Solar Simulator

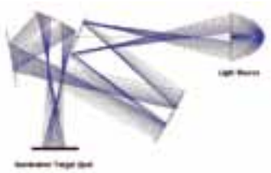
Fully Reflective Technology

Sun Dogs - Original Photograph by Eric Axdahl from Wikipedia Image:Sundogs - New Ulm.JPG

Sciencetech solar simulators produce high intensity, uniform illumination on a target area. Typically, high power solar simulators use an ellipsoidal reflector to capture light from an arc lamp source (usually xenon) inside the reflector, an arrangement that results in a light pattern with a bright outer region and a dark center. This non-uniformity is unacceptable in many solar simulator applications. Where better uniformity is required, many solar simulator designs use diffusers to reduce the non-uniformity, but this results in a reduction in intensity and a distortion of the spectrum on the target area.

Fully Reflective Design

Sciencetech's solution to these problems is to use a unique system of mirrors that "fold" the light onto the target plane so that less light is lost and there is no spectral distortion. Sciencetech is the only manufacturer that uses this fully reflective principle, making our SS series solar simulators much more efficient. Figure 1 shows the optical arrangement of Sciencetech's all reflective solar simulators.



Air Mass Filters

Solar simulators are adjusted to imitate the spectral distribution of sunlight for a variety of environments such as outside the earth's atmosphere, or at sea level for various sun angles. The spectral distribution from the xenon arc lamp source is altered and refined using Air Mass (AM) filters. Sciencetech's AM filters are designed to be used individually for standard conditions (though they can also be arranged in series to produce other spectral distributions). Many solar simulator systems require filters to be used in series to achieve the same performance as Sciencetech's filters, for example using AM0 and AM1.0 filters in series to achieve AM1.0 spectral distribution, whereas Sciencetech's AM1.0 filter is used alone to achieve the same result, reducing the associated power loss and filter cost.

Introduction to Solar Simulators

Solar Simulation

Sciencetech Solar Simulators use high pressure xenon arc lamp sources and air mass filters to match the spectrum of light emitted by the sun to Class A standards. Using the xenon lamp allows the design of an optical system that produces an intense, collimated beam. The spectra of the xenon source and the sun are both close to that of a 5800K blackbody, the biggest difference being the xenon lines present in the arc spectrum, and atmospheric absorbtion in solar spectra. The difference is especially pronounced in the 800-1100nm range because of the intense line output of the lamp. An AM0 filter reduces this effect so that the average level in specified bands matches solar levels above the atmosphere to better than 25%, although complete elimination of the xenon lines while preserving the rest of the spectrum is impossible with a practical filter. AM1.0, 1.5 and 2.0 filters further modify the visible and UV portions of the spectrum for different sea-level conditions. A xenon-mercury lamp is available for applications which depend on the UV spectral region where it provides better power levels the xenon lamp.

Figure 2 shows the typical output spectra of Sciencetech's Fully Reflective Solar Simulators. These spectra combine the spectral curves of the xenon arc lamp source, air mass filter, and mirrors used inside the solar simulator beam homogenizer. Actual output spectra may vary due to the condition of the lamp and possible manufacturing tolerances of the air mass filters. In order to simplify visual comparison of the spectral curves of our solar simulators with ASTM standard curves, the simulator outputs are normalized to the corresponding standard spectrum. The normalization covers the range for which standards are defined: 300-1200nm.

For applications that require a smoother spectral match longer than 750nm a custom dual-source unit with both Xenon and Tungsten lamps can be provided.

The Solar Constant

The radiation from the sun is measured in two ways for use in a variety of fields of research. The Solar Constant is the irradiance or intensity of light incident at the surface of the Earth's atmosphere on a plane normal to the angle of incidence. This value is defined by theWorld Meteorological Organization to be 1366.7Wm-2. The irradiance of the sun at the Earth's surface varies under different conditions due to absorption and scattering effects in the atmosphere, and so a number of other constants are important with regards to the irradiance of a solar simulator.

Below the atmosphere the radiation can be divided into two components: direct radiation that comes from the sun itself, and scattered radiation coming from the rest of the sky, including a portion reflected back from the ground. When discussing filters, the direct radiation spectrum is imitated using a direct (D) filter, and the total includingscattered sky and ground radiation is matched by using a global (G) filter that imitates both components together. The table below gives the 1 SUN irradiance values for both filter types at a number of common conditions that can be simulated.

