5	12.5	12.2				
900-1100	15.9	15.9	16.1	Uniformity			
					ASTM	IEC	JIS
					%	%	%
A	.75 to 1.25			A	2	2	2
B	.6 to 1.4			B	5	5	3
C	.4 to 2.0			C	10	10	10

All Abet Solar Simulators are shipped with a Certificate attesting it has been tested to and meets or exceeds all applicable class standards.



Certificate of Compliance
 Product: Sun 3000 Solar Simulator
 Applicable Standards: ASTM E 927-10; IEC 60904-9 Ed. 2.0; JIS C 8912

15-Aug-2012

Model 11018A

SN 343

Spectral fit

Band	Error	Class A limits	Status
400-500 nm	-3.3%	25%	Pass
500-600 nm	2.4%	25%	Pass
600-700 nm	1.0%	25%	Pass
700-800 nm	-2.7%	25%	Pass
800-900 nm	-1.9%	25%	Pass
900-1100 nm	3.6%	25%	Pass

Nonuniformity

Field	Nonuniformity	Class A limit	Status
160x160	1.9%	2%	Pass

Instability

	Period	Instability	Class A limit	Status
STI	0.5 sec	0.36%	0.5%	Pass
LTI	10 min	0.95%	2.0%	Pass

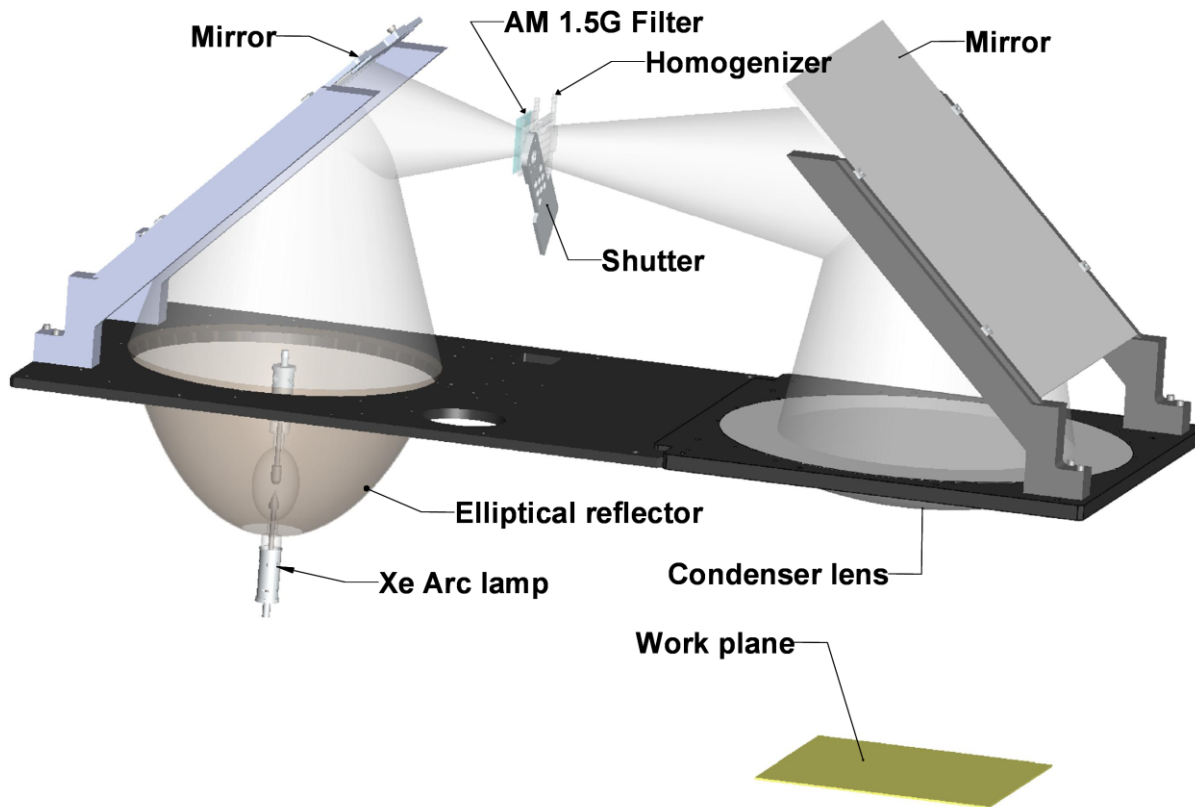
Irradiance: 1 Sun at 36.5 A
 Reference cell used: ReRaRef 6

System Class: AAA

[Signature]

Signature

Components of a Solar Simulator



Schematic presentation of Abet Technologies Solar Simulator

Optical train

Most DC arc lamp based solar simulators utilize a set of components similar to the one above which represents Abet Technologies preferred way of producing Class AAA Solar Simulator performance.

A **Xe short arc lamp** is energized by a power supply, not shown. The lamp is located inside an **elliptical reflector** which collects a high percentage of its light output. Lamp's output is refocused near an optical **homogenizer** assembly which consists of two sets of offset lenslet arrays. The homogenizer, working together with the ellipse and the **condenser lens**, creates uniform illumination that Class A specifications call for.

Mirrors are used to fold the optical path as needed for the work plane location and to make the instrument more compact.

Spectrum shaping elements, like an **AM 1.5G filter**, are located just before the homogenizer assembly to assure reproducible spectral shaping across the whole work plane.

Optical shutter is located after the spectral filters and the homogenizer so that those optical elements and their mounts can come to a thermal equilibrium after the initial system warm-up and deliver stable performance with every shutter opening cycle.

Some systems ship with a **photofeedback** accessory, not shown. The photofeedback accessory consists of optical sampling heads and control loop electronics to further improve output stability.

System performance is specified at the **Work Plane** location. The Gen II optical design of Abet Solar Simulators assures in-spec performance over a significant range of work plane distances – please check the specifications tables.

Low Cost Solar Simulators

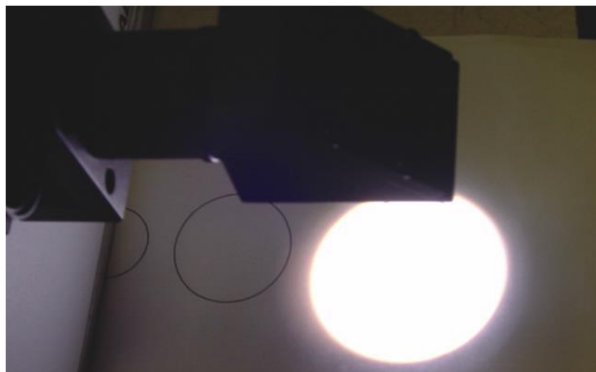
Cost effective and functional design



Abet Technologies Model 10500 Low Cost Solar Simulator with a 10513 90° Uniform Illumination Accessory with Manual Shutter

Cost Effective Patented Solution

Abet Technologies model 10500 is a patented, US Pat. No. 8116017, low cost solar simulator providing an attractive alternative to more fully featured and expensive solar simulators for applications that do not require a large area illuminated field. The optical system of the 10500 produces a collimated 25 mm beam. Focus or defocus it for higher irradiance or larger solar cells. One sun output is achievable up to a 35 mm diameter illuminated field.



10500 Low Cost Solar Simulator with the 10512 90° Uniform Illumination Accessory

- 1Sun Output Over 35 mm Diameter Field
- ASTM, IEC & JIS Class A AM1.5G Output
- Compact Integrated Design
- Fast F/1.0 Fused Silica Condenser
- DC Xenon Arc Lamp

Innovative Optical Design

The 10500 utilizes a fast F/1 optical system and rear reflector to collect radiation from the lamp, allowing over 3 suns output over smaller fields. The beam can be collimated at 25 mm diameter or defocused to illuminate larger cells. Focus, lateral, and rear reflector adjustments allow for optimizing beam size and uniformity. One sun performance for up to a 35 mm diameter illuminated field with uniformity of +/- 25% can be achieved with careful alignment. Smaller areas within the illuminated field will provide higher levels of uniformity if required.

Adaptable System Configuration

The 10500 offers a flexible design that can be adapted to your particular needs. The standard configuration is a horizontal output full spectrum solar simulator with an AM 1.5G filter included. For down beam illumination, a 90 beam turner is available.

Complete test solutions

Best test results are obtained when the 10500 is equipped with one of the class B uniformity capable Uniform Illumination Accessories, see ordering information, which can be ordered with working distances to 450 mm and offer a manual shutter option. A low cost 15151 calibrated reference cell facilitates quantitative metrology.

Product line update

Take a look at the performance improvements designed into the SunLite™ line of Abet Solar Simulators.

Specifications

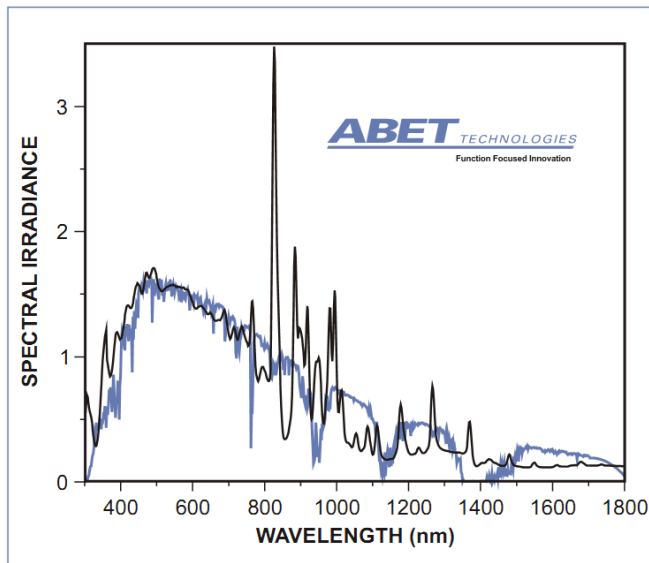
Illumination field.....	User adjustable
1 Sun Irradiance.....	35 mm Diameter (max)
Spectral Match with AM1.5G Air Mass Filter ¹	
ASTM.....	Class A
IEC.....	Class A
JIS.....	Class A
Temporal Stability	
ASTM.....	Class A
IEC.....	Class B
JIS.....	Class A
Irradiance uniformity	
Basic Model.....	No classification
With Uniform Illumination Accessory capable of	
ASTM.....	Class B
IEC.....	Class B
JIS.....	Class B
Ozone-free Xe Arc Lamp (included).....	150 W
Typical life	1500 hours
Elapsed Time Meter (included)	
Working Distance.....	User selectable
Universal Input 90-250V, 50-60Hz, power supply included	
Standard Output Direction.....Horizontal	
¹ With the optional uniform illumination accessory; no class specification for basic system	
Optional 90° Beam Turner Accessories provide infinitely adjustable beam direction selectivity.	
Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.	

Ordering Information

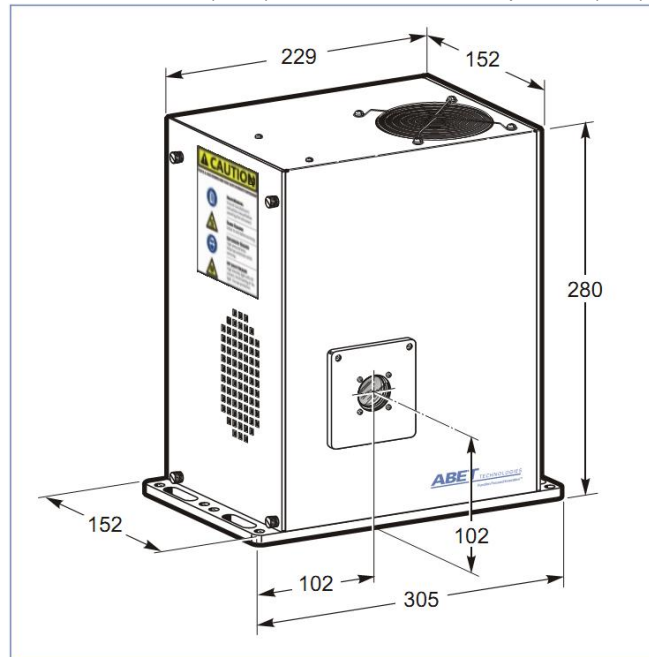
10500	AM 1.5G Solar Simulator including Lamp, Power Supply and AM 1.5G Filter
10511	Horizontal Output Uniform Illumination Accessory, 100mm Working Distance (up to 450mm optional)
10512	90° Uniform Illumination Accessory, 100 mm Working Distance (up to 450mm optional)
10513	90° Uniform Illumination Accessory with Manual Shutter, 100 mm Working Distance
10515	90° Uniform Illumination Accessory 70 mm Offset
10516	90° Uniform Illumination Accessory 200 mm Offset
10517	Uniform Illumination Accessory 450 mm Offset
20037	90° Beam Turner Accessory
13014	Replacement 150 W Xe Arc Lamp
15151	Low cost reference cell, 10x10 mm, see page 21 for details

Available Options

If you require a different spectral shaping or working distance option, please contact us with your requirements – many additional solutions are available for photovoltaic or life sciences applications.



Spectral output curve of the Abet Technologies model 10500 Low Cost Solar Simulator (black) and standard AM 1.5G spectrum (blue).



Dimensional diagram of the Abet Technologies model 10500 Low Cost Solar Simulator. The 10500 Solar Simulator is designed as a free standing instrument. If you need to mount it in a more particular way, an array of universal metric/English mounting holes in its base will allow an easy adaptation – please contact us for dimensional details.

Abet Technologies offers an expanding line of ASTM, IEC and JIS standards compliant products for solar cell PV-IV testing, steady state solar simulators, test stations, software, calibrated reference cells and a selection of electronic loads for low and high current cells. Visit www.abet-technologies.com or contact us at sales@abet-technologies.com.

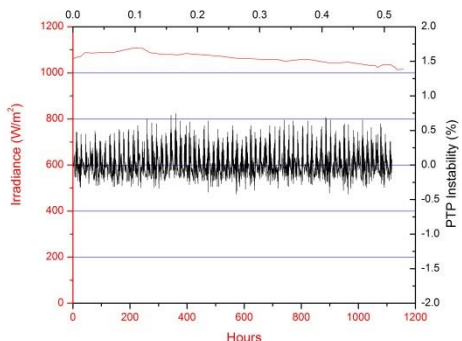
SunLite™ Solar Simulators

Cost effective and full featured: 0.2 to 20 Suns

- Gen III Optics for High Efficiency Illumination
- Infinitely Adjustable Irradiance, Reproducibly Settable
- Class A AM1.5G Spectral Match
- Class A stability
- 50x50 mm Class B uniformity
- Manual Shutter Included, Electronic Shutter Optional
- HEPA filtered air cooling

More Features, Lower Price

Abet Technologies' model 11002 SunLite™ Solar Simulators set a new standard for 50x50 mm field solar simulators using only a 100 W Xe arc lamp. A wide range of reproducible irradiance settings is made possible by the available irradiance control option. Highly stable long term and short term output allows for reproducible metrology.



Long term (over 1000 hrs.) and short term (0.5 sec) stability of the 11002 SunLite™ Solar Simulator.

This lower cost simulator replaces the Sun 2000 Model 11000 unit.

Innovative Optical Design

The 11002 SunLite™ Solar Simulator utilizes an optimized optical system to deliver more than one AM1.5G sun irradiance over a 50x50 mm area utilizing only a 100 W Xe arc lamp. For test needs at other than one sun conditions order the attenuation option offering a wide and reproducible range of irradiance control or the 20 Suns capable Model 11003.

Adaptable System Configuration

The 11002 SunLite™ Solar Simulator offers a flexible design that can be adapted to many particular needs. Standard configuration is a downward output system with an AM 1.5G filter included which is easily converted to a horizontal or up pointing output system using only a screwdriver. The long working distance design makes it highly compatible with glove box based test needs.

Complete test solutions

Combine the SunLite™ Solar Simulator with one of Abet Technologies' many test stations to match DSSC, Perovskite, Silicon, Thin Film, or numerous other solar cell materials. For standards compliant PV IV metrology add the Tracer™ hardware control and data analysis software and one of the full featured 15150 family or the low cost 15151 calibrated reference cells. Temperature control and vacuum pumps are available as needed.

Abet Technologies' Model 11002 SunLite™ Solar Simulator with the 15279 option for infinitely and reproducibly adjustable irradiance control as well as the 15278 electronic shutter option.



SunLite™ Specifications

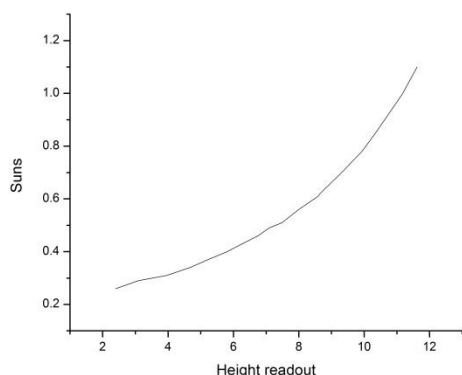
Illuminated field (1 sun).....	>= 50x50 mm
Irradiance Model 110022 to 1.2 suns
Model 11003.....	.2 to 20 suns
Spectral Match with the included AM 1.5 Filter	
ASTM.....	Class A
IEC.....	Class A
Temporal Stability	
ASTM.....	Class A
IEC.....	Class A
Irradiance uniformity	
ASTM.....	Class B
IEC.....	Class B
Prealigned Ozone-free Xe Arc Lamp (included)	100 W
Typical life	1000 hours
Manual shutter included	
Adjustable height stand and base plate included	
HEPA filtered cooling fan included	
Elapsed time meter (ETM) included	
Universal Input 90-250V, 50-60Hz, power supply included	
Output direction down/up/horizontal customer modifiable	
Standard N-BK7 condenser limits user UV exposure. All fused silica condenser available if needed.	

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.

Available Options

Add the Model 15278 electronic shutter option to allow computer control for light soaking and timed irradiance.

Add the 15279 continuously adjustable height stand with electronic readout for infinite resolution, reproducible irradiance control.



Typical irradiance of the 11002 SunLite™ Solar Simulator using the model 15279 option.



Typical non-uniformity map of an Abet Technologies model 11002 SunLite™ Solar Simulator, 50x50 mm; <5% standard

Clean Cooling

Any dust or dirt particles introduced into an optical system can degrade system performance and shorten the life of critical optical components. SunLite™ sources utilize a HEPA filtered cooling air to extend the life of the delicate optical components.

User friendly

Prealigned lamps make lamp replacement hassle free. Standard maintenance, lamp or filter replacement, does not require any tools. Easily switch from down to up or horizontal output. Long working distance for ease of glove box use. Compact and quiet for easy fit in the lab.

Ordering Information

11002	SunLite™ Solar Simulator with settable height stand, manual shutter, HEPA filtered cooling
11003	SunLite™ Solar Simulator, 0.2 to 20 Suns, with settable height stand, manual shutter, HEPA filtered cooling
15278	Electronic shutter option
15279	Quick height adjustment stand with electronic readout
13013	Prealigned 100 W Xe Arc lamp with reflector
11002-F	Replacement HEPA filter
15151	Low cost reference cell
15151-KG5	Low cost reference cell with KG5 filter

Abet Technologies offers an expanding line of ASTM, IEC and JIS standards compliant products for solar cell PV-IV testing, steady state solar simulators, test stations, software, calibrated reference cells and a selection of electronic loads for low and high current cells. Visit www.abet-technologies.com or contact us at sales@abet-technologies.com.