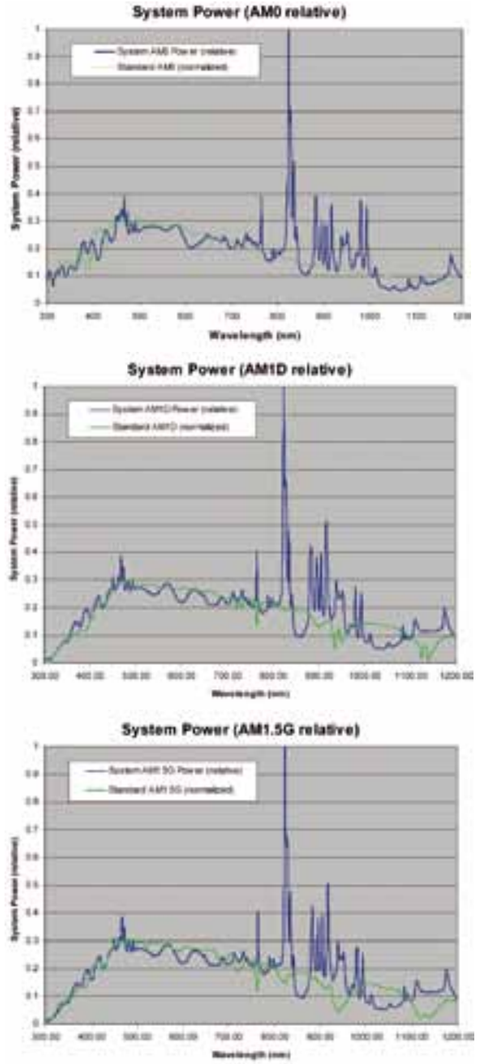


Fig. 2: Spectral Irradiance Curves

Solar Spectrum	Filter	Power Density (mWcm-2)
In Space	AM0	136
Direct solar spectrum at 0° zenith angle	AM1.0D	85
Global solar spectrum at 0° zenith angle	AM1.0G	100
Direct solar spectrum at sea level and 37.5° zenith angle	AM1.5D	90
Global solar spectrum at sea level and 37.5° zenith angle	AM1.5G	100
Direct solar spectrum at sea level and 60.1° zenith angle	AM2.0	65

Detectors available today can detect spectra between 250- 2500 nm, so the irradiance constants for this range have been provided.

The Air Mass filters reduce the total light power output by the solar simulator, though Sciencetech's independent AM filters lose less than filters produced by other manufacturers that must be stacked. The transmissions relative to unfiltered light between 250-2500nm for Sciencetech's AM filters are approximately as follows:

Unfiltered Light	100%
AM0 Direct	61.3%
AM1 Direct	67%
AM1.5 Direct	65%
AM1.5 Global	58.5%
AM2 Direct	57.3%

Performance Measurements

Sciencetech Solar Simulators use high pressure xenon arc lamp sources and air mass filters to match the spectrum of light emitted by the sun to Class A standards. Using the xenon lamp allows the design of an optical system that produces an intense, collimated beam. The spectra of the xenon source and the sun are both close to that of a 5800K blackbody, the biggest difference being the xenon lines present in the arc spectrum, and atmospheric absorbtion in solar spectra. The difference is especially pronounced in the 800-1100nm range because of the intense line output of the lamp. An AM0 filter reduces this effect so that the average level in specified bands matches solar levels above the atmosphere to better than 25%, although complete elimination of the xenon lines while preserving the rest of the spectrum is impossible with a practical filter. AM1.0, 1.5 and 2.0 filters further modify the visible and UV portions of the spectrum for different sea-level conditions. A xenon-mercury lamp is available for applications which depend on the UV spectral region where it provides better power levels the xenon lamp.