Sun 2000 Solar Simulators

Cost effective and versatile UV to IR sources



Abet Technologies Model 11048-1 3 kW multi-sun UV solar simulator, customer reconfigurable to a full spectrum 2 suns 300x300 mm field simulator.

Abet Technologies' Sun 2000 family of solar simulators, characterized by Class B irradiance uniformity performance, covers wide range of illuminated field sizes, 55x55 mm through 300x300 mm, square or rectangular. One sun and High Output models are offered. AM 1.5G spectrum models are complemented by a variety of other spectral offerings: AM 0, AM 1D, AM 1.5 D, AM 2D, Atmospheric UV Edge, and UV C, UV B/C, and UV A/B/C blocked, full spectrum, UV only and spectrum switchable models.



Abet Technologies Model 11044 Sun 2000 203 x 203 mm Solar Simulator.

Innovative and complete

The Abet Gen II optical design dramatically increases the percentage of photons reaching the work plane. This higher optical efficiency allows the use of lower power lamps to illuminate a given size field, e.g. more than one AM 1.5G sun is achieved with a 550 W lamp over a 160x160 mm field.

All electronics are packaged in the lamp house – no clutter of high power cables to deal with. A digital shutter timer allowing both manual and external control is included with every unit.

Standard maintenance, lamp or filter replacement, does not require any tools.

Locking indicator dials on all the system controls provide for a reproducible and stable setup.

Most units come with a built-in beam imaging accessory to assist in system alignment.

Clean Cooling

Any dust or dirt particles introduced into an optical system can degrade system performance and shorten the life of critical optical components. Sun 2000 sources utilize a HEPA filtered cooling air to extend the life of the delicate optical components.

- Gen II Optics for High Efficiency Illumination
- Class A Spectral Match to the applicable standard
- Class A stability
- Class B Uniformity
- DC Xe Arc Lamp, 550W to 3 kW
- Wide range of Working Distances
- Full Spectrum/UV Switchable models
- Long Life Shutter Included
- Digital Shutter Timer Included
- Long Life Lamps
- HEPA Filtered Cooling

Adaptable

Abet Technologies offers a number of spectral and field size options to match your application. The Sun 2000 family standard offerings range from 55x55 mm to 400x400 mm one sun or more uniformly illuminated field versions for Photovoltaic and UV applications.

Standard High Output models offer over 20 AM 1.5G Suns. Higher irradiances are available from concentrated models.

Square and rectangular illuminated field models to match device shapes and sizes.

Up-pointing and horizontal output direction models complement the standard down pointing ones.

Long working distances allow easy interface to glove boxes.

The compact design of the systems, combined with the long working distance optics, leaves the space below these instruments wide open for any sample positioning or testing equipment.

Beyond the standard AM 1.5 and AM 0 filters many other filters are offered to fine tune the spectral characteristics of the source for your particular application.

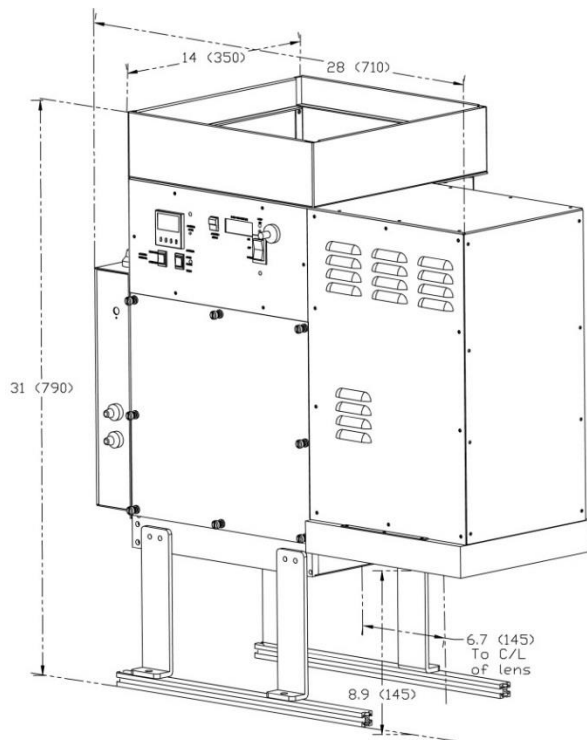
Sun 2000 Solar Simulator Specifications, 1 sun models

Model #	Field size (mm)	Stability (%)	Uniformity (%)	Lamp (W)	Ozone free	Lamp life (hours)	Working distance (mm typ.)	Irradiance AM 1.5G suns (max. typ.)	AM 1.5G spectral match
11016	100x100	1	5	550	☑	1500	100±50	2.1	A
11018	160x160	1	5	550	☑	1500	200±50	1.3	A
11044	203x203	1	5	1000	☑	1500	200±50	1.3	A
11046	254x254	1	5	1400	☑	1500	200±50	1.3	A
11047	100x250	1	5	1000	☑	1500	200±50	1.3	A
11048	300x300	1	5	2000	☑	2000	400±75	1.3	A

The Sun 2000 models listed above are most popular with our customers. They deliver around one sun irradiances and limit UV exposure by utilizing an N-BK7 condenser lens. However, if your test needs require a multi-sun level of irradiance see page 11 in this brochure. For systems with UV content matching AM0 or terrestrial atmospheric UV edge see page 12. Pages 14-17 offer similar systems in the Abet Technologies Sun 3000 Class AAA family of Solar Simulators. The above are the most popular field size models. Please let us know if your needs require a different one – many additional square and rectangular shaped field size systems can easily be manufactured.

Certified

Each Sun 2000 Solar Simulator for which standards exist ships with a performance certificate according to the customer selected standard: ASTM, IEC or JIS.



Dimensional diagram of the Abet Technologies model 11018 and 11042 Sun 2000 Solar Simulators



Abet Technologies Model 11018 Sun 2000 160x160 mm Solar Simulator

Available Options

All models listed above include an AM 1.5G filter for ordering convenience. Other filter options can be substituted or added at the time of ordering.

Working distances listed above are typical – many additional solutions are available. In particular, the up-pointing and horizontal output models are often shipped with longer working distances to accommodate a glove box or more complex test bench requirements.

The 11088 Photofeedback option is no longer necessary to achieve Class A stability performance.

The 11075 Attenuator Set allows great flexibility in irradiance control for 150-550 W systems.

See the ordering information on page 15 for a list of standard options. Please contact Abet if you need something different.

Sun 2000 Solar Simulators, High Output models

Model #	Field size (mm)	Stability (%)	Uniformity (%)	Lamp (W)	Ozone free	Lamp life (hours)	Working distance (mm typ.)	Irradiance AM 1.5G suns (max. typ.)	AM 1.5G spectral match
11014	55x55	1	5	550	☑	1500	125±25	7	A
11038	55x55	1	5	1000	☑	1500	125±25	12	A
11040	100x100	1	5	1000	☑	1500	100±50	4	A
11042	160x160	1	5	1000	☑	1500	200±50	2	A
11048	300x300	1	5	3000	☑	1500	400±75	2.1 (3.2) ¹	A

¹ With the 14205 field reducer option

The Sun 2000 models listed above are most popular with our customers. They deliver multi-sun irradiances and limit UV exposure by utilizing an N-BK7 condenser lens. For systems with UV content matching AM0 or terrestrial atmospheric UV edge see page 14. Pages 16-18 offer similar systems in the Abet Technologies Sun 3000 Class AAA family of Solar Simulators.

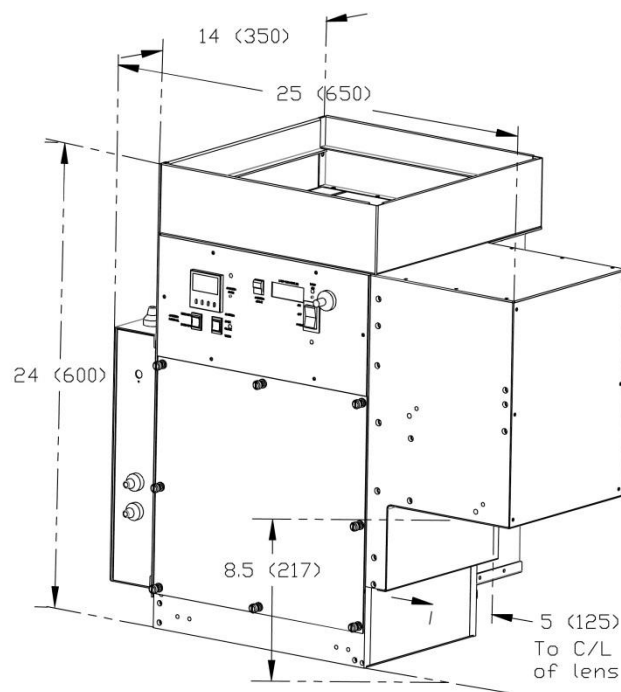
Many other combinations of lamp power levels and field sizes can be easily assembled without any additional engineering charges. For field sizes up to 254x254 mm any of the standard lamps, 150W, 300W, 550W, 1000W, or 1400W can be used, when matched to the appropriate power supply selection, to obtain a wide variety of irradiance levels.

Certified

Each Sun 2000 Solar Simulator for which standards exist ships with a performance certificate according to the customer selected standard: ASTM, IEC or JIS.



Abet Technologies Model 11014 Sun 2000 High Output 55x55 mm Solar Simulator



Abet Technologies Model 11014 Sun 2000 High Output 55x55 mm Solar Simulator

Available Options

All models listed above include an AM 1.5G filter for ordering convenience. Other filter options can be substituted or added at the time of ordering.

Working distances listed above are typical – many additional solutions are available. In particular, the up-pointing and horizontal output models are often shipped with longer working distances to accommodate a glove box or more complex test bench requirements.

The 11088 Photofeedback option is no longer necessary to achieve Class A stability performance.

See the ordering information on page 15 for a list of standard options. Please contact Abet if you need something different.

Sun 2000 Solar Simulators, Full Spectrum and UV models

Model #	Spectrum (nm)	Field size (mm)	Stability (%)	Uniformity (%)	Lamp (W)	Ozone free	Lamp life (hours)	Working distance (mm typ.)	Irradiance UV suns (max. typ.)
12060-1	280-400	160x160	1	5	1400	☑	1500	200±50	6
12060-2	280-2500	160x160	1	5	1400	☑	1500	200±50	6
12060-3	Switchable	160x160	1	5	1400	☑	1500	200±50	6

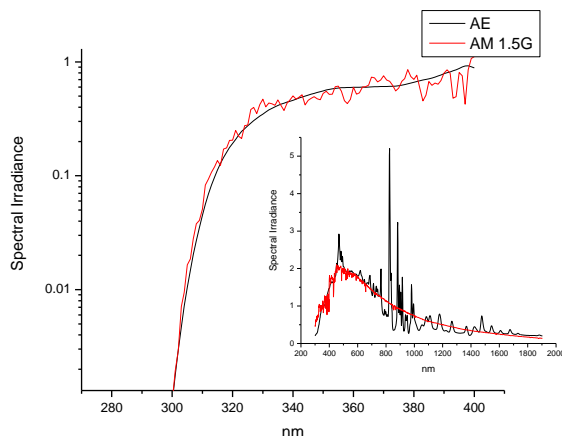
Any of the SUN 2000 models on the previous and following pages can be ordered as Full Spectrum, UV, or Switchable by adding a -1, -2, or -3 suffix to its model number as shown in the example above. All of these systems are equipped with a Fused Silica condenser lens. The "-1" units replace one of the mirrors with a 280-400 nm Dichroic Reflector to allow accelerated UV aging tests without excessive heating of the test devices. The "-2" Full Spectrum (280-2500 nm) units are often used with an AM 1.5G or AM 0 filter. The "-3" systems allow operation in either mode – full spectrum or 280-400 nm by a simple swap of frame mounted reflectors. This option can be customer added to either "-1" or "-2" models when the need arises.

Certified

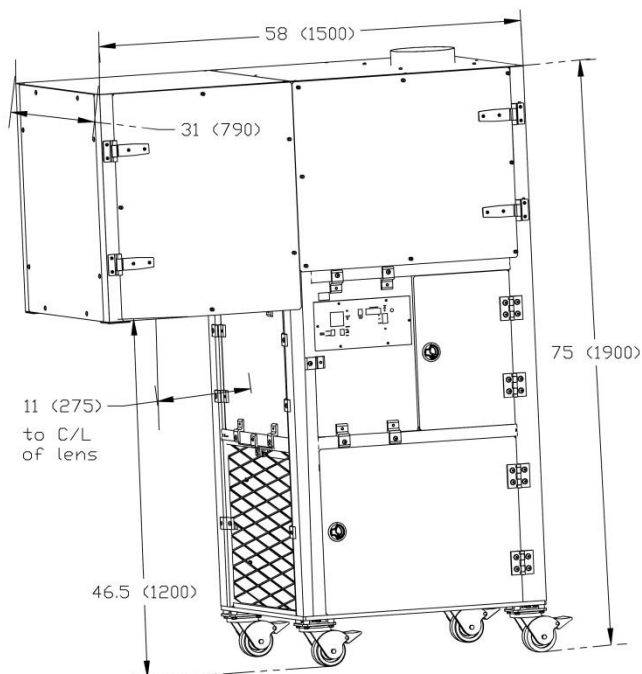
Each Sun 2000 Solar Simulator for which standards exist ships with a performance certificate according to the customer selected standard: ASTM, IEC or JIS.

Spectrally corrected

Several filter options are available for these systems to match their performance to the test requirements: AM 0 filter for extraterrestrial cells, Atmospheric Edge (AE) filter for terrestrial cells with response below 360 nm and for life sciences, UVC, UVB/C, and UVA/B/C blocking filters for material and life sciences.



Atmospheric Edge (AE) filtered output of 11042-1 system (black), scaled down, overlaid with the AM 1.5G UV spectrum (red).
Insert: AM 0 filtered output of model 11016-2 system (black) overlaid with the AM 0 spectrum (red).



Dimensional diagram of the Abet Technologies model 11048 Sun 2000 Solar Simulator

Available Options

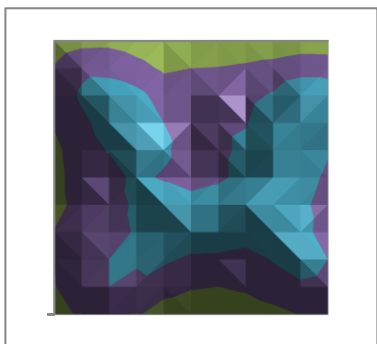
Many combinations of lamp power levels and field sizes can be easily assembled without any additional engineering charges. For field sizes up to 254x254 mm any of the standard lamps, 150W, 300W, 550W, 1000W, or 1400W can be used, when matched to the appropriate power supply selection, to obtain a wide variety of irradiance levels. High UV output "-1" 280-400 nm models are often used for accelerated UV damage testing.

See the ordering information on page 15 for a list of standard options. Please contact Abet if you need something different.

Sun 2000 Specifications

Illumination field.....55x55 to 300x300 mm
 Irradiance.....1 to 20 suns
 Spectral Match with AM 1.5G, AM 0, AM 1.5D Filters
 ASTM.....Class A
 IEC.....Class A
 JIS.....Class A
 Temporal Stability
 ASTM.....Class A
 IEC.....Class A
 JIS.....Class A
 Irradiance uniformity
 ASTM.....Class B
 IEC.....Class B
 JIS.....Class B
 Ozone-free Xe Arc Lamp (included)150 to 3000 W
 Typical life1500 hours
 HEPA filtered cooling fan included
 Elapsed Time Meter (included)
 Universal Input 90-250V, 50-60Hz, power supply included
 Standard Output Direction.....Down pointing

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.



Non-uniformity map of an Abet Technologies model 11016 Solar Simulator, 110x110 mm, 3%.

Ordering Information

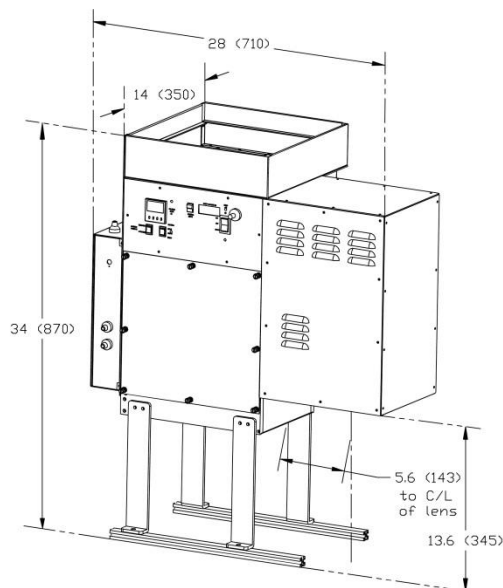
All standard Sun 2000 Solar Simulators include a Lamp, a Universal Input 90-250V Power Supply, an AM 1.5G Filter and a N-BK7 condenser lens. Add "-2" for a Fused Silica condenser lens, "-1" for a 280-400 nm dichroic option, "-3" for a Full Spectrum/280-400 nm convertible unit; add "U" for up-pointing option, "H" for horizontal output.

11014 55x55 mm, 550 W
11038 55x55 mm, 1000 W
11016 110x110 mm, 550 W
11040 110x110 mm, 1000 W
11018 160x160 mm, 550 W
11042 160x160 mm, 1000 W
12060 160x160 mm, 1400 W
11044 203x203 mm, 1000 W
11045 100x250 mm, 1000 W

11046 254x254 mm, 1400 W
11048 300x300 mm, 2000 W

Accessories and options

11054 AM 0 filter, 2x2 in.
11056 AM 1.5G filter, 2x2 in.
11058 AM 1.5D filter, 2x2 in.
11057 AM 1D filter, Ø 3 in.
11059 AM 2D filter, Ø 3 in.
11060 UVA/B/C Blocking Filter, Ø 3 in.
11063 AE filter (Atmospheric Edge), Ø 3 in.
12163 AE filter for 300x300 mm systems
11064 UVC Blocking Filter, Ø 3 in.
11065 UVB/C Blocking Filter, Ø 3 in.
11051 Replacement HEPA filter
11068 Beam Attenuator - 21%
11069 Beam Attenuator - 33%
11070 Beam Attenuator - 50%
11071 Beam Attenuator - 60%
11072 Beam Attenuator - 67%
11073 Beam Attenuator - 77%
11075 Attenuator Set - All Six Attenuators
11088 Photofeedback option, 0.5% stability
14205 Field reducer assembly, 300x300 to 200x200 mm
11051 HEPA Filter
12185 System Elevator, Adjustable Height Mount
13014 150 W Xenon Arc Lamp
13020 300 Watt Xenon Arc Lamp, OF
13021 550 Watt Xenon Arc Lamp, OF
13024 1kW Xenon Arc Lamp, OF
13025 1.4kW Xenon Arc Lamp, OF
13026 2.0kW Xenon Arc Lamp, OF
13027 3.0kW Xenon Arc Lamp, OF



Dimensional diagram of the Abet Technologies model 11016 and 11040 Sun 2000 Solar Simulators

Sun 3000 Solar Simulators

Cost effective and versatile UV to IR sources



Abet Technologies Model 11000A Sun 3000 55 x 55 mm Solar Simulator.

Innovative and complete

Abet Technologies' Sun 3000 family of Class AAA Solar Simulators covers wide range of illuminated field sizes, 55x55 mm through 400x400 mm.

The Abet Gen II optical design dramatically increases the percentage of photons reaching the work plane. This higher optical efficiency allows the use of lower power lamps to illuminate a given size field, e.g. more than one AM 1.5G sun achieved with a 1 kW lamp over a 210x210 mm field.

All electronics are packaged in the lamp house – no clutter of high power cables to deal with. A digital shutter timer allowing both manual and external control is included.

Most units come with a built-in beam imaging accessory to assist in system alignment. Locking indicator dials on all the system controls provide for a reproducible and stable setup.

Standard maintenance, lamp or filter replacement, does not require any tools.

- Gen II Optics for High Efficiency Illumination
- Class A Spectral Match
- Class A Stability
- Class A Uniformity
- DC Xe Arc Lamp, 150W to 3 kW
- Wide range of Working Distances
- Full Spectrum/UV Switchable models
- Multi-sun output models
- Long Life Shutter Included
- Digital Shutter Timer Included
- Long Life Lamps
- HEPA Filtered Cooling

Adaptable

Up-pointing and horizontal output direction models complement the standard down pointing ones.

Long working distances allow easy interface to glove boxes.

The compact design of the systems, combined with the long working distance optics, leaves the space below these instruments wide open for any sample positioning or testing equipment.

Beyond the standard AM 1.5 and AM 0 filters many other filters are offered to fine tune the spectral characteristics of the source for your particular application.

Clean Cooling

Any dust or dirt particles introduced into an optical system can degrade system performance and shorten the life of critical optical components. Sun 3000 sources utilize a HEPA filtered cooling air to extend the life of the delicate optical components.

Sun 3000 Solar Simulator Specifications, 1 sun models

Model #	Field size (mm)	Stability (%)	Uniformity (%)	Lamp (W)	Ozone free	Lamp life (hours)	Working distance (mm typ.)	Irradiance AM 1.5G suns (max. typ.)	AM 1.5G spectral match
11000A	55x55	0.5	2	550	☑	1500	200±50	2.0	A
11016A	110x110	0.5	2	550	☑	1500	300±50	1.3	A
11018A	160x160	0.5	2	1000	☑	1500	300±50	1.3	A
11044A	210x210	0.5	2	1000	☑	1500	200±50	1.3	A
11046A	254x254	0.5	2	1400	☑	1500	200±50	1.3	A
11048A	300x300	0.5	2	2000	☑	2000	400±75	1.3 (2.1) ¹	A

¹With the 3kW lamp

The Sun 3000 models listed above are most popular with our customers. They deliver one sun irradiances over the lamp lifetime and limit UV exposure by utilizing an N-BK7 condenser lens. However, if your test needs require a Class AAA multi-sun level of irradiance or UV content matching AM0 or terrestrial atmospheric UV edge see page 18 in this brochure. The above are the most popular field size models. Please let us know if your needs require a different one – many additional square and rectangular shaped field size systems have been manufactured.

Certified

Each Sun 3000 Solar Simulator ships with a performance certificate according to the applicable ASTM, IEC and JIS standards.



Certificate of Compliance
 Product: Sun 3000 Solar Simulator Model 11018A SN 343
 Applicable Standards: ASTM E 927-10; IEC 60904-9 ED. 2.0; JIS C 8912

Spectral fit

Band	Error	Class A limits	Status
400-500 nm	-3.3%	25%	Pass
500-600 nm	2.4%	25%	Pass
600-700 nm	1.0%	25%	Pass
700-800 nm	-2.7%	25%	Pass
800-900 nm	-1.9%	25%	Pass
900-1100 nm	3.6%	25%	Pass

Nonuniformity

Field	Nonuniformity	Class A limit	Status
160x160	1.9%	2%	Pass

Instability

	Period	Instability	Class A limit	Status
STI	0.5 sec	0.36%	0.5%	Pass
LTI	10 min	0.95%	2.0%	Pass

Irradiance: 1 Sun at 36.5 A
 Reference cell used: ReRaRef 6

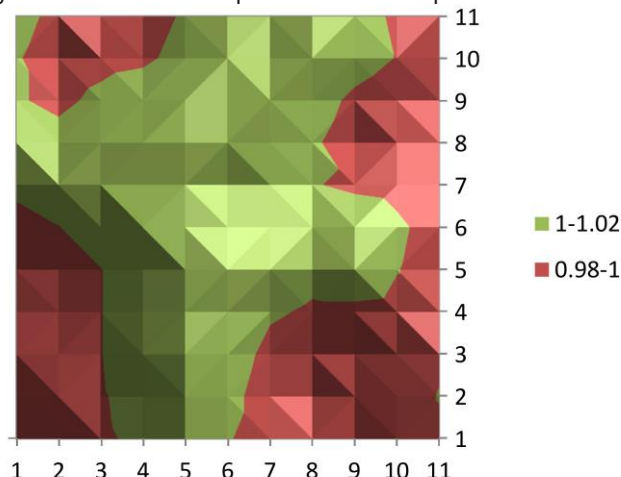
System Class: AAA

[Signature]

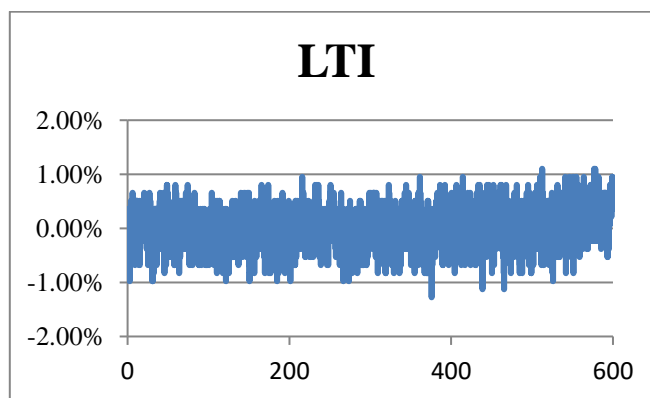
Signature

Available Options

All models listed above include an AM 1.5G filter for ordering convenience. Other filter options can be substituted or added at the time of ordering. Motorized filter wheels are available. Working distances listed above are typical. Systems can be optimized, at no extra cost, at other distances. In particular, the up-pointing and horizontal output models are often shipped with longer working distances to accommodate a glove box or more complex test bench requirements.



Non-uniformity map of an Abet Technologies model 11018A Solar Simulator, 160x160 mm, 1.6%.



Output stability, 10 min, of Abet Technologies model 11018A Solar Simulator, 1.1%

Sun 3000 Solar Simulators, High Output and UV models

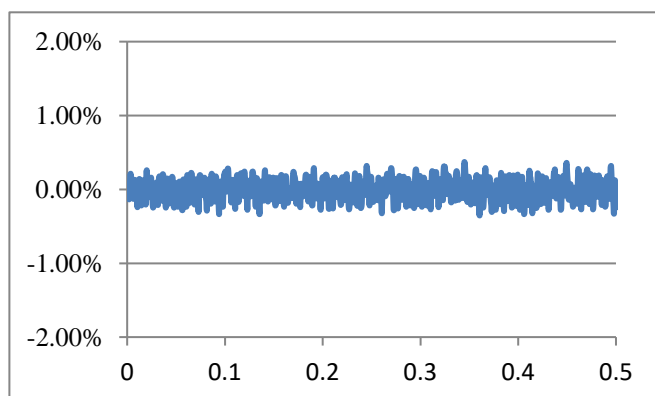
Model #	Field size (mm)	Stability (%)	Uniformity (%)	Lamp (W)	Ozone free	Lamp life (hours)	Working distance (mm typ.)	Irradiance AM 1.5G suns (max. typ.)	AM 1.5G spectral match
11038A	55x55	0.5	2	1000	☑	1500	200	4	A
11040A	110x110	0.5	2	1000	☑	1500	300	2	A
11060A	160x160	0.5	2	1400	☑	1500	300	1.8	A

The above table shows a sampling of more than one sun Class AAA systems available from Abet Technologies. If they do not satisfy your requirements please let us know what your needs are. For those who require a full UV content in their solar simulators Abet offers systems with a Fused Silica condenser lens. Add "-1" to model number for 280-400 nm Dichroic Reflector equipped units to allow accelerated UV aging tests without excessive heating of the test devices. The "-2" Full Spectrum (280-2500 nm) units are most often used with an AM 0 filter for testing of extraterrestrial solar cells. The "-3" systems allow operation in either mode – full spectrum or 280-400 nm by a simple swap of frame mounted reflectors. This option can be customer added to either "-1" or "-2" models when the need arises.

Available Options

Many combinations of lamp power levels and field sizes can be easily assembled without any additional engineering charges. For field sizes up to 254x254 mm any of the standard lamps, 150W, 300W, 550W, 1000W, or 1400W can be used, when matched to the appropriate power supply selection, to obtain a wide variety of irradiance levels. High UV output "-1" 280-400 nm models are often used for accelerated UV damage testing.

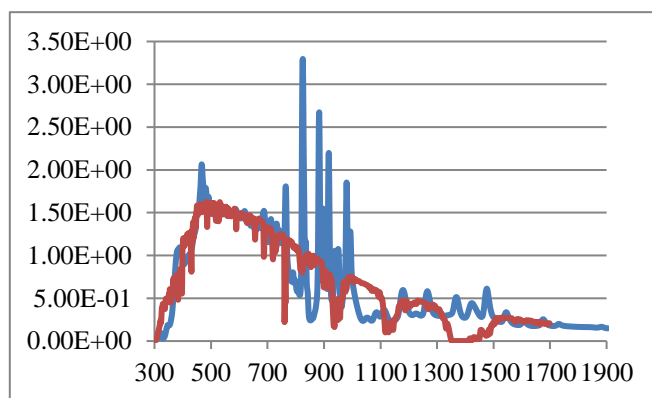
See the ordering information on page 19 for a list of standard options. Please contact Abet if you need something different.



Output stability, 0.5 min (STI), of Abet Technologies model 11018A Solar Simulator, 0.36%

Spectrally corrected

A number of filter options are available for these systems to match their performance to the test requirements: AM 0 filter for extraterrestrial cells, Atmospheric Edge (AE) filter for terrestrial cells with response below 360 nm and for life sciences, UVC, UVB/C, and UVA/B/C blocking filters for material and life sciences.



Typical AM 1.5G filtered output of model 11016A system (blue) overlaid with the AM 1.5G spectrum (red).

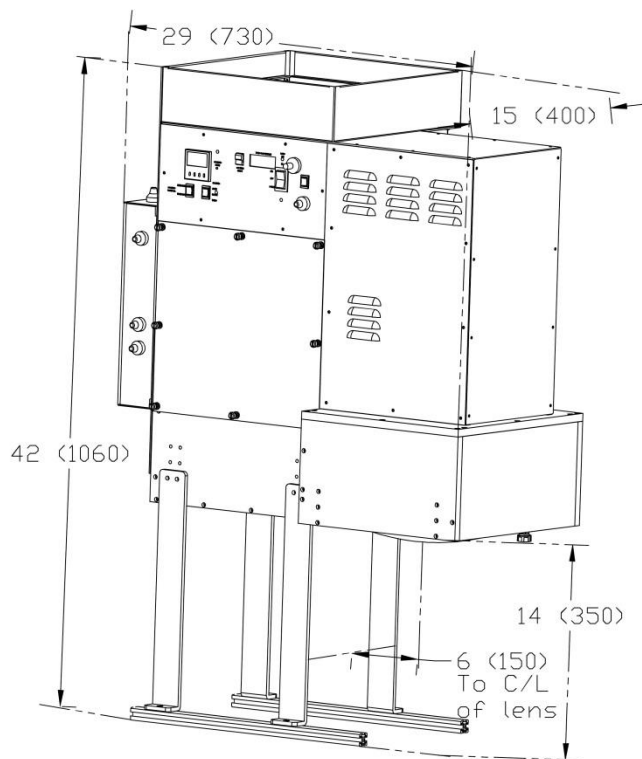
Band	Error	Class A limits	Status
400-500 nm	0.2%	25%	Pass
500-600 nm	-0.2%	25%	Pass
600-700 nm	-1.2%	25%	Pass
700-800 nm	-1.5%	25%	Pass
800-900 nm	-1.3%	25%	Pass
900-1100 nm	3.8%	25%	Pass

Class A stability

Most of Abet Technologies' Solar Simulators achieve Class A stability without the need for Photofeedback function. The 11088 Photofeedback option is included with the system, for the few Sun 3000 models that do not, to assure Class AAA performance.

Sun 3000 Specifications

Illumination field.....	55x55 to 400x400 mm
Irradiance.....	1 to 5 suns
Spectral Match with AM 1.5G, AM 0, AM 1.5D Filters	
ASTM.....	Class A
IEC.....	Class A
JIS.....	Class A
Temporal Stability	
ASTM.....	Class A
IEC.....	Class A
JIS.....	Class A
Irradiance uniformity	
ASTM.....	Class A
IEC.....	Class A
JIS.....	Class A
Ozone-free Xe Arc Lamp (included)	150 to 3000 W
Typical life	1500 hours
HEPA filtered cooling fan included	
Elapsed Time Meter (included)	
Universal Input 90-250V, 50-60Hz, power supply included	
Standard Output Direction.....	Down pointing



Dimensional diagram of the Abet Technologies model 11018A Sun 3000 Solar Simulator, 160x160 mm

Ordering Information

All standard Sun 3000 Solar Simulators include a Lamp, a Universal Input 90-250V Power Supply, an AM 1.5G Filter and a N-BK7 condenser lens. Add "-2" for a Fused Silica condenser lens, "-1" for a 280-400 nm dichroic option, "-3" for a Full Spectrum/280-400 nm convertible unit; add "U" for up-pointing option, "H" for horizontal output.

11000A	55x55 mm, 550 W, filter and lamp included
11038A	55x55 mm, 1000 W, filter and lamp included
11016A	110x110 mm, 550 W, filter and lamp included
11040A	110x110 mm, 1000 W, filter and lamp included
11018A	160x160 mm, 1000 W, filter and lamp included
12060A	160x160 mm, 1400 W, filter and lamp included
11044A	210x210 mm, 1000 W, filter and lamp included
11046A	254x254 mm, 1400 W, filter and lamp included
11048A	300x300 mm, 2000 W, filter and lamp included

Accessories and options

11080	AM 0 filter, Ø 3 in.
11079	AM 1.5G filter, 70x70 mm
11084	AM 1.5D filter, 70x70 mm
11057	AM 1D filter, Ø 3 in.
11059	AM 2D filter, Ø 3 in.
11060	UVA/B/C Blocking Filter, Ø 3 in.
11063	AE filter (Atmospheric Edge), Ø 3 in.
12163	AE filter for 300x300 mm systems
11064	UVC Blocking Filter, Ø 3 in.
11065	UVB/C Blocking Filter, Ø 3 in.
11068	Beam Attenuator ¹ - 21%
11069	Beam Attenuator ¹ - 33%
11070	Beam Attenuator ¹ - 50%
11071	Beam Attenuator ¹ - 60%
11072	Beam Attenuator ¹ - 67%
11073	Beam Attenuator ¹ - 77%
11075	Attenuator Set - All Six Attenuators ¹
12185	System Elevator, Adjustable Height Mount
13014	150 W Xenon Arc Lamp
13020	300 Watt Xenon Arc Lamp, OF
13021	550 Watt Xenon Arc Lamp, OF
13024	1kW Xenon Arc Lamp, OF
13025	1.4kW Xenon Arc Lamp, OF
13026	2.0kW Xenon Arc Lamp, OF
13027	3.0kW Xenon Arc Lamp, OF
11051	Replacement HEPA filter

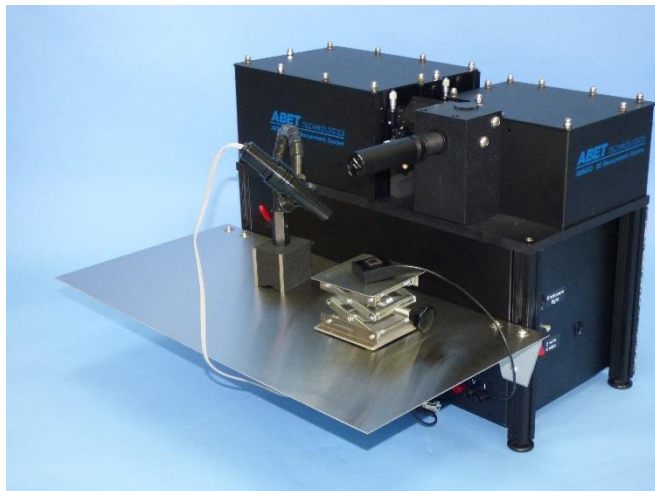
¹ For 150 W and 550 W lamps only

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.

Abet Technologies offers an expanding line of ASTM, IEC and JIS standards compliant products for solar cell PV-IV testing, steady state solar simulators, test stations, software, calibrated reference cells and a selection of electronic loads for low and high current cells. Visit www.abet-technologies.com or contact us at sales@abet-technologies.com.

QE (IPCE) and IQE

Spectral Metrology Tools



Abet Technologies Model AB6000 Quantum Efficiency measurement tool (dark enclosure not shown)

AAA: Adaptable, Advanced, Affordable

Abet Technologies Quantum Efficiency tools, updated for 2019, ship in many flavors making them completely adaptable to the customer's metrology needs. The advanced LED based light source offers stable, long life performance. Choose the spectral range of interest to you and the source will be populated to match your needs. Choose the Xe/QTH source for higher output.

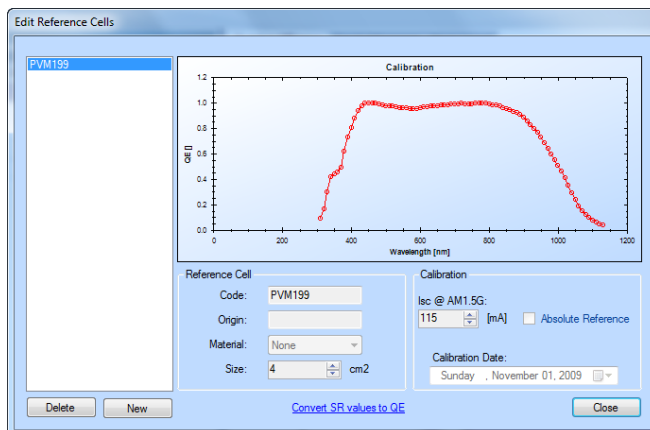
Complete

Your system ships with all the necessary hardware and software. A built in Windows 10 or higher PC allows full control of test parameter settings and instrument performance. PHOTOR software controls the instrument and offers complete data analysis capabilities.