JIS-C-8912 standards for photovoltaic cell testing. These parameters are listed as:
1) Non-uniformity of spatial irradiance
2) Spectral match to a reference spectral irradiance
3) Temporal instability of irradiance, and performance classifications are:

Parameter	Class A	Class B	Class C
Non-Uniformity	±≤2%*	±≤5%**	±≤10%
Spectral Match	±25%	±40%	>±40%
Temporal Instability	≤2%***	≤5%****	≤10%

ASTM: * 3% for target size ≥30cm;
JIS: ** 3%; *** 1%; **** 3%

1) Non-Uniformity of Spatial Irradiance
ASTM standards require that at least 36 intensity readings covering a minimum of 25% of the total surface area be taken and averaged in order to determine the nonuniformity. The maximum and minimum values are compared and the uniformity is classified as Class A, B or C as indicated above.

2) Spectral Match to a Reference Spectral Irradiance
The output spectrum of the solar simulator is compared to that of natural sunlight. Standards are defined for the range from 400nm to 1100nm which is divided into 100nm or 200nm intervals. The deviation of the radiation in each interval from the standard values (detemined from tables in ASTM G173-03) determines the Class for the interval, and the worst performing interval determines the class of the solar simulator for this parameter. Class A spectral match is available with Sciencetech's solar simulators depending on model and AM filters.

3) Temporal Instability of Irradiance
This parameter represents the fluctuation of the measurement system during the interval required to fully obtain a current-voltage (I-V) curve which depends on the application. Sciencetech's solar simulators reach 1% stability after a 5 minute warmup.

Each solar simulator is configured to your needs.
The design of the reflective solar simulator permits a trade-off between power and uniformity. Higher uniformity can be had at a lower power; or power can be increased with some loss in uniformity.

SF150 Collimated Solar Simulator

Sciencetech is proud to offer a low cost lens based SF150 solar simulator system that includes arc lamp housing, bulb, power supply with igniter, filter holder, and UV fused silica collimator. An option for fiber optic illumination is available, requiring an additional condenser and fiber mount. This model is commonly used for applications where beam size can be traded for cost efficiency. Class A uniformity can be reached by carefully selecting the optical components and target location. The SF150-A simulator has been designed for this purpose.

With a 150W (ozone free) xenon lamp and 2" optics the SF150 can produce a collimated class A uniformity 1 Sun AM1.5G beam up to 1.5" diameter. The system uses Sciencetech's 201-100 air cooled arc lamp housing powered by the Sciencetech 500-220 power supply and igniter A multiple filter holder allows the user to selectively trim the xenon spectrum to match the desired Air Mass spectrum. The solar filters available are for AM0, AM1.0, AM1.5 direct and global, and AM2.0. Other filters such as dichroics and bandpass filters are available for further modification of the spectrum. Please specify which filters should be sent with the solar simulator when ordering.

Power Output

The solar simulator can achieve over 1.6 SUNs (160mW/cm2) at a 25mm (1") diameter target port with an AM1.5G filter and 150W lamp. By using a larger lamp-powered at 200W xenon lamp over 2 SUNs (200mW/cm2) can be achieved. Normally, the solar simulator is operated at 1 SUN (100mW/cm2) with the use of an AM solar filter, but it can be over-powered to compensate for light loss when the fiber bundle attachment or probe is used.

Spectral Range

The solar simulator provides a broadband spectral range of 250nm-2500nm without any filters. Please note that the spectrum may be affected if a fiber optic bundle attachment or hand probe attachment is used.

SF150 Technical Specifications

Lamp Housing
- Sciencetech 201-100 air-cooled research arc lamp housing, Includes back spherical reflector, alignment adjustments
- Center beam line height: 136.88mm (5.389") (not including adjustable feet)
- One collimating lens 25mm (1") or 50mm (2") diameter UV Fused Silica at the housing exit port

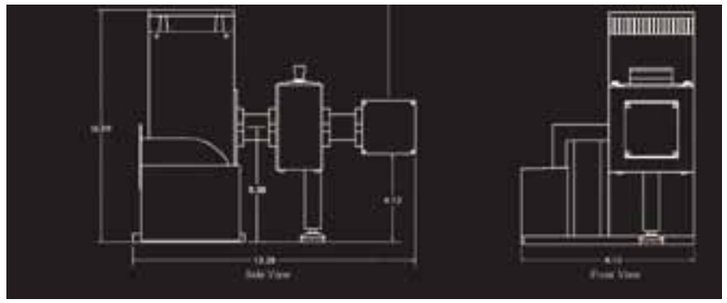
Lamp 100-150XOF, 150W ozone free, xenon lamp