The high-power LED based light source provides stable, long life, easy to modulate output. A fast scanning 250 mm class direct drive monochromator provides high light output. Micrometer driven slits allow reproducible bandwidth control. Spot size reproducibly adjustable with micrometer driven variable slits.

Also included are the required bias light(s), a bias voltage supply ($\pm 10V$), a dual channel lock-in amplifier, an I/V converter with 1k to 10M gain ranges, all necessary reference and monitor cells, temperature monitoring electronics, and as ordered cell mounting and contacting hardware, temperature control, XY translation stages for QE mapping, or the Internal Quantum Efficiency option.

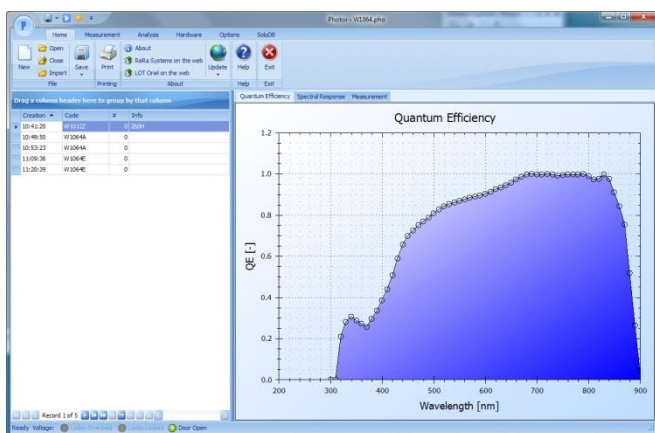
- Complete, Photor driven solutions for spectral characterization
- LED or Xe/QTH based light engines allow DC to high frequency monochromatic light generation.
- 250 mm focal length, direct drive monochromator offers high scan speed and generous light output
- Software included for internal and network database management
- Single and multi-junction devices
- EQE (IPCE) and IQE capabilities
- Spectral ranges 300-1800 nm
- Built-in Windows PC and dual channel lock-in amplifier
- Variable bias light (white or multi-color)
- $\pm 10VDC$ bias



PHOTOR screen with reference cell data

PHOTOR Software

The PHOTOR software package provides a complete control of all system functions in all the models of Abet Technologies' AB6000 family of EQE/IQE systems. Photor also offers standards compliant data analysis for QE, IPCE, IQE, Spectral Response, single and multi-junction, Mismatch Factor, and short circuit current for different ASTM standard spectra. PHOTOR has been developed using the latest Microsoft.NET technology resulting in a Microsoft Office look and feel, minimizing the user learning curve. The algorithms used in PHOTOR meet all the current IEC standards for Spectral Response measurements. Relative measurements can be easily scaled to calibrated currents for different spectral irradiances. All such calculations are done using the ASTM G173 Reference Solar Spectral Tables.



Data can be stored in a local or network database. Intuitive data management and comparison is enabled by the built-in database search and measurement selection capabilities of the Photor software package.

Quick start-up

All systems are shipped completely assembled. Lift yours from the shipping plate to your bench, plug it in and start collecting data within minutes.

Optimized and Flexible Design

A monitor cell is used in every scan to assure data accuracy and reproducibility.

The included DC mode electronics and completely dark enclosure allow QE metrology on organic cells and other slow response materials.

Computer controlled multi-color bias lights and voltage bias option allows multi-junction cells metrology. System design flexibility allows testing of a wide variety of cell types. A partial listing includes: poly silicon, c-Si, mc-Si, nc-Si, III-V compound cells; thin film: Perovskites, CdTe, CIS, CIGS, SI; 3rd generation: organic polymer, dye.

XY scan and multiplexer options offer automated EQE map generation or multiple devices scanning.

Ordering Information

Please use this ordering information as a starting point and contact Abet Technologies or her distributors for any additional product selection guidance.

AB6000 Xe/QTH QE Measurement System includes:

- Installed Photor software package
- 300-1100 nm range
- 100W Xe and 100W QTH bulbs light engine
- DC to 300 Hz chopper
- Order sorting filter wheel
- 250 mm class dual grating direct drive Monochromator
- Dark enclosure with convenience setup light
- Computer controlled Tungsten halogen bias light
- Si monitor cell
- Si reference cell
- Light delivery and spot generating optical assembly capable of down, horizontal and up light delivery
- Micrometer controlled spot size
- Complete electronics bay with
 - voltage and light bias supplies
 - IV converter
 - dual channel 18-bit digital lock-in electronics
 - monitor cell electronics
 - reference cell electronics
- Intel NUC PC with Windows 10
- PC monitor, keyboard and mouse
- Sample Si cell with its QE data to allow system check
- Set of alligator clip cables for basic device connectivity.

AB6000 Xe/QTH QE - IR Measurement System includes:

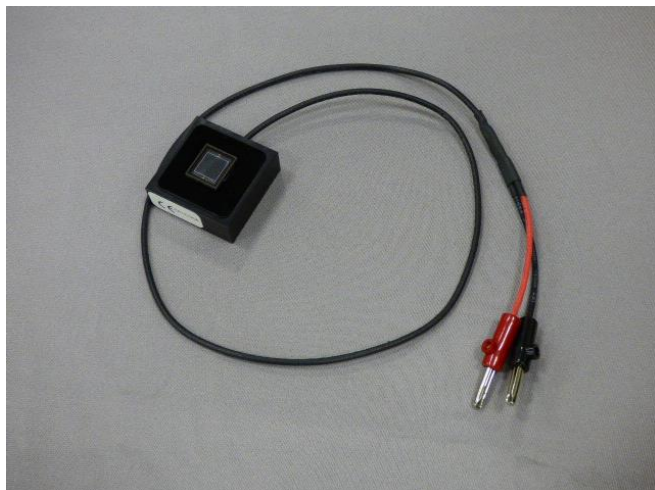
- All the items above plus
- Germanium reference and monitor cells
- Three color bias lights

Please order probes and chuck to match your cells separately.

Accessories and Options

AB2160	300-1100 nm IQE total reflectance option
AB2161	300 nm – 1800nm IQE total reflectance option
AB2162	IQE total transmittance option; requires either AB2160 or AB 2161
AB2170	motorized XY table, 160x160 range min
AB2142	Computer controlled multi-color bias light with selectable LEDs (standard selections 455 nm and 810 nm)
15090	Universal test platform
15090-M	Magnetic base
15250F-R	Micromanipulator, precision, right handed
15250F-L	Micromanipulator, precision, left handed
15251L	Micromanipulator, low resolution
	For 50x50 mm or smaller devices
15545	Test station, bottom-bottom contact
15114	DSSC test station, 2.54 mm contact spacing

QE Si and Ge Reference cells



Abet Technologies Model AB2152-1 QE Si Reference cell

QE measurement necessity: Traceable reference cells

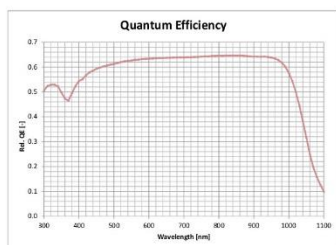
Abet Technologies' NIST traceable Si and Ge reference cells were designed for highly linear response at signal levels typical of QE and IQE metrology.

Complete

Each cell shipped with a calibration certificate and a .csv file for easy integration with your QE software package.



Device Code: RR1331
Date: 20-Sep-16



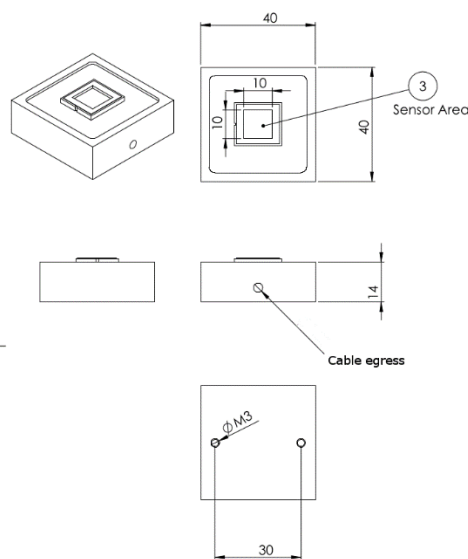
System: SP2000ST
Lab: RERA IV Converter
Rev: Rev B
Software: Beta Plotter
Reference: SQP100
Contact calibration lab for error analysis

RERA SOLUTIONS

Approved:
E. Haverkamp

A sample calibration certificate

- 280 nm to 1800 nm calibration options
- NIST traceable calibration



Dimensional diagram

Calibration accuracy

Silicon:

- ±3% (440 - 980 nm)
- ±5% (280 - 439 nm)
- ±7% (200 - 279 nm, 981 - 1100 nm)

Germanium:

- ±5% (700 - 1800 nm)

Ordering Information

- AB2152-1** Si reference cell, 300-1100 nm NIST traceable Calibration (ask for 280 nm optional calibration)
- AB2152-2** Ge reference cell, 700-1800 nm NIST traceable calibration

These cells are included with the AB6000 QE systems as required for the wavelength range of interest.

Solar Reference Cells



Abet Technologies Model 15150 Reference Cell

Quantitative Metrology

All solar simulators are subject to output variations with time due to component aging. Reference cells need to be used to allow both the initial system setting and later the maintenance of irradiance levels. Abet Technologies offers an array of reference cell models to match your metrology needs and budget.

Convenient

Standard models provide current output allowing the use of I_{sc} as the irradiance level indicator. Those models also allow a complete four wire PV IV curve generation. Your PV IV system check can be performed by comparing your lab collected data with that included with the reference cell calibration documentation.

Shunted models include a high stability $1\ \Omega$ shunt resistor converting reference cell current to a voltage output for easy measurement with any voltmeter. You cannot use the shunted models to obtain an IV curve.

- Traceable to NIST, NREL, Fraunhofer ISE and ISPRA standard artifacts
- Calibration accuracy established through international comparisons
- Spectral mismatch minimizing selection of C-Si, PERC Si, KGx and other filters, GaAs, and triple junction InGaP, InGaAs, Ge cells
- Low cost models for entry level calibrated metrology

Spectral mismatch

No solar simulator provides 100% spectral match to the standard spectrum. Therefore all efficiency measurements include some spectral mismatch induced errors. Correcting for those errors can be accomplished in two ways. One can measure quantum efficiency of the device under test (DUT) and the reference cell as well as measure the spectral irradiance of the solar simulator (a rather extensive set of measurements). Else, a simpler way is to use a reference cell with spectral characteristics close to the DUT.

Reference cell to DUT matching

Use standard Si reference cell for Mono-crystalline Silicon, Multi-crystalline Si, CIGS; use PERC Si cells for PERC devices

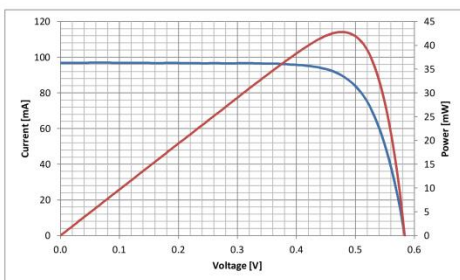
Use Si reference cell filtered with KG1, KG2, KG3, or KG5 for Amorphous Si (a-Si), Dye sensitized cells; 780nm for Perovskite on Si

Use GaAs reference cell for Gallium Arsenide (GaAs), Cadmium Telluride (CdTe)

Silicon and GaAs Reference Cells

ABET TECHNOLOGIES, INC.
168 Old Gate Lane
Milford, Connecticut 06460

Device Code: RR-109-O
Date: 10-Mar-11 2:06 PM
Reference: PVM199
Area: 4 cm²
Irradiance: 1000 W/m²
Spectrum: AM1.5G
Temperature: 24.4 °C
Corrected to STC: Yes



I_{sc}	96.8 mA	J_{sc}	24.2 mA/cm ²
V_{oc}	584 mV	I_{mpp}	89.8 mA
FF	75.7 %	V_{mpp}	476 mV
Eta	10.7 %		

Source: Abet Technologies Solar Simulator
Load: Keithley 2400
Temperature: PT100
Software: Refla Tracer
Contact calibration lab for error analysis

Approved:
E. Haverkamp

Sample calibration report for a Model 15150 Solar Reference Cell

Spectral Calibration option

A Relative Spectral Calibration option is available for all the 15150 and 15155 Reference Cell models to assist in Spectral Mismatch determination and correction.

Electrical connections

The reference cell mounts are equipped with two LEMO ERA.0S.304.CLL connectors. One of those brings out the four wire output and sense from the cell. The other serves as a Pt100 sensor connection. A 2 m long, 4 mm banana plug terminated cable is provided for cell output connection. A matching LEMO connector is provided to allow making of the Pt100 sensor connection.

Note: For shunted cells only I_{sc} (or its equivalent output voltage) is measured and reported.

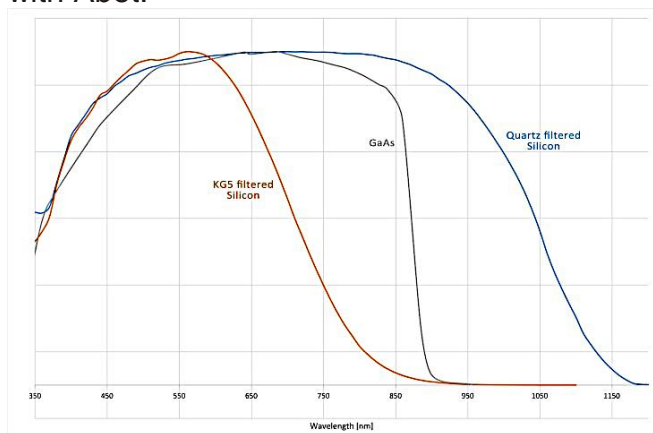
Specifications

Si and GaAs Reference cells

Solar cell.....Mono-crystalline Si or GaAs
Solar cell area.....4 cm²
Window.....Fused Silica
Calibration conditions.....1000 Wm⁻²
AM 1.5G, 25°C
Parameters reported..... I_{sc} , V_{oc} , I_{mpp} , V_{mpp}
FF, efficiency
Uncertainty in I_{sc}±3%
Temperature sensor.....4 wire Pt100
Typical I_{sc} Si.....125 mA
GaAs.....100 mA

Model 15150-KG5 models ships with a KG5 window. The calibration uncertainty in I_{sc} for the KG-5 filtered cells is also +/-3%.

Other filter options available – please consult with Abet.



Typical quantum efficiency curves

WPVS Compatible Mount

The full featured Abet 15150 series of reference cells comply with the 62x62 mm WPVS standard dimensions to allow easy intercomparison of different devices. Overall dimensions 105 x 74 x 16 mm.

Triple Junction Reference Cells



Abet Technologies Model 15152 Reference Cell

Triple junction cell metrology

Multi-Junction solar cell metrology is more complicated than that of a single junction one. As these cells are made of multiple layers, a multi-source/LED solar simulator is usually employed to allow adjustment of band to band irradiance ratios. Our triple junction reference cells can be used to set the correct irradiance for each single junction.

Specifications

InGaP/InGaAs/Ge Cells

Solar cell area.....4 x 1 cm²
Window.....Fused Silica
Calibration conditions.....1000 Wm⁻²
AM 1.5G, 25°C

Parameter reported for each component cellI_{sc}
Uncertainty in I_{sc}.....±3%
Temperature sensor.....4 wire Pt100
Typical I_{sc} InGaP: 15 mA
InGaAs: 15mA
Ge: 25 mA

Connectors:

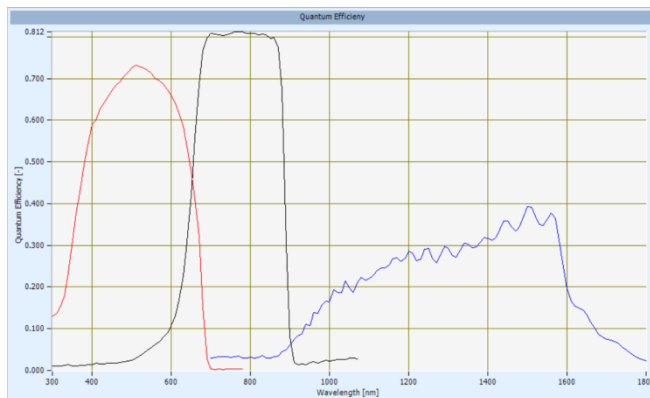
Triple junction: LEMO ERA.0S.304.CLL
Component Cells: LEMO EGG.1B.306
Pt100 (4 wire): LEMO ERA.0S.304.CLL

Construction

The device consists of 4 x 1cm² shunted cells mounted in an area of 2x2 cm. Water cooling is possible. Calibration data is provided for the three (3) individual component cells. A component cell is a single junction cell made exactly the same as the triple junction cell. So each component cell has three layers, where only one layer controls the I_{sc}.

Example

The 'middle' component cell consists of a layer of InGaP (top), InGaAs (middle) and Ge (bottom). Only the InGaAs and Ge are electrically active, so you measure a single junction InGaAs cell since Ge can source more than InGaAs. Since there is an (inactive) InGaP cell on top, the blue part of the spectrum is filtered. This allows you to measure what the InGaAs cell would 'see' in the stack of a normal triple junction cell while avoiding current limiting contributions of the top layer. InGaP and Ge are active for the top layer measurement, only Ge is for bottom.



Typical quantum efficiency of individual cells

Note: Only I_{sc} (or its equivalent output voltage) is measured and reported. A six wire cable for the component cells and a four wire one for triple junction cell are included. A LEMO connector is included for Pt100 wiring.

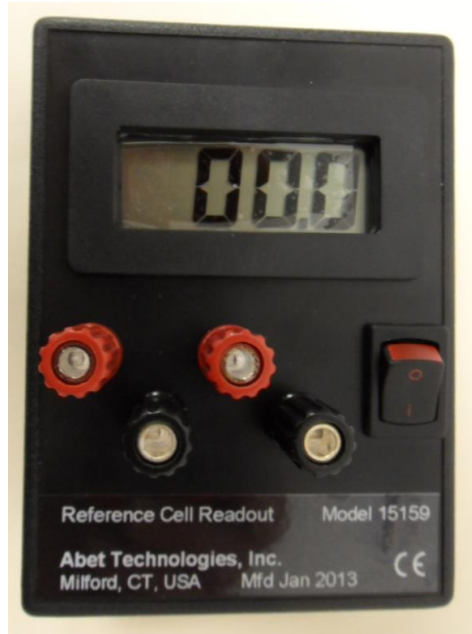
Using the solar reference cells

Model 15150 series reference cells without a shunt can be utilized using the PV-IV curve tracer electronics. They can also be used in a standalone mode using a low input impedance current meter like Abet Technologies Model 15159 Calibrated Readout. Four wires are attached to the sensor to make 4-point measurements possible. These wires are terminated with banana connectors (two red and two black). The Pt100 temperature sensor is connected by means of 4 wires. Any 4-wire capable Pt100 readout device can be used to measure the temperature.

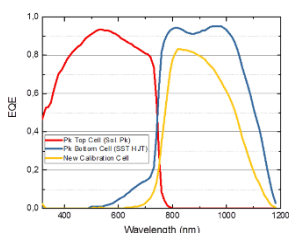
Calibrated Readout

Model 15159 Calibrated Readout can be calibrated for a particular Model 15150 reference cell to display 100.0 when the cell is exposed to one AM 1.5G sun irradiance. It can also be shipped calibrated to offer 1.0 Ohm input impedance and be then usable with a number of different cells, displaying their calibrated I_{sc} at one sun irradiance conditions.

Please note that unless the cell and readout are calibrated together there will be a slight systematic error introduced due the readout voltage burden moving cell operating point away from the short circuit condition.

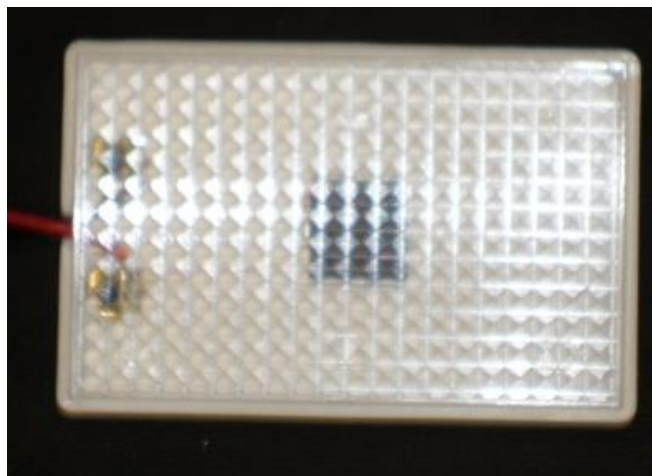


Abet Technologies Model 15159 Calibrated Readout



15150-780 Reference cell response with Perovskite on Si cell. (Data courtesy of Dr. Brett Kamino)

Low Cost Reference Cell



Abet Technologies Model 15151 Reference Cell

Model 15151 reference cells offer an entry level means for calibrated solar cell metrology. Each 10x10 mm cell comes calibrated to deliver 100 mV output at one AM 1.5G sun which can be easily read with any voltmeter. Calibration accuracy is 6% at the time of shipment. Enclosure size is 55x36x7 mm. Model 15151-KG5 cells add a KG5 window to more closely match spectral response of amorphous Silicon and Dye Sensitized Cells.

Relative responsivity data option is not available for the 15151 family of cells.

Ordering Information

15150	Si Reference Cell, 20x20 mm
15150-KG5	Si Reference Cell, 20x20mm, KG5 filter window
15150-780	Si Reference Cell, 20x20 mm, 780nm filter for Perovskite on Si cells
15150-P	PERC Si Reference Cell, 20x20 mm
15151	Low cost Si reference cell, 10x10 mm
15151-KG5	Low cost reference cell, 10x10 mm, KG5 filter
15152	Triple Junction Reference Cell, 4 x 10x10 mm
15155	GaAs Reference Cell, 20x20 mm
15153	Spectral Response Calibration, Triple Junction
15154	Spectral Response Calibration, Si or GaAs

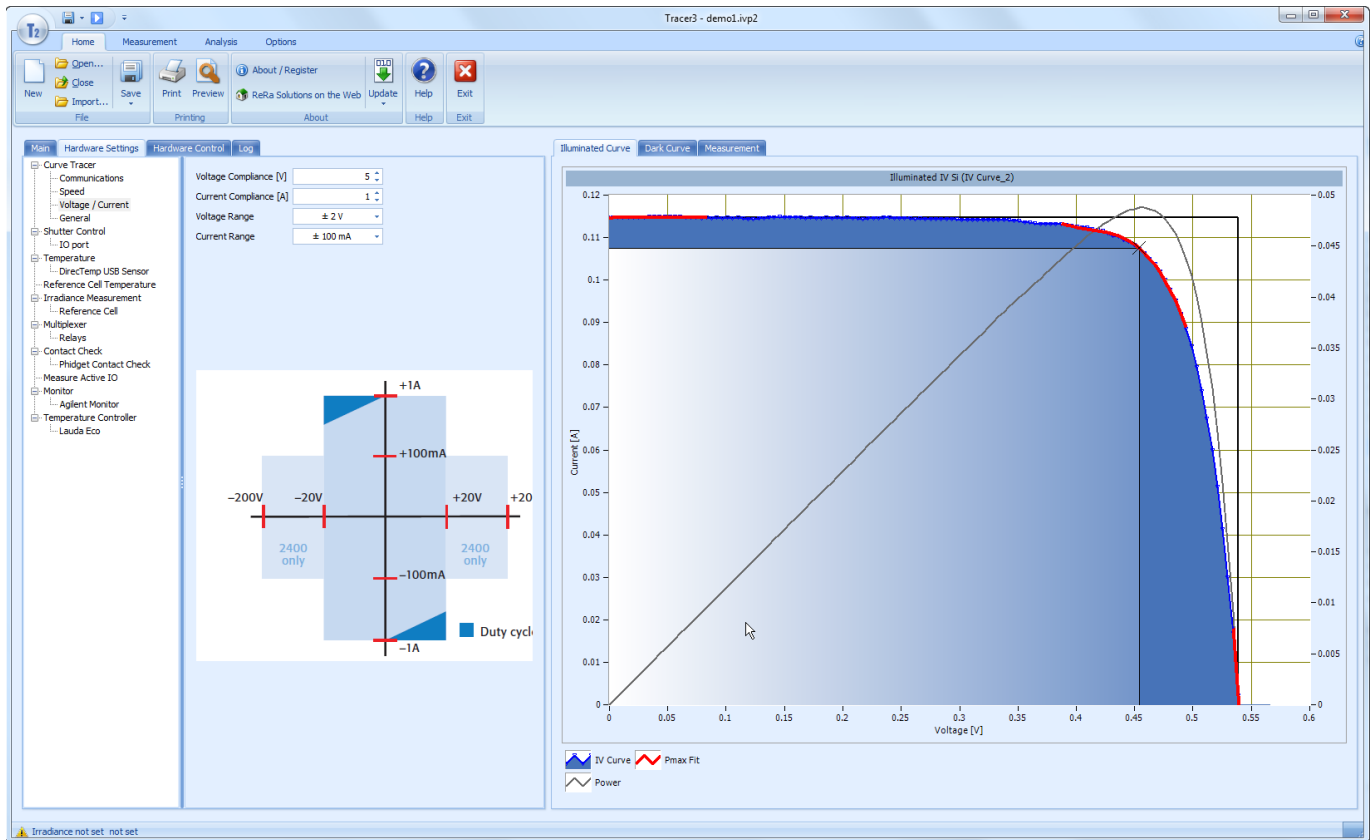
Add "S" to any reference cell model number for shunted version.

Add "-KGx" to any reference cell model number to replace fused silica window with a KG1, KG2, KG3, or KG5 filter. Other filter options available on request.

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.

Tracer™ PV IV Software

Complete solar cell and module IV-curve tracing and analysis



Tracer 3 – Power and Convenience

This third generation Tracer™ software package, Model 15000, builds on the field experience with the previous offerings and greatly simplifies hardware interaction while adding more data acquisition and analysis power.

In Tracer™ you will find your all-in-one solution for the measurement and elaboration of IV-curve measurements. Tracer™ natively supports all of the Abet offered electronic loads including the complete range of Keithley 24xx and 26xx SourceMeters™, Kepco bipolar amplifiers and Agilent DMMs.

Tracer™ was developed with the latest Microsoft.NET Technology, which resulted in a modern “Microsoft Office” look and feel and assures stable operation on the Microsoft Windows platform.

Computer Requirements

- Microsoft Windows 7 or higher
- Support for both x86 and x64 bit.
- Minimum Intel Core i3 (or similar), 2Gb memory

Elaboration algorithms

The algorithms used in Tracer meet the IEC-standards for Efficiency measurements. Different dedicated fitting algorithms to extract the two-diode model parameters are included. Spectral Mismatch correction is supported.

Organic cells

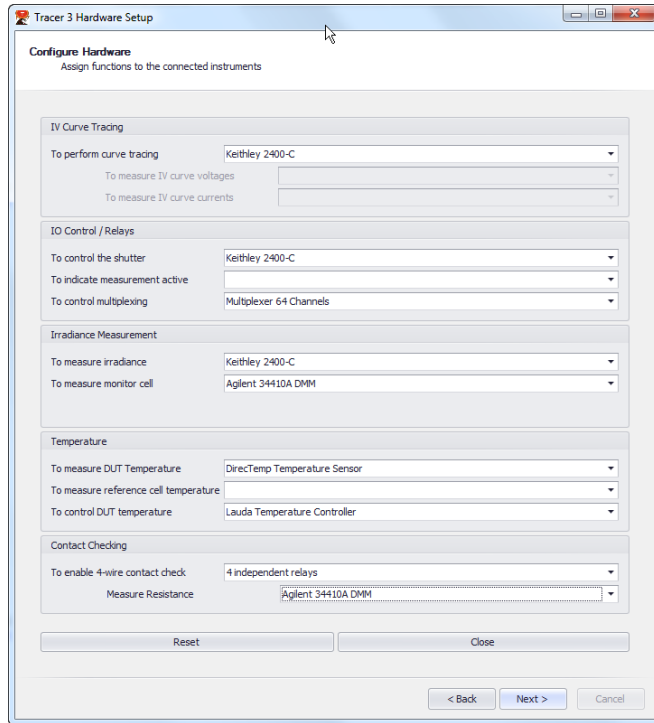
Since crystalline cell-based models may not represent organic materials quite as well Tracer™ supports import of additional fitting algorithms that may be better suited for analysis of these cells.

Tracer Analyzer

If you need to analyze your data away from the lab a lower cost Tracer Analyzer software package is available with all the analysis power of the standard package but without its instrument control features.

Hardware Configuration

The hardware configurator is a flexible tool which allows creation of a large number of different setups. The configuration can be a simple IV measurement system based on a Keithley Source-Meter™ and low-cost solar simulator. For the more expert user it is possible to configure Tracer to be used in a highly sophisticated setup, with contact checking, irradiance monitoring, multiplexing, motion control and temperature readout/control.



Tracer™ has the ability to control the following instruments:

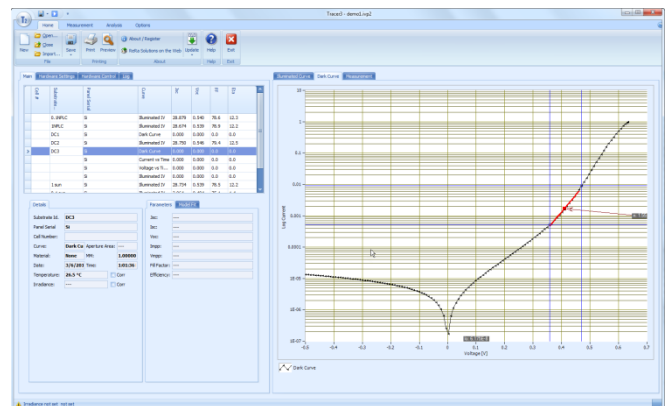
- Complete range of Keithley Source-Meters™ (both 2400 and 2600 series) and Keysight source measure units
- Kepco Bi-Polar power supplies
- Common models of Keithley and Agilent DMM's and multiplexers
- DirecTemp high precision temperature sensors
- Lauda ECO liquid chiller/heaters
- All of Abet's applicable instruments (Reference Cells, Loads, Read Out units, Shutter Controllers, Module measurement systems, Temperature measurements devices, XY positioning tables and multiplexers)

Example: you have a Keithley 2400 Source-Meter™ and Agilent 34410A DMM available. You can configure Tracer™ to measure the solar cell by the front input of the Keithley 2400, use the rear input to measure the reference cell. Use the Agilent DMM to measure a Pt100 that is connected to your solar cell and also use it, with the help of an Abet multiplexer, for a continuous monitor cell.

- **Measurements:** V_{oc} , I_{sc} , J_{sc} , V_{mpp} , I_{mpp} , FF , η , R_{sh} , R_s , n , $Suns$ over V_{oc} , I vs. time, V vs. time and more
- IEC standards compliant correction to STC
- Wide range of Electronic Loads (Source-Meters) and Solar Simulators supported
- Single cell and module metrology
- Light and Dark curve measurement
- Long term measurements and light soaking
- Temperature dependency analysis
- Full database support (SQL, MySQL)
- Numerous solar cell material specific models included
- Integrated scripting engine
- Remote control (http) for simple integration in existing applications

Automatic Data Storage

All data is stored in native project files. Export to many different file formats is included (.txt, .csv, .xlsx, etc....). Tracer™ supports the usage of MySQL or SQL Server databases. Our experts can help you set up a database system where all measurements are automatically stored. A simple viewer that shows the results in the database is included with the software package.



Tracer™ 3 Dark curve data screen

Components of a PV IV system

- Solar Simulator
- Electronic load
- Vacuum chuck
- Contact probes
- Data acquisition and analysis software
- Reference cell
- Temperature monitoring or control
- Dark enclosure
- Alignment microscope
- Motion control

A wide selection of PV IV system components is available from Abet Technologies to match the specific test requirements of different cell types and sizes. Some of those components, like our solar simulators, software and reference cells are more fully described on previous pages.

Here we focus on the remaining parts of the system.

Electronic load options

PV IV curves span a range of currents from pA levels to tens of Amps. Since not everybody needs to cover that whole range of values we describe the useful ranges for load options available from Abet.

Different models of Keithley SourceMeters™ cover a wide range of current levels. The more economical 2400 series SourceMeters™ work well with low to mid-range capacitance cells. Stabilizing circuits can be used to extend their load capacitance capabilities but at some cost to speed. The 2600 series units offer native High Capacitance mode, for up to 50 μ F capacitance cells, and higher speed of operation. Keysight source measurement models offer competitive performance.

For higher current measurement ranges Abet combines a wide range of Kepco and other manufacturer's bipolar amplifiers with USB control circuitry and Keysight (Agilent) high speed DMMs to offer loads rated up to 125 A and 1000 W and still capable of dark curve generation.



Elements of Abet 15295 Universal load, 10A capacity

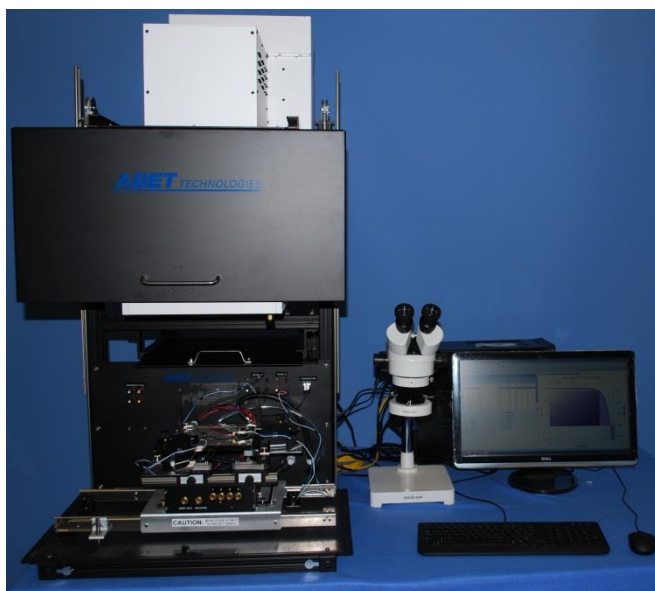
Our updated 15295 universal load combines two high speed Keysight (Agilent) 3446XA DMMs with a custom bipolar amplifier and a multifunctional USB interface to produce a selection of electronic load systems capable of dark curve and up to 125 A current metrology for up to 10 mF capacitance cells. Adding a third DMM allows simultaneous reading of a monitor cell.

In the table below, we list the current measurement specifications for some of the loads available from Abet. Please consult manufacturer's individual instrument data sheets for the full range of their specifications. Please ask us if you need a different load type.

Abet Standard Loads	Max current	Resolution	Accuracy
15295 Abet Universal Load, max. cell capacitance 1 mF	125 A	100 pA	40 nA
Keithley 2401 (and 2400)	1 A	50 pA	300 pA
Keithley 2440	5 A	500 pA	700 pA
Keithley 2601B	3 A	100 fA	100 pA
Keithley 2601B, 50 μ F max. high cap. mode	3 A	1 pA	500 pA
Keithley 2635B	3 A	1 fA	120 fA
Keithley 2635B, 50 μ F max. high cap. Mode	1.5 A	1 pA	400 pA
Keysight B2901A	3 A	100 fA	60 pA

All specifications subject to change without notice.

PV IV system chucks, stages and accessories



Abet Technologies 11018A Sun 3000 Solar Simulator with a 15514 Dark Enclosure with 15448 Slide assembly, 15510 Vacuum Chuck, 15511 Micromanipulator base, two 15250 Micromanipulators, 15552 Stereo Zoom Microscope, and a PC with Tracer™ PV IV software

Chucks and stages

Over the years Abet's standard selection of chucks developed for silicon solar cells has been complemented with many custom designs for newer technologies and these are now offered as standard products, too.

If you do not find what you need on the following pages, please let us know and we can quote yet another custom design.

Sandbox designs, placing a variety of test devices on a single substrate, are often used to cut the cost and speed up development efforts. Ossila 8-device substrates are an example of such technologies for thin film devices.

Abet Technologies developed a number of test arrangements to work with such devices, some with fixed contact pattern, some with variable position contacts.

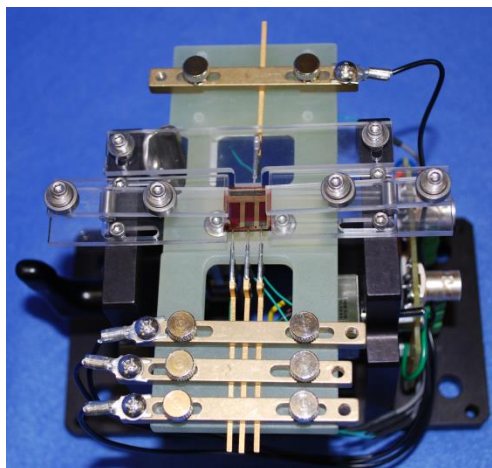
Manual and electronic multiplexing options are available.

For thin film substrate, superstrate and sandwich devices we have a number of inexpensive mount and contact solutions.

Flip chuck option for ease of alignment.

Temperature monitoring and cooling options are offered when device mounting means allow.