Coupling & Filters
- Standard filter holder mounts one filter, an additional filter holder or lens can be added upon request

Version/ Model	Description
SF150	Low cost 150 W solar simulator system including light source, p ower supply and igniter, and collimator
SF150-A	SF150 with coupling lens
SFXXX	Higher power units, up to 1KW, are available for larger targets or higher intensity levels

Power Supply & Igniter
- Sciencetech 550-200 highly regulated, linear, adjustable power supply for arc lamps up to 250W; 510- IG igniter for 210 series arc lamp housing

Input: 110-115v/60Hz or 220-240v/50Hz (selectable)
Power: 0-200W
Operating Voltage: 0-30V
Operating Current: 0-10A
Pre-ignition Voltage: >80V
Ripple at Maximum Current: <1%
Stability After Warm-up: 0.05%
Line Voltage Regulation: 0.02% current variation for 5V line change
Display: Digital LCD
Cooling Fan: 120VAC cooling fan
Spatial Non-uniformity: 14% typical, 2% at selected target locations or with additional coupling optics

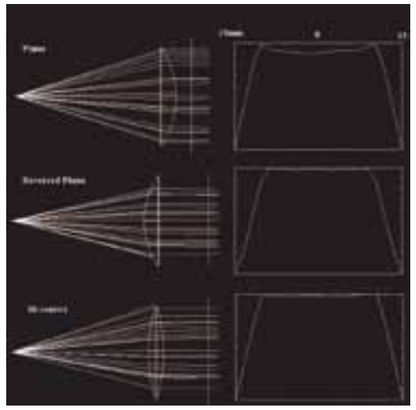


SF 150 Solar Simulator

The SF150 illuminator provides a collimated uniform beam. But just how uniform and how collimated depend on the particular lens used and the location of the target field. Modeling with Zemax for a point source and a 1” diameter f/1.5 collimator lens, plano or biconvex gives the table below. It shows the collimation radius for a point source and the position and uniformity at the optimum location.

Lens	Collim.	Unif.(+-)	Diam.	Pos. (past lens)
Plano	0.5°	5%	20mm	~10mm
Plano Rev	2°	<2%	18mm	~17mm
BiConvex	0.7°	<2%	22mm	~20mm

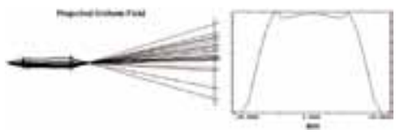
Optics Power Distribution



A plano lens is normally mounted convex side out for best collimation, but it can be reversed instead to get much better uniformity, although collimation is much worse. A biconvex lens gives a good tradeoff.

In practice, the collimation radius is actually larger due to the length of the arc itself. With a 1.5” f.l. collimator this amounts to 1.7°; 0.9° degrees with a 3” f.l. collimator. (The lens contribution remains the same).

A problem for uniformity is that the optimum position is so close to the collimating lens. For many applications the uniform field can be projected to a different size and location with additional optics. In most cases a single coupling lens can be used, but if full collimation is wanted the final lens must be at least as big as the target.



SS150 Fully Reflective Solar Simulator

The Sciencetech SS150 fully reflective solar simulator is designed for general research applications, particularly solar cell testing following the ASTM E927-05 and IEC-904- 9 standards. The diameter of the illuminated target can be adjusted, and can illuminate solar cells in the 5 x 5cm to 10 x 10cm (2"x2" to 4"x4") size range at 1 SUN.

The SS150 features a fully reflective design that does not require lenses or diffusers to make the output uniform at the target plane. This results in optimum throughput efficiency for the solar simulator, making Sciencetech solar simulators more efficient than competitive designs. The fully reflective design uses only mirrors to direct the light beam from the arc lamp source to the target plane, and produces high intensity, uniform illumination at the target plane. This design provides 1.3 times the output power at the target of competing simulators that use the same wattage of arc lamp and diffusers to make the light field uniform at the target. The high pressure xenon lamp gives an excellent basic match for solar simulation and the solar spectral distribution at different Earth conditions can be simulated through use of Air Mass filters.