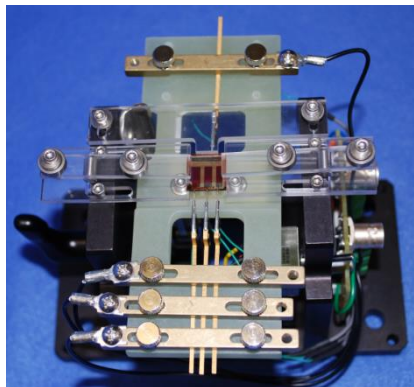
- Vacuum chucks with zones for standard and custom cell sizes, 3 mm to 300 mm
- Four wire test methodology standard
- Top-bottom, top-top, and bottom-bottom contact geometries accommodated
- Electrical contacts: spring loaded bus bars, micromanipulators, custom probes
- Bus bar and micromanipulator options easily field switchable on 155XX chucks
- Dark enclosures
- Glove box compatible models
- Multi-cell devices multiplexing models
- Top, side or bottom illuminated models
- Flip chuck for ease of contact alignment
- Wide temperature range cooling/heating
- Basic models can be field modified for temperature control
- Calibrated temperature monitoring
- Attenuator for Bowden method of R_s determination included in many models
- Light color filtering options
- All tools and components for normal use and maintenance included



15545 Back contact, three device cells test station

Multiple device and sandwich cells test stations

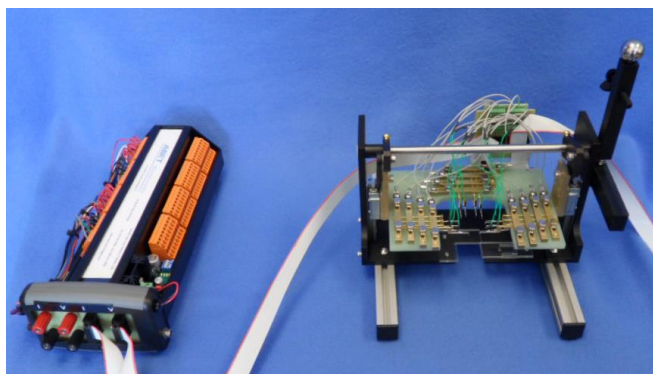
Top-illuminated superstrate stages



15545 Back contact, three device cells test station

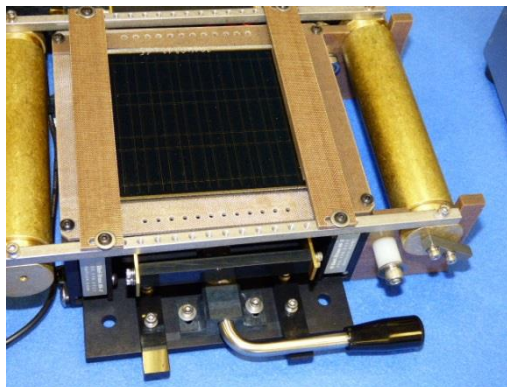
The 15545 back contact station has adjustable contacts for up to three superstrate devices and one common contact. A three-position toggle switch allows selection of the DUT. Up to 25x25 mm cells can be accommodated.

We have designed many additional variants of this station for our customers allowing larger device sizes or more than three devices.



15545-B Adjustable back contact, eight device cells test station with 15277 multiplexer. Top or bottom illumination compatible.

Manual and computer controlled electronic multiplexing options have been shipped.

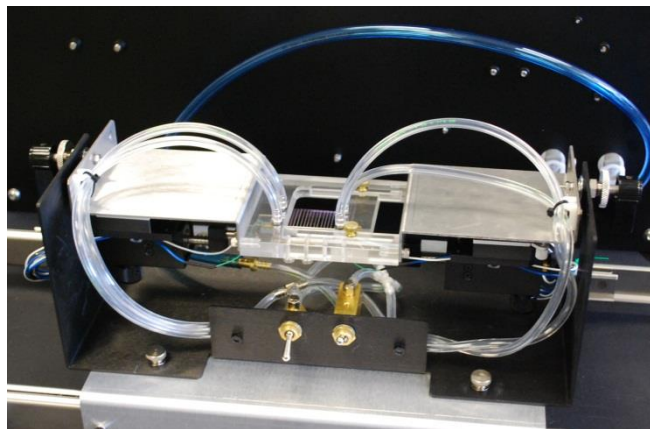


15545-MOD Mini-module test stage

The 15545-MOD allows testing of individual cells in a mini-module as well as the whole mini-module with the help of custom electronic multiplexer.

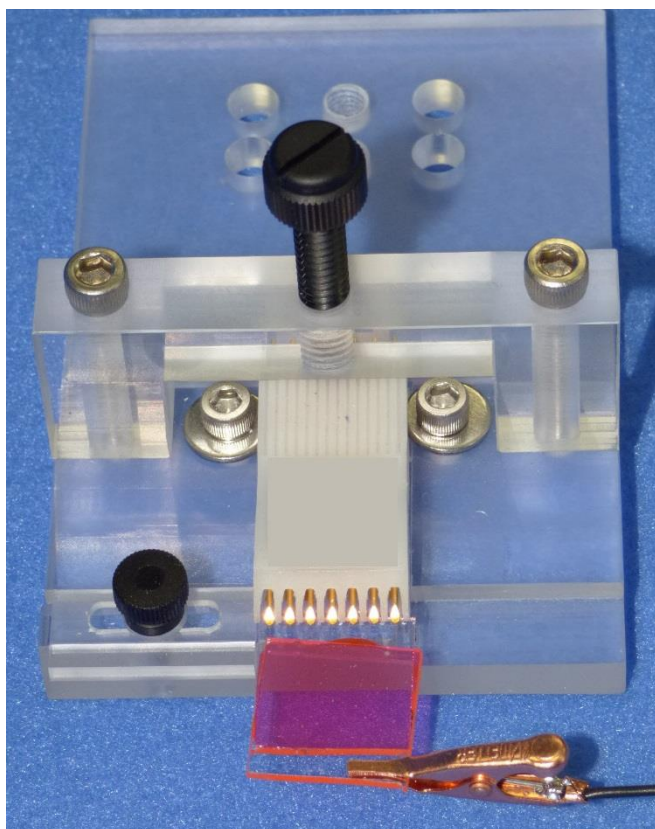
Abet Technologies model 15511 Vacuum Flip Chuck is used for back contact cells with small contact pads. The chuck allows contact alignment under a microscope and then is flipped 180° for top illumination. It is usually mounted on a slide to allow translation between the alignment and exposure locations. Alternatively, solar simulator and microscope can be slide mounted. Up to 50x50 mm active area can be probed on a maximum of a 100x100 mm substrate.

Two 15250 micromanipulators are required to contact the cell.



15511 Vacuum Flip Chuck with two 15250 micromanipulators on a 15448 slide assembly

DSSC and Thin Film Superstrate, Substrate or Sandwich device stages



Abet Technologies' Model 15114 Stage with a DSSC cell

Simpler Design, Lower Price

Abet Technologies' model 15114 Stage facilitate testing of small solar cells with electrodes located on the sides. Standard version allows testing cells with 1-7 devices (set on 2.54 mm centers).

Stage is top or bottom illumination compatible.

Our design goal was to use the minimum necessary number of parts to make an easy to use fixture compatible with a large variety of solar cell device architectures. We think the picture tells the story.

This stage is compatible with solar cells of sandwich construction as well as superstrate and substrate thin film devices.

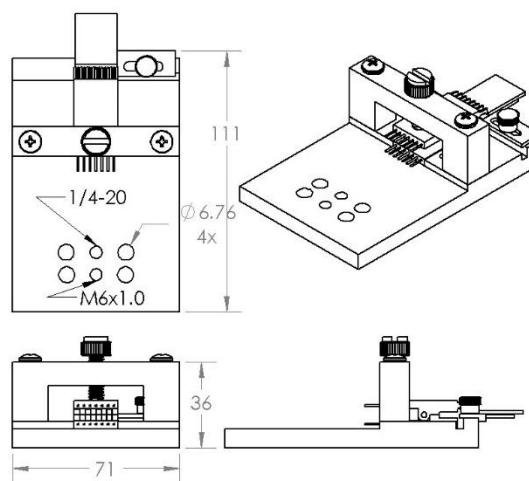
Gold plated rounded contact pads provide good electrical contact without damaging the thin film materials.

Manual and electronic multiplexing options allow quick testing of all the devices on a substrate. Tracer or Photor software sequences can be used to automate data acquisition.

- Low cost, flexible test fixtures
- Work with any solar cell with edges-located electrodes
- Top and bottom illumination compatible
- Allow multiplexing of 1-7 or 1-12 devices on 2.54 mm centers
- 1 mm to 5 mm thick devices accommodated
- Adjustable locator allows correct and reproducible device positioning
- Metric and English screw mounting compatible

Flexible and extendable capabilities

The design is easily adaptable to a larger number of devices per substrate (as long as the 2.54 mm spacing rule is obeyed). Thicker than 5 mm devices can be easily accommodated if Abet is notified at the time of ordering. Thinner than 1 mm devices can be easily accommodated with a number of design options which depend on the substrate fragility. Flip mounting options available if device architecture and illumination conditions require it.

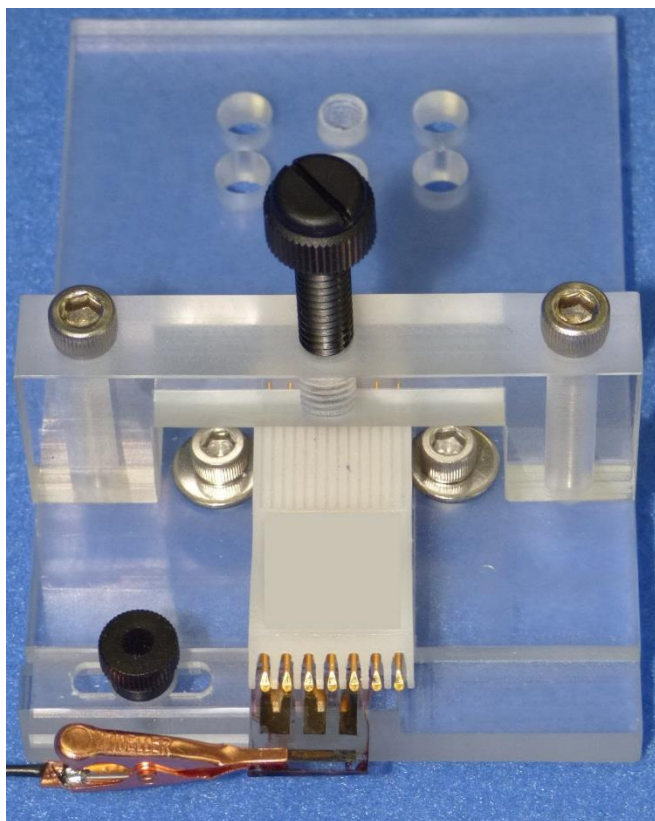


15114 stage dimensions

15114 Stage Specifications

Device size 3 – 25 mm
Device thickness 1 – 5 mm
Number of devices per substrate 1 – 7
Gold plated round contacts for thin film protection
Manual and electronic multiplexing options
Metric and English mounting accommodation included

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.



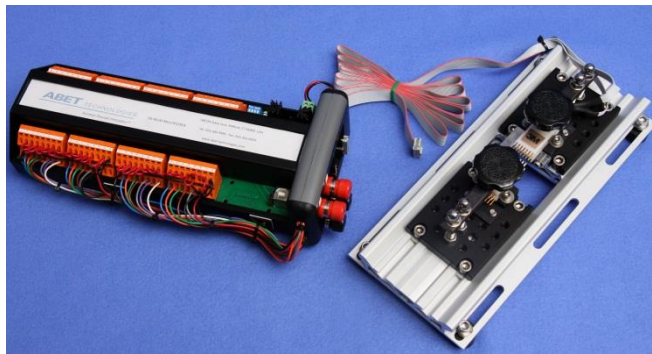
Abet Technologies' Model 15114 Stage with a three-device solar cell

15110 Stage Specifications

Device size 3 – 25 mm
Device thickness 1 – 5 mm
Number of devices per substrate 1 – 12
Gold plated round contacts for thin film protection
Manual and electronic multiplexing options

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.

The 15110 station, like the 15114, uses modified chip testing clips to contact device electrodes located on 2.54 mm centers. In this more robust system 14-contact clips (7 positions, top and bottom) are used. The signals can be selected manually or a 15277 Multiplexer, with 64 relays, 1A capacity, can be used to speed up test procedures under Tracer™ software control.



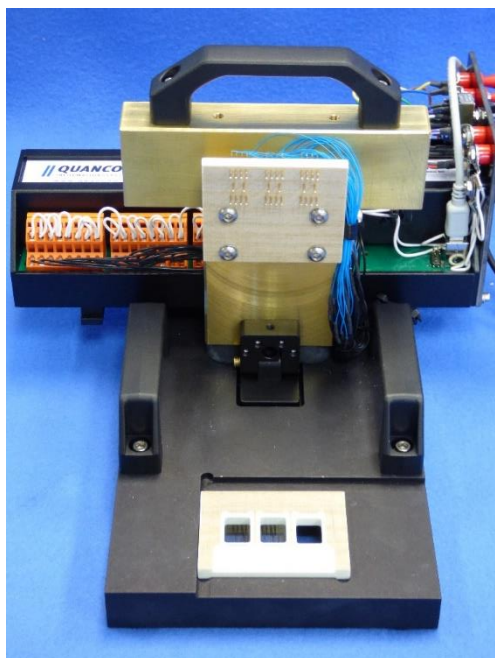
15110 station with 15277 Multiplexer

Ordering Information

15110	DSSC test stage, 2.54 spacing
15114	DSSC test stage, 2.54 spacing
15283	Manual multiplexer
15277	Electronic multiplexer
15151	Low cost reference cell
15151-KG5	Low cost reference cell with KG5 filter

Abet Technologies offers an expanding line of ASTM, IEC and JIS standards compliant products for solar cell PV-IV testing, steady state solar simulators, test stations, software, calibrated reference cells and a selection of electronic loads for low and high current cells. Visit www.abet-technologies.com or contact us at sales@abet-technologies.com.

Bottom illuminated stages for Ossila and similar devices



Abet Technologies 15114-3 test stage for three 8-device Ossila superstrate based solar cells with a 15277 multiplexer

Multiple device cell test stations

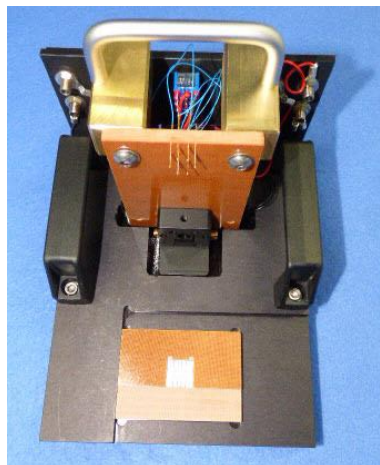
Sandbox designs, placing a variety of test devices on a single substrate, are often used to cut the cost and speed up development efforts. Abet Technologies developed a number of test arrangements to work with such devices. Here we show two of those.

The 15114-3 station accommodates up to three devices based on 8-device Ossila substrates.

The signals can be selected manually or a 15277 Multiplexer, with 64 relays, 1A capacity, can be used to speed up test procedures under Tracer™ software control.

- Multiple superstrate device stages
- Four wire test methodology standard
- Glove box compatible bottom illumination
- Electrical contacts: spring loaded probes
- 4 to 64 relay multiplexer options
- Reference cell locators assure irradiance measured at device level
- All tools and components for normal use and maintenance included

The 15114-4 stage accommodates a 15x15 mm substrate with 4 devices.



Abet Technologies 15114-4 test stage for a 15x15 mm 4-device superstrate based solar cell with a 4-relay multiplexer

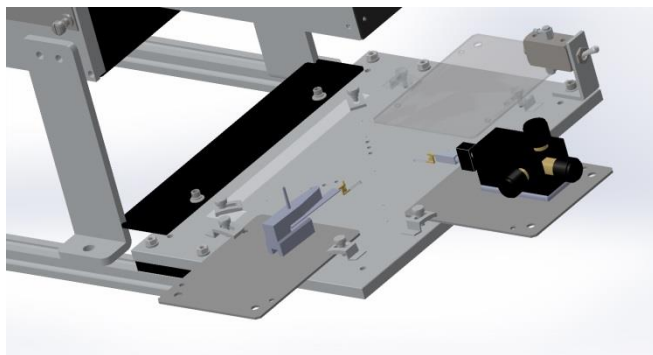
Both stages are designed for bottom illumination for glove box compatibility.

A recessed locator area positions the 15150 series reference cell sensor at the same height as the devices being tested to assure correct irradiance metrology.

These very flexible designs can be easily modified for your devices if the contact geometry or device count is different. Please let us know your needs.

Universal PV IV Vacuum Test Platform

Abet Technologies Model 15090 Universal Test Platform with adjustable 15090-M magnetic bases and 15250F-L and 15251L micromanipulators.



Adaptable Entry Level Tool

Reproducible cell positioning and reliable electrical contacts are key to meaningful metrology. The versatile 15090 Universal Test Platform offers those qualities for those with entry level budgets.

Reconfigurable vacuum zones

User can easily modify vacuum distribution to match cell sizes being measured: a single vacuum hole for the smaller cells, multiple vacuum holes for larger ones.

Electrically isolated

The chuck is electrically isolated to allow its use as one of the cell contacts. It can be mounted to the supporting rails on one of the Abet's Sun 2000 or Sun 3000 simulators or used free standing with the optional Model 15090-F levelling feet.

Micromanipulator ready

Use the basic platform with vacuum base micromanipulators or add the optional 15090-M magnetic bases to allow use with Abet's magnetic base micromanipulators. Base positions are adjustable to optimize micromanipulator locations.

The following micromanipulators are compatible with this test platform: the high resolution 15250F-L and 15250F-R models and the 15251L low resolution unit.

Locators included

Fixed position cell locators for 156x156, 125x125 and 100x100 mm cells as well as an adjustable locator for smaller cells are included with the basic product.

A positioning bar assures proper location under Abet's SunLite, Sun 2000 or Sun 3000 Solar Simulator.

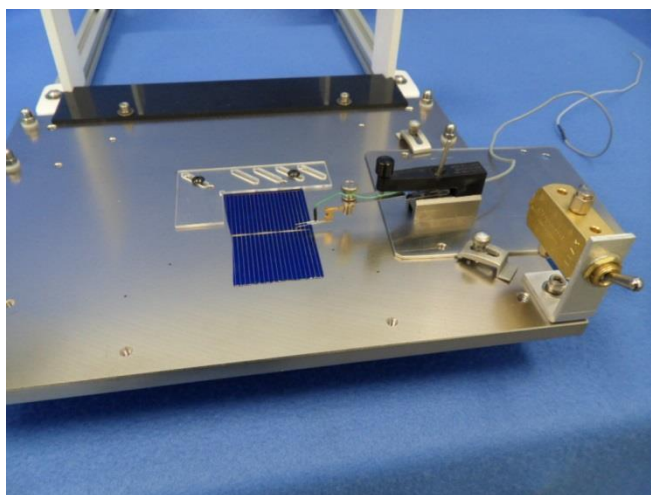
Temperature monitoring ready

Attach the optional Model 15170 Calibrated temperature monitor for STC corrected metrology.