This solar simulator requires a special lamp in order to achieve good spatial uniformity (100-150XOF-SS). This is due an irregularity in the glass surface where the hole used for gas insertion is closed off in the normal manufacture of these arc lamps. (The larger fully reflective solar simulators do not require special lamps)

Other Spectral Applications

Power Density From Sciencetech’s Fully Reflective 150W Solar Simulator	2350W/m^2
Power Density From Diffuser Based Competitive 150 W Solar Simulator:	1805 W/m^2
Improvement in output: **1.3X**	

Highlights

Standard Features
- Fully reflective design for optimum power throughput and efficiency
- No light absorbing diffuser or lens
- 150W ozone free xenon arc lamp system
- 50-100mm (2-4") diameter target size (Please specify when ordering)
- Built-in dual filter holder for 76 x 76mm (3" x 3") filters
- Filters can be exchanged or removed through an access panel
- Standard horizontal operation, vertical option
- Air cooled

Optional Features
- Floor stand for vertical operation
- Folding mirror to redirect output beam
- Electronic shutter
- Optical feedback intensity stabilizer
- Water cooling

The output light spectral distribution can also be custom tailored with different removable transmission and reflection filters such as a "water" filter or dichroic mirror. For UV type illuminators we offer a mercury-xenon lamp to enhance UV output. This solar simulator is often configured with a xenon lamp and AM1.5G filter to illuminate a 76mm (3") diameter spot at 1 SUN for solar cell testing.

Spectral Range

The SS150 provides a broadband spectral range of 250- 2500nm without any filters.

Solar Cell Testing

Version/ Model	Description
SS150	Sciencetech 150W Fully Reflective Solar Simulator

Solar cell testing requires strict uniformity to meet the ASTM E927-05(2005) and IEC-904-9 ANSI standards. For the fully reflective solar simulators to meet the Class A uniformity requirement only the inside portion of the illuminated target spot is used. This is because the uniformity falls rapidly at the outer edge of the illuminated target spot, so the last few millimeters at the edge only meet Class C. The inside spot maintains a 2% non-uniformity, which is in compliance with the ASTM E937-05(2005) and IEC-904-9 ANSI standards for solar cell testing. Sciencetech also offers optional computer generated spatial filters to meet particular needs (for example 1% non-uniformity).

Technical Specifications

Total Output Power on Target: 9W with 150W arc lamp (no filter)

Uniformity: Constant within 15% over full field; 2% over central field

Stability of Power on Target (Short Term): ± 1% after 10 minutes

Stability of Power on Target (Long Term Due to Aging of Lamp): –20% (after 1000 hrs)

Wavelength Control: Solar and Bandpass Filter

Dimensions (without power supply): 635 x 304 x 177mm (25" x 12" x 7")

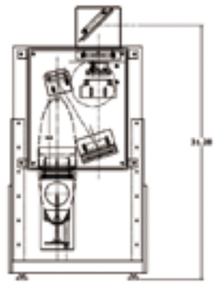
Weight (approx.): 15 kg (33lbs)

Target Diameter: (Typical, class B uniformity):
50mm (2") at 380mm (15") from output
100mm (4") at 890mm (35")

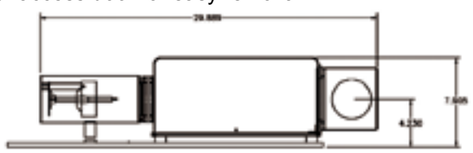
Power Density: (no filters, 2" diameter target): 2350 W/m^2

Distance to Target (typical range): (from output window of solar simulator) 380-890mm (15" – 35")

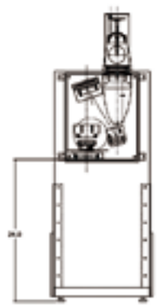
Input Aperture: f/2.5
Filter holder accepts up to three 76 x 76mm (3" x 3") AM filters in series includes a filter access door for easy removal



Vertical Configuration I
(Projects Target Spot On Wall)



Horizontal Configuration
(Output Beam Folding Mirror can Rotate to Project Sideways, Downwards, or Upwards)



Vertical Configuration II
(Projects Target Spot on Table/Floor)

Output Power

Using an AM1.5G filter, the SS150 produces 1.5 SUN on a 76mm (3") diameter field at a distance of 609mm (24") with class B uniformity. This can illuminate a sample such as a solar cell up to 50 x 50mm (2" x 2") in size.