- Reconfigurable vacuum zones
- Locators for 3 mm to 156x156 mm cells included
- Accepts up to three magnetic bases
- Electrically isolated
- Four wire metrology ready
- Temperature monitoring available
- Hard Nickel plated for reliable electrical contact
- Free standing and simulator mounted options

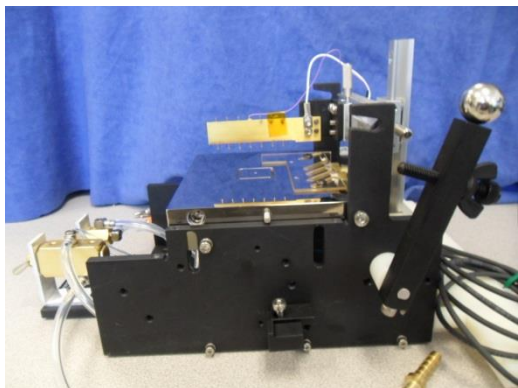
Ordering Information

15090	Universal test platform, hard Nickel plated
15090-P	Universal test platform, insulating
15090-M	Magnetic base
15090-F	Levelling feet
15170	Calibrated temperature monitor
15250F-R	Micromanipulator, precision, right handed
15250F-L	Micromanipulator, precision, left handed
15251L	Micromanipulator, low resolution For 50x50 mm or smaller devices



Abet Technologies Model 15090 Universal Test Platform with an adjustable 15090-M magnetic base and a 15251L micromanipulator

50x50 mm class Vacuum Chuck



Abet Technologies' Model 15500 chuck with model 15502 bus bar option

Full featured and field proven

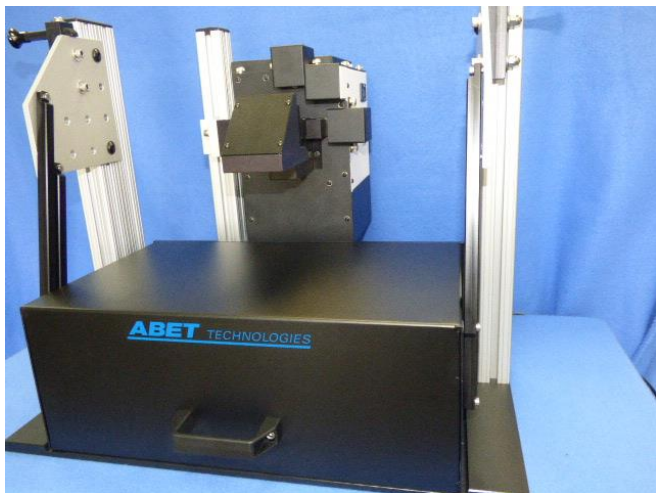
Abet Technologies' model 15500 vacuum chuck facilitates testing of a wide variety of top-bottom contact solar. Its multizone design allows testing devices with sizes ranging from 3x3 mm to 50x50 mm.

Base sense probe, vacuum actuated, allows 4-wire metrology.

Top contact options include the Model 15502 set of socket mounted spring probes in one or more bus-bars or, the Model 15501 magnetic base option and one, or more, 15250 or 15251 Micromanipulators mounted Kelvin probes.

Temperature monitoring is always included.

A spectrum neutral metal mesh attenuator is included for Bowden method R_s value extraction.



Abet Technologies Model 15504-1 dark enclosure with 11002 SunLite simulator PV IV setup

- Dual zone vacuum chuck for 3x3 mm to 50x50 mm cells
- Vacuum actuated sense probe
- 4-wire metrology standard
- Contact options:
 - Probe Bar
 - Micromanipulators
- Temperature monitored and temperature control ready
- Dark Enclosures options

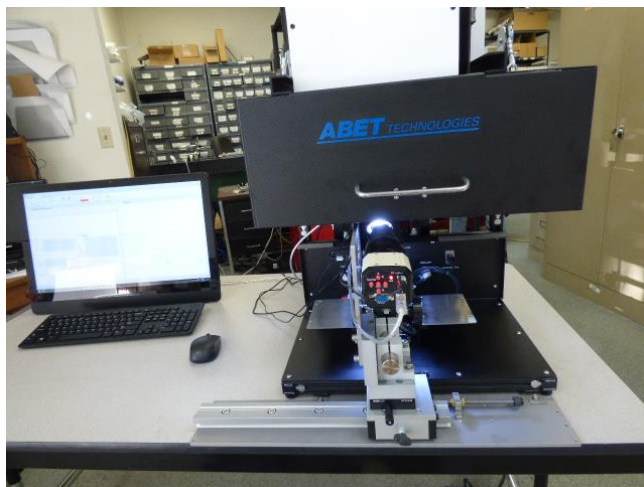
Flexible and extendable capabilities

Each chuck includes a set of adjustable locators for reproducible cell metrology.

Thermally conductive, electrically insulating pads are available for top-top geometry cells.

Adding a heated recirculating chiller allows temperature-controlled operation. Maximum temperature is 70 °C. Ask for high temperature option if you plan to run tests beyond that level.

The 15504 Dark enclosure options allow dark curve acquisition.



Abet Technologies Model 15504 dark enclosure with Sun 3000 simulator with slide mounted zoom camera probe alignment option

1550X Specifications

15500

Device size 3 – 50 mm

Individual Vacuum zones 2

Temperature monitored

Temperature control ready

Vacuum actuated base sense probe

15502

One Bus bars included

Gold-plated spring-loaded probes

Serrated ends standard, round ones available

Current probes 6

Isolated Sense probes 1

15501

Two side-mounted magnetic bases

15250

Precision micromanipulators

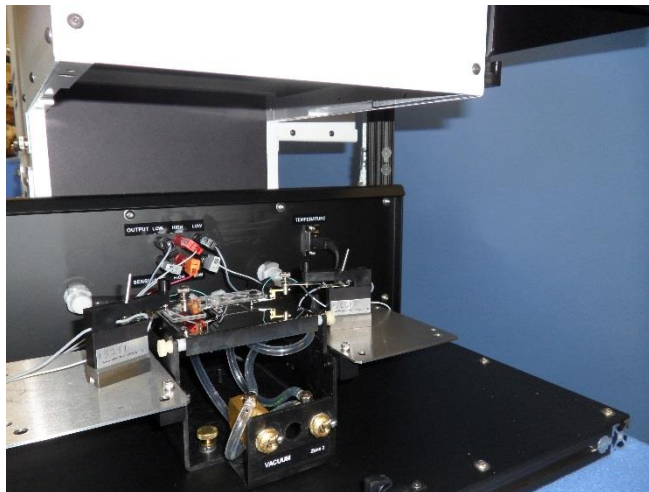
Kelvin probes standard

Extension mounts to allow full chuck surface access

15251

Low resolution micromanipulator – Kelvin probe standard

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.



Abet Technologies' Model 15500 chuck with model 15501 magnetic base option and 15251 micromanipulators

Ordering Information

15500 50x50 mm cells dual-zone vacuum chuck with calibrated temperature sensor, temperature control ready

15501 Micromanipulator base option for 15500. Order micromanipulators and probes separately

15502 Probe bar and actuator option for 15500. Includes one probe bar

15503 Additional probe bar and mount for 15502

15504 Dark enclosure for the 15500 and Sun 2000 or 3000

15504-1 Dark enclosure for the 15500 and SunLite

15250-R Micromanipulator, precision, right handed

15250-L Micromanipulator, precision, left handed

15251 Micromanipulator, low resolution. For 50x50 or smaller devices

IK1B10D1F Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm.

IK2B10D1F Long mount Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm

15201-S Replacement spring loaded pins (8), serrated end

15285 Heating/cooling recirculator

15447 Stand-alone microscope alignment slide assembly

15275 Vacuum pump, 115 VAC. 21 LPM; 650 mm Hg max vacuum

15276 Vacuum pump, 230 VAC. 17 LPM; 650 mm Hg max vacuum

Other Kelvin and single contact probes available. Please inquire.



Abet Technologies' Model 15500 Stage with Model 15501 magnetic base and Model 15504 Dark enclosure in use with a Sun 3000 Solar Simulator

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156x156 mm class Vacuum Chuck



Abet Technologies' Model 15510 chuck with model 15511 magnetic base option

Full featured and field proven

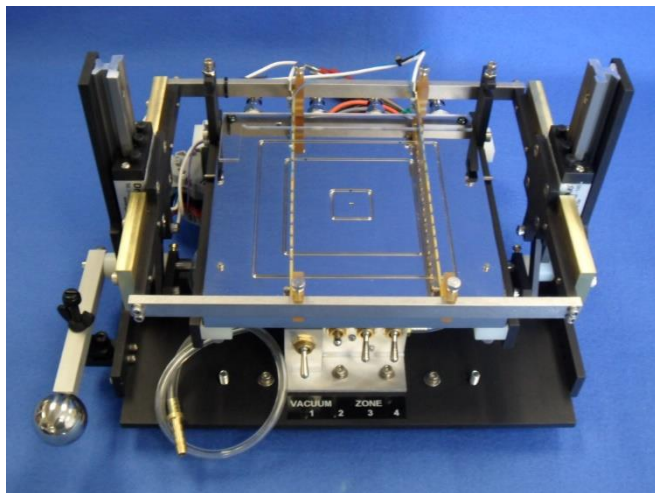
Abet Technologies' model 15510 vacuum chuck facilitates testing of a wide variety of top-bottom contact solar cells. Its multizone design allows testing devices with sizes ranging from 3x3 mm to 156x156 mm.

Base sense probe, vacuum actuated, allows 4-wire metrology.

Top contact options include the Model 15512 set of socket mounted spring probes in two or more bus-bars or, the Model 15511 magnetic base option and one, or more, 15250 or 15251 Micromanipulators mounted Kelvin probes. Switching between the bus-bar and micromanipulator contact options does not require any tools.

Temperature monitoring is always included.

A spectrum neutral metal mesh attenuator is included for Bowden method R_s value extraction.



Abet Technologies' Model 15510 chuck with model 15512 bus-bars

- Multizone vacuum chuck for 3x3 mm to 156x156 mm cells
- Vacuum actuated sense probe
- 4-wire metrology standard
- Contact options: Probe Bars and Micromanipulators
- Temperature monitored and temperature control ready
- Optional Dark Enclosure
- Alignment microscopes available

Flexible and extendable capabilities

Each chuck includes a set of adjustable locators for reproducible cell metrology.

Thermally conductive, electrically insulating pads are available for top-top geometry cells.

Magnetic bases are mounted on sliders and articulated arms for full flexibility in micromanipulator positioning.

Adding a heated recirculating chiller allows temperature-controlled operation.

Including the rail option with the 15514 Dark enclosure lets the user align to small contact pads under a microscope.

1551X Chuck Specifications

15510

Device size 3 – 156 mm

Individual Vacuum zones 5

Temperature monitored

Temperature control ready

Vacuum actuated base sense probe

15512

Two Bus bars included

Gold-plated spring-loaded probes

Serrated ends standard, round ones available

Current probes 14

Isolated Sense probes 1

15511

Two articulated-arm slide mounted magnetic bases

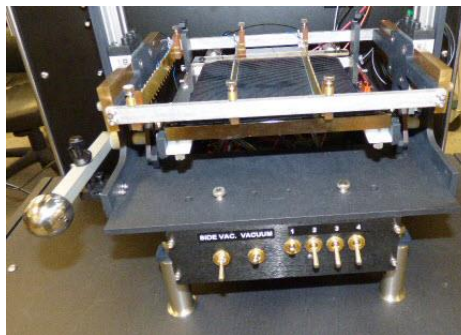
15250

Precision micromanipulators

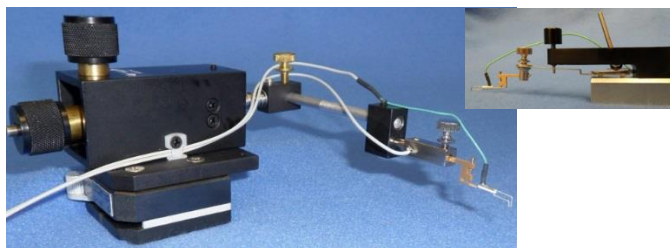
Kelvin probes standard

Extension mounts to allow full chuck surface access

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.



Abet Technologies' Model 15510 chuck with model 15512 bus bar

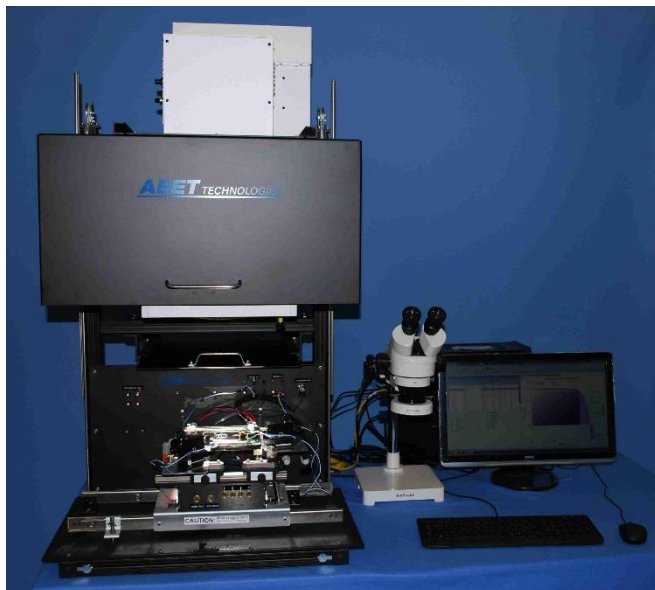


Abet Technologies 15250 and 15251 (insert) Micromanipulators

Ordering Information

- 15510** 156x156 mm cells multi-zone vacuum chuck with calibrated temperature interface, temp. control ready; special DSSC cell vacuum zone included
- 15511** Micromanipulator base option for 15510. Order micromanipulators and probes separately
- 15512** Probe bar and actuator option for 15510. Includes two probe bars
- 15513** Additional probe bar and mount for 15512
- 15514** Dark enclosure for the 1551x family of stations
- 15250-R** Micromanipulator, precision, right handed
- 15250-L** Micromanipulator, precision, left handed
- 15251** Micromanipulator, low resolution. For 50x50 or smaller devices
- IK1B10D1F** Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm.
- IK2B10D1F** Long mount Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm
- 15201-S** Replacement spring loaded pins (8), serrated end
- 15553** Stereo zoom probe alignment microscope, 3.5-45X, LED ring illuminator, USB camera, 2 Megapixels
- 15447** Stand-alone microscope alignment slide assembly

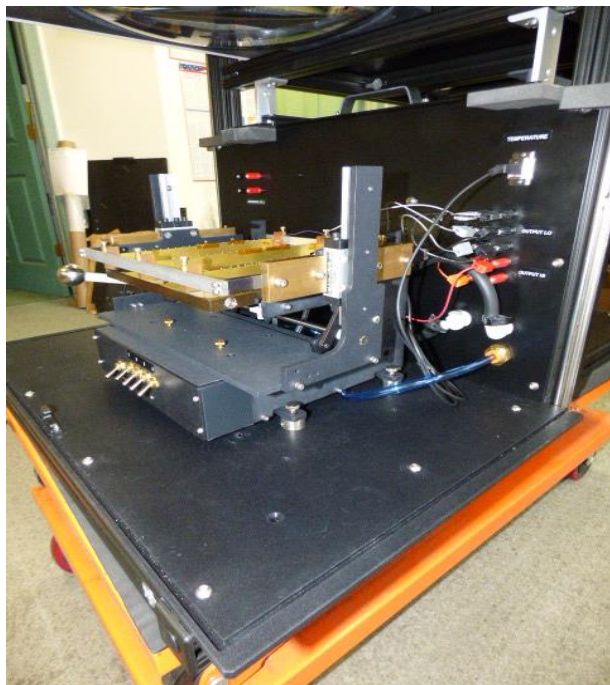
Other Kelvin and single contact probes available. Please inquire.



Abet Technologies' Model 15510 Stage with a large selection of its optional accessories in use with a Sun 3000 Solar Simulator

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210x210 mm class Vacuum Chuck



Abet Technologies' Model 15520 chuck with model 15522 bus-bars and 15524 dark enclosure

Full featured and field proven

Abet Technologies' model 15520 vacuum chuck facilitates testing of a wide variety of top-bottom contact solar cells. Its multizone design allows testing devices with sizes ranging from 3x3 mm to 210x210 mm.

Base sense probe, vacuum actuated, allows 4-wire metrology.

Top contact options include the Model 15522 set of socket mounted spring probes in two or more bus-bars or, the Model 15521 magnetic base option and one, or more, 15250 Micromanipulators mounted Kelvin probes.

Temperature monitoring is always included.

A spectrum neutral metal mesh attenuator is included for Bowden method R_s value extraction.

15524 Dark Enclosure option allows dark curve IV collection.

- Multizone vacuum chuck for 3x3 mm to 210x210 mm cells
- Vacuum actuated sense probe
- 4-wire metrology standard
- Contact options: Probe Bars and Micromanipulators
- Temperature monitored and temperature control ready
- Optional Dark Enclosure
- Alignment microscopes available

Flexible and extendable capabilities

Each chuck includes a set of adjustable locators for reproducible cell metrology.

Thermally conductive, electrically insulating pads are available for top-top geometry cells.

Adding a heated recirculating chiller allows temperature-controlled operation.

1552X Chuck Specifications

15520

Device size 3 – 210 mm
Individual Vacuum zones 5
Temperature monitored
Temperature control ready
Vacuum actuated base sense probe

15522

Two Bus bars included
Gold-plated spring-loaded probes
Serrated ends standard, round ones available
Current probes 18
Isolated Sense probes 1

15521

Two articulated-arm slide mounted magnetic bases

15250

Precision micromanipulators
Kelvin probes standard
Extension mounts to allow full chuck surface access

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.

300x300 mm class Vacuum Chuck



Abet Technologies' Model 15530 chuck with model 15531 magnetic base option, 15532 probe bar option, 15533 additional probe bar, and 15534 dark enclosure

Full featured and field proven

Abet Technologies' model 15530 vacuum chuck facilitates testing of a wide variety of top-bottom contact solar cells. Its multizone design allows testing devices with sizes ranging from 3x3 mm to 300x300 mm. An optional front located vacuum zone allows testing of small, 3-50 mm, devices using micromanipulator probes.

Base sense probe, vacuum actuated, allows 4-wire metrology.

Top contact options include the Model 15532 set of socket mounted spring probes in two or more bus-bars or, the Model 15531 magnetic base option and one, or more, 15250 Micromanipulators mounted Kelvin probes. Switching between the bus-bar and micromanipulator contact options does not require any tools.

Magnetic bases are mounted on sliders and articulated arms for full flexibility in micromanipulator positioning.

Temperature monitoring is always included.

A spectrum neutral metal mesh attenuator is included for Bowden method R_s value extraction.

Optional 15534 dark enclosure allows dark curve data collection.