Distance from Exit	15" 381 mm	24" 610 mm	35" 889 mm
Beam Diameter (Class B)	2" 51 mm	3" 76 mm	4" 102 mm
Area (cm^2)	20.3	45.6	81.1
Power Density without filters (mW/cm2)	502	239	125
Power Density with AM0 filter (mW/cm^2)	308	147	77
Power Density with AM0 filter solar constants (SUN)	2.3	1.1	0.6
Power Density with AM1.5G filter (mW/cm^2)	294	140	73
Power Density with AM1.5G filter solar constants (SUN)	3.1	1.5	0.8

Spatial Non-uniformity

This model is designed specifically for solar cell testing and meets ASTM Class A standards at 2% at 1/2 the Class B field diameters listed above.

Spectral Match

The spectral match for the SS150 also meets Class A standards and is shown below for each interval:

Interval	Actual	ASTM	ASTM
400~499 nm	21.2%	18.4%	15%
500~599 nm	20.9%	19.9%	5%
600~699 nm	16.4%	18.4%	-11%
700~799 nm	12.2%	14.9%	18%
800~899 nm	14.0%	12.5%	11.2%
900~1100 nm	12.5%	15.9%	-21%

Component Information

The Sciencetech SS150 solar simulator consists of standard modules integrated on a common base bracket.

Sciencetech 200-100 Arc Lamp Housing

Sciencetech 200-100 arc lamp housing with quartz windows (>250 nm), air cooled. Includes f/4.5 ellipsoidal reflector for high light throughput and lamp position alignment adjustments.

Sciencetech 550-200 Adjustable Arc Lamp Power Supply and 500-IG Igniter

Power	Arc lamps up to 200W
Main Input	90-270VAC (auto-switch)
Frequency	50/60 Hz
Wattage	150 W
Aux. Output	12 V/3.5 VA (isolated or for fan)
Lamp stage output	0-12 V/20 mA
Lamp Output Stability Current regulation	better than 1%
Ripple	less than 1%
Lamp Ignition High Voltage	25 kV
Ignition Voltage power supply	80 V
Maximum Current	24 Amp

Sciencetech 100-150XOF 150W Xenon Arc Lamp

Ozone Free Voltage	17.5 Volts DC
Current	2900 lm
Light intensity	
Luminous flux	2900 lm
Average luminance	200cd/mm^2
Arc size	0.5mm x 1.6mm
Average life	1200hrs (horizontal), 3000hrs (vertical)
Diameter	20mm
Cooling Fan	120VAC cooling fan

Sciencetech 5511BC Beam Homogenizer

Includes housing, segmented folding mirror, coupling mirror, filter holders, mount for 150W arc source to beam conditioner, model AD-LBC Adapter for 200-400 arc lamp to beam conditioner

Solar Filters

Please note that the solar filters are sold separately. Please check the Accessories section for available Solar Filter choices. The SS150 uses 76 x 76mm (3" x 3") filters.

High Power Fully Reflective Solar Simulators

Sciencetech manufactures four high power versions of its ultra-high efficiency solar simulator. The smallest is the 500W unit, which approaches the power output of most conventional 1000W systems on the market. Sciencetech also manufactures 1000W, 1600W and 2500W units which provide significantly greater illumination levels than competing models of the same power rating.
A 7.5KW system that uses three 2.5KW units is described in the next section. For still higher power levels please contact the Sciencetech Special Development Group at Sales@Sciencetech-inc.com
Sciencetech solar simulators are ideal for high intensity applications and where energy level is important. A high pressure xenon arc lamp is used as the light source in this solar simulator model. The spectral distribution of this source, combined with specially calibrated Air Mass filters, can simulate the sun's true spectral distribution at various conditions on Earth and in Space (the Sun at various angles in the sky, or without atmospheric interference).

These units feature a fully reflective design that does not require lenses or diffusers to make the output uniform at the target plane. This results in optimum throughput efficiency for the solar simulator, making Sciencetech solar simulators more efficient than competitive designs. The fully reflective design uses only mirrors to direct the light beam from the arc lamp source to the target plane, and produces high intensity, uniform illumination at the target plane.

Version/ Model	Description
SS0.5KW	0.5kW Model with Power Supply
SS1.0KW	1.0kW Model with Power Supply
SS1.6KW	1.6kW Model with Power Supply
SS2.4KW	2.5kW Model with Power Supply

Highlights

- Ozone free xenon arc lamp (500W, 1000W, 1600W or 2500W)
- Adjustable digital switching power supply with built-in igniter
- Horizontal or vertical operation
- Access panel for easy changing of filters
- MgF2 coated mirrors for UV, Visible and IR operation
- Air cooled

Optional Features

- Spare xenon arc lamp
- Floor stand for vertical operation
- Folding mirror to redirect output beam
- Computer controlled electronic shutter
- Computer controlled optical feedback intensity stabilizer

Technical Specifications

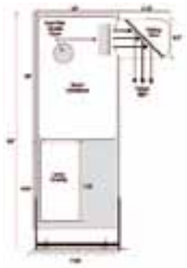
Arc Lamp Power Supply	240VAC @ 20A (2500W Lamp)
Uniformity	2-10% over target area
Uniform Area Diameter	50-200mm (2”-8")
Power Stability on Target (Short Term)	±1% after 30min
Power Stability on Target (Long Term Due to Aging of Lamp)	-20% (after 1000 hrs)
Mounting Options	Horizontal or Vertical
Filter Holders	Up to three air mass solar filters and/or bandpass filters
Dimensions (Without Power Supply)	122 x 76 x 36cm (Horizontal). (48" x 30" x 14") Dimensions change for vertical set-up due to adjustable height.
Cooling Fan	120VAC cooling fan
Weight (approx.)	55kg (121 lbs)

Beam Direction

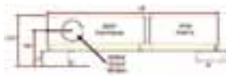
The solar simulator can be mounted in a vertical or horizontal position, please specify which orientation when ordering.

When in a horizontal position, the output beam exits from a side panel and illuminates an area on the wall (or whatever you put in front of it). An optional 90° folding mirror can be mounted at the output window to allow the beam to be redirected upward, downward, left or right.

For vertical operation a floor mounted stand is used. The output beam exits horizontally, and the optional folding mirror can be used to direct the beam upward, downward, left or right.



Vertical Mounting Dimensions



Horizontal Mounting Dimensions

Output Power

The solar simulators can be adjusted in favor of higher power or better uniformity. The following tables give 'typical' levels derived from measurements made with a variety of different setups, and so numbers may seem inconsistent. Diameters should be reduced 40% from Class B sizes to get 2% (class A) uniformity.

As a rough but convenient rule of thumb, to illuminate a target diameter D at a 1 SUN level requires a lamp power P(in kW) ~= (D/8")^2 = (D/20cm)^2.

Specific AM filters require: Global-10% less; Direct- 30% less; AM0-25% more

500W Solar Simulator

Distance from Exit	10" 254 mm	18" 457 mm	20" 508 mm	30" 762 mm	36" 914 mm
Beam Diameter (Class B)	3.7" 94 mm	5" 127 mm	5.3" 135 mm	7" 178 mm	8" 203 mm
Area (cm^2)	69.4	126.7	143.2	248.8	323.7
Power Density without filters (mW/cm^2)	510	226	190	110	78
Power Density with AM0 filter (mW/cm^2)	310	136	110	65	47
Power Density with AM0 filter (SUN)	2.3	1.0	0.8	0.5	0.3
Power Density with AM1.0 direct filter (mW/cm^2)	280	120	100	59	43
Power Density with AM1.5G filter (mW/cm^2)	298	132	111	64	46
Power Density with AM1.5G filter (SUN)	3.1	1.4	1.2	0.7	0.5

1000W Solar Simulator

Distance from Exit	10" 254 mm	20" 508 mm	30" 762 mm	36" 914 mm
Beam Diameter (Class B uniformity)	3.7" 94 mm	5.3" 135 mm	7" 178 mm	8" 203 mm
Area (cm^2)	69.4	143.1	248.8	323.7
Power Density