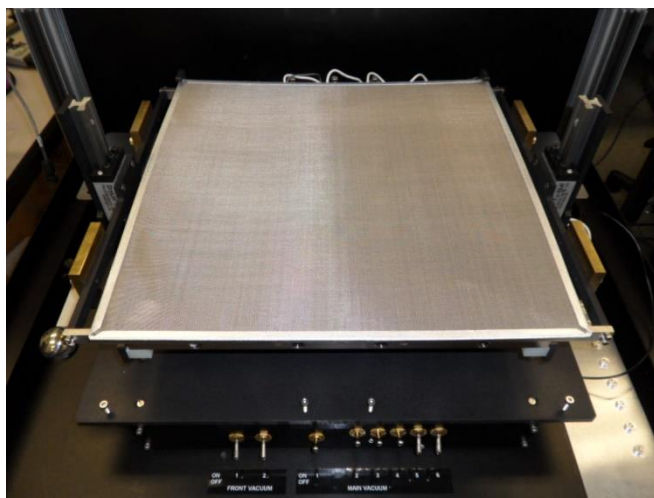
- Multizone vacuum chuck for 3x3 mm to 300x300 mm cells
- Vacuum actuated sense probe
- 4-wire metrology standard
- Contact options: Probe Bars and Micromanipulators
- Temperature monitored and temperature control ready
- Optional Dark Enclosure
- Optional motorized chuck and probe bars
- Alignment microscopes available

Flexible and extendable capabilities

Each chuck includes a set of adjustable locators for reproducible cell metrology.

Thermally conductive, electrically insulating pads are available for top-top geometry cells.

Adding a heated recirculating chiller allows temperature-controlled operation.



Spectrally neutral metal mesh attenuator for Bowden method R_s metrology

1553X Chuck Specifications

15530

Device size 3 – 300 mm
 Individual Vacuum zones 6
 Temperature monitored
 Temperature control ready
 Vacuum actuated base sense probe

15532

Two Bus bars included
 Gold-plated spring-loaded probes
 Serrated ends standard, round ones available
 Current probes 28
 Isolated Sense probes 1

15531

Two articulated-arm slide mounted magnetic bases

15250

Precision micromanipulators
 Kelvin probes standard
 Extension mounts to allow full chuck surface access

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.



Model 15530 300x300 mm stage with dark enclosure closed generating a dark IV curve using 15295 Universal load.



Model 15530SP 300x300 mm stage motorized chuck for CIGS mini-modules for automatic single cell and full mini-module IV metrology in use with a Sun 3000 Solar Simulator, a 15295 100V electronic load and four alignment microscopes. The simulator equipped with a filter wheel for Red and Blue and Attenuated measurements.

Ordering Information

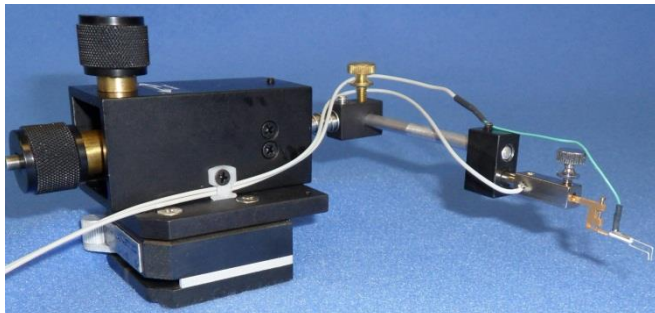
- 15530** 300x300 mm cells multi-zone vacuum chuck with calibrated temperature interface, temp. control ready
- 15531** Micromanipulator base option for 15530. Order micromanipulators and probes separately
- 15532** Probe bar and actuator option for 15530. Includes two probe bars
- 15533** Additional probe bar and mount for 15532
- 15534** Dark enclosure for the 1553x family of stations
- 15250-R** Micromanipulator, precision, right handed
- 15250-L** Micromanipulator, precision, left handed
- IK1B10D1F** Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm.
- IK2B10D1F** Long mount Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm
- 15201-S** Replacement spring loaded pins (8), serrated end

Other Kelvin and single contact probes available. Please inquire.

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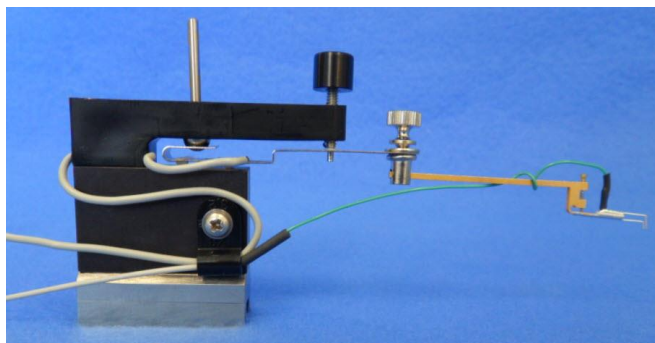
PV IV Systems accessories

Micromanipulators

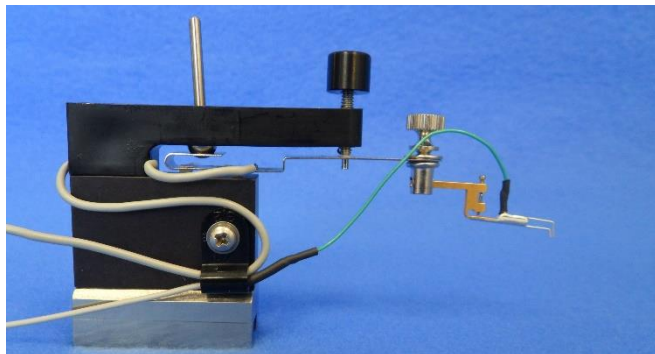


Abet Technologies 15250-L precision micromanipulator with an extender attached

Abet offers high and low resolution micromanipulators. Use the low resolution 15251 micromanipulator for contacting pads down to .5 mm. For higher resolution work use the precision 15250 micromanipulators. The right and left-handed 15250 micromanipulators are mounted on switchable magnetic bases and come with a set of extender rods to allow contacts on up to 300x300 mm stages. The extender kits also allow right angle probe mounting to further extend their positioning flexibility. Each micromanipulator is shipped with a Kelvin probe.



15251 Micromanipulator with a long mount Kelvin probe



15251 Micromanipulator with a Kelvin probe

Heating/Cooling Recirculators

The 15285 Heating/Cooling Recirculator has a -20°C to 135°C range (please check the working fluid and chuck temperature limits which will typically be narrower). Other specifications are as follows: 0.1°C temperature resolution, 0.07°C temperature stability, 0.1 bar pressure, 10 l/min flow rate, 200W cooling capacity at 20°C, 1100 W heater, 7 l reservoir, and 54.1 x 22.1 x 64.5 cm dimensions.

Computer temperature control options are available for this and other similar recirculators.



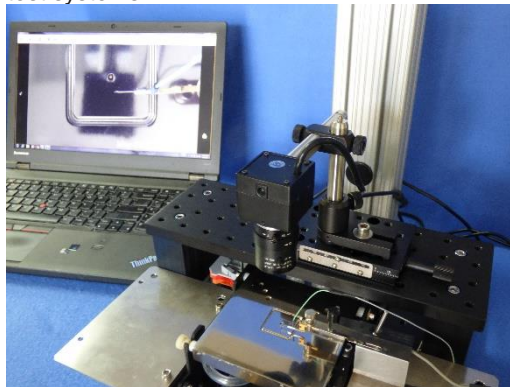
Vacuum pumps



Approximately 20 l/min rated vacuum pumps are available in the line voltage and frequency of your country.

Alignment microscopes and cameras

Numerous choices of stereo zoom microscopes, microscope cameras and positioning slides allow construction of versatile test systems.



Ordering Information, PV IV Stations

Software

15000 Tracer™ PV IV Control and Measurement Software

Stations

- 15090** 156x156 Universal test platform
15500 50x50 mm cells multi-zone vacuum chuck with calibrated temperature interface, temp. control ready
15501 Micromanipulator base option for 15500. Order micromanipulators and probes separately
15502 Probe bar and actuator option for 15500. Includes one probe bar
15503 Additional probe bar and mount for 15502
15504 Dark enclosure for the 1550x family of stations
- 15510** 156x156 mm cells multi-zone vacuum chuck with calibrated temperature interface, temp. control ready; special DSSC cell vacuum zone included
15511 Micromanipulator base option for 15510. Order micromanipulators and probes separately
15512 Probe bar and actuator option for 15510. Includes two probe bars
15513 Additional probe bar and mount for 15512
15514 Dark enclosure for the 1551x family of stations
15515 DSSC bottom contact micromanipulator base option for 15510
- 15520** 210x210 mm cells multi-zone vacuum chuck with calibrated temperature interface, temp. control ready
15521 Micromanipulator base option for 15520. Order micromanipulators and probes separately
15522 Probe bar and actuator option for 15520. Includes two probe bars
15523 Additional probe bar and mount for 15522
15524 Dark enclosure for the 1552x family of stations
- 15530** 300x300 mm cells multi-zone vacuum chuck with calibrated temperature interface, temp. control ready; auxiliary front section for small cells metrology
15531 Micromanipulator base option for 15530. Order micromanipulators and probes separately
15532 Probe bar and actuator option for 15530. Includes two probe bars
15533 Additional probe bar and mount for 15532
15534 Dark enclosure for the 1553x family of stations

Special cells stations

- 15110** Station, Multiplexer Enabled, 12 devices, 2.54 pad spacing
15111 Station, flippable for microscope alignment, 100x100 mm, order micromanipulators separately
15114 25x25 mm DSSC test stage, 2.54 mm device spacing
15545 Back contact, three device cells test station, 25x25 mm

Micromanipulators and probes

- 15250-R** Micromanipulator, precision, right handed
15250-L Micromanipulator, precision, left handed
15251 Micromanipulator, low resolution. For 50x50 or smaller devices
IK1B10D1F Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm.
IK2B10D1F Long mount Kelvin probe with flat tip BeCu .38 mm dia contacts separated by 0.64 mm

*Other Kelvin and single contact probes available.
Please inquire.*

Ordering Information (cont'd)

Electronic loads

- 15295** Universal electronic loads with two Keysight High Speed DMMs and a **Kepeco Bipolar Amplifier**; please specify your max. current/voltage; add a third DMM if using a monitor cell.

Keithley SourceMeter™ or **Keysight Source Measure** unit - see page 29 for suggested models

- 778927-01** USB to GPIB adapter for Keithley 2400 series
15274 Stabilizing circuit for Keithley 2400 series

Temperature control/measurement

- 15285** Heating/cooling recirculator
15170 Calibrated temperature interface, USB

Accessories and spares

- 15552** Stereo zoom probe alignment microscope, 3.5-45X, LED ring illuminator
15553 Stereo zoom probe alignment microscope, 3.5-45X, LED ring illuminator, USB camera, 2 Megapixels
15447 Stand-alone microscope alignment slide assembly
- 15185** Monitor cell
- 15171** Bowden R_s determination method attenuator, 156x156
15172 Bowden R_s determination method attenuator, 200x200
15173 Bowden R_s determination method attenuator, 300x300
- 15275** Vacuum pump, 115 VAC. 20 LPM; 650 mm Hg max vacuum
15276 Vacuum pump, 230 VAC. 20 LPM; 650 mm Hg max vacuum
- 15277** Multiplexer, 64 1A capable relays (smaller relay count units available)
- 15201-S** Replacement spring loaded pins (8), serrated end

Solar Simulators

See Solar Simulator pages 6-19

Reference cells

See Reference cell pages 23-26

Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.

UV and DUV Exposure Sources



Abet Technologies Model 12008 1W 6 x 6 DUV Exposure Source

Innovative, Integrated and Adaptable

The Abet Gen II optical design, shared with all the solar simulators on the preceding pages, dramatically increases the percentage of photons reaching the work plane. All components are integrated in a single housing. 4x4 and 6x6 inch illuminated fields are most popular, other field sizes are available.

Dichroic reflectors are available to narrow down the spectral range. Additional spectral shaping can be achieved with filters, e.g. Model 12075 T-Topping for SU-8 resist, frequently used for MEMS generation.

Ordering Information

A small sampling of Abet UV and DUV exposure systems and accessories. Please contact Abet with your UV source and mask alignment requirements.

- 12002 200 W Hg Source, 4x4 in, 350-450
- 12008 1 kW DUV HgXe source, 6x6 in
- 12075 T-Topping filter for SU-8

- Gen II Optics for High Efficiency Illumination
- Hg and HgXe 200 W to 1 kW Lamps
- +/- 5% Uniformity
- Long Life Shutter Included
- Digital Shutter Timer Included
- HEPA Filtered Cooling
- Ozone venting attachment for DUV

Specifications

Irradiance uniformity..... +/-5% or better
Electronic shutter (long life)included
Electronic shutter timerincluded
Elapsed Time Meterincluded
Working Distance..... 8 in/200 mm (typical)
Universal Input 90-250V, 50-60Hz, power supply included
Standard Output Direction.....Down
Horizontal output optional
HEPA filtered cooling fan.....included
Below are typical output powers in the 350 to 450 nm spectra region for two different wattage sources. Information on other spectral regions is available on request.

Work Plane Size	200 W Hg Systems	500 W Hg Systems
2 x 2 Inch	378mW cm ²	865mW cm ²
4 x 4 Inch	94mW cm ²	215mW cm ²
6 x 6 Inch	42mW cm ²	97mW cm ²
8 x 8 Inch	23mW cm ²	52mW cm ²

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Abet Technologies Model 12002 200 W Hg source with a mask aligner for SU-8 based MEMS.

Arc Lamp Light Sources

Cost effective and functional design



Abet Technologies Model LS 150 Light Source with a 20035S 45° mount with manual shutter, UV 280-400 nm

Cost Effective Patented Solution

Abet Technologies Model LS 150 is a patented, US Pat. No. 8116017, low cost, high output Xe arc lamp light source. The entire source, power supply, lamp, and the optical compartment are housed in a compact enclosure, 9x6x11 inches (230x150x280 mm). The unit's base allows mounting on inch or metric spaced optical tables with the optics axis centered over the hole pattern for easy integration with the rest of your setup.

- Patented low cost design
- Fast F/1 Condenser
- Wide range of optical accessories
- Open space and fiber compatible



Abet Technologies Model LS 150 Light Source with a 20037 45° full spectrum reflector and with a 20065 Filter wheel

Adaptable System Configuration

Abet Technologies offers a number of accessories to adapt this light source to your needs. However, if you would like to use components offered by other manufacturers go right ahead and mix and match. The output face of LS sources allows easy mounting of 1" (25 mm) optics cells. Inexpensive adapters for C-mount, Oriel flanging system, and a variety of Thor Labs mounts allow you to use accessories from most leading suppliers like Abet, Thor, Linos, Edmund, and Newport-Oriel.



Abet Technologies Model LS 150 Light Source with a 20093 F/2 Fiber adapter and a fused silica fiber bundle

Specifications

Condenser.....F/1 Fused Silica
 150 W Xe Arc Lamp - choose from the selection offered
 Elapsed Time Meter (included)
 Working Distance..... User selectable
 Standard Output Direction.....Horizontal
Optional 90° Beam Turner Accessories provide infinitely adjustable beam direction selectivity.
 Manual shutter.....Available
 Uniform Illumination accessories available, see p.7
 Universal Input 90-250V, 50-60Hz, power supply included

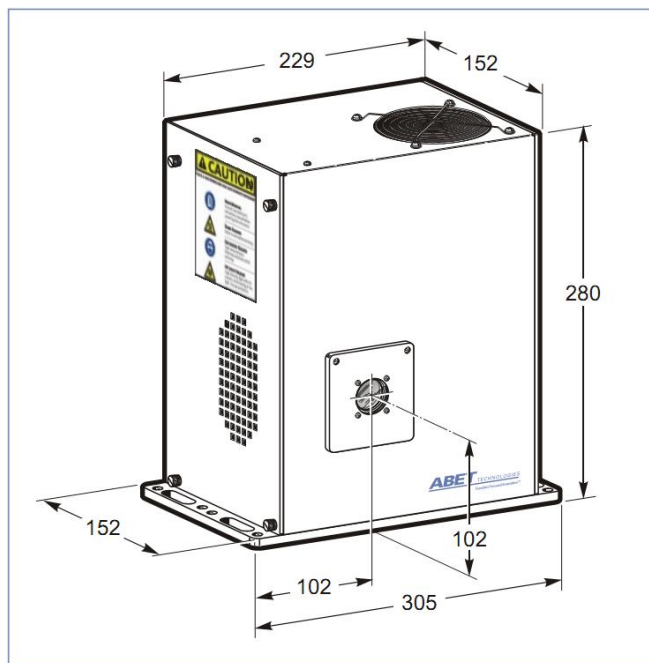
Abet Technologies regularly continues to upgrade our products, therefore all specifications are subject to change without notice.

OEM ready

A compact OEM version of the patented LS 150 Light Source is available for inclusion in your instrument. The 115x140x178 mm module holds the lamp and allows alignment and focusing. Order a power supply and output optics for a complete source.



OEM LS 150 module



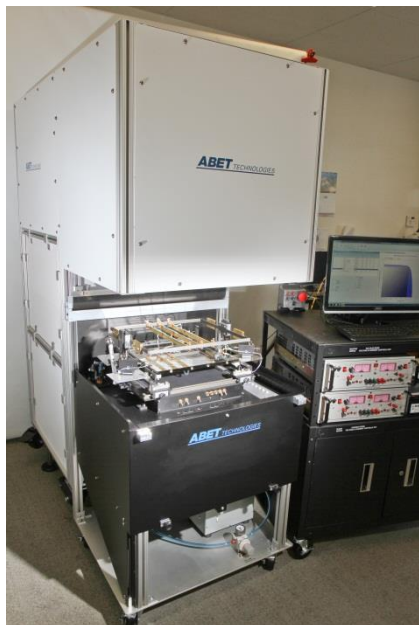
Dimensional diagram of the Abet Technologies Model LS 150 Light Source. The LS 150 is designed as a free standing instrument. If you need to mount it in a more particular way, an array of universal metric/English mounting holes in its base will allow an easy adaptation – please contact us for dimensional details.

Ordering Information

- | | |
|--|---|
| LS 150 | Light Source for 150 W Xe lamp
(Order lamps separately, see below) |
| 13014 | UXL-150-MO lamp, ozone free |
| 13015 | UXL-150-SMO long life lamp, ozone free |
| 13016 | XBO-150W/1lamp, ozone free |
| 13017 | XBO-150W/4 lamp, high UV |
| 20032 | Adapter to Oriel 1.5 in. series flange |
| 20033 | Adapter C-mount |
| 20034 | 45° mount, no optics |
| 20034S | 45° mount, no optics, manual shutter |
| Add "S" to the model numbers below for manual shutter | |
| 20035 | 45° mount, UV 280-400 nm |
| 20036 | 45° mount, UV 350-450 nm |
| 20037 | 45° mount, Full reflector |
| 20038 | 45° mount, VIS 420-680 nm |
| 20043 | Optics mounting cell, Max: Ø1 in, 7.5 mm thick |
| 20044 | Optics mounting cell, Max: Ø1 in, 12.7 mm thick |
| 20052 | F/1 focusing condenser |
| 20053 | F/2 focusing condenser |
| 20055 | F/4 focusing condenser |
| 20065 | Filter wheel, six-position, Max: Ø1 in, 3 mm thick;
use optics cells for thicker filters |
| 20066 | Manual shutter, LS 150 |
| 20087 | SMA Fiber Adapter, F/1 |
| 20088 | SMA Fiber Adapter, F/2 |
| 20092 | 11 mm Ferrule Fiber Adapter, F/1 |
| 20093 | 11 mm Ferrule Fiber Adapter, F/2 |

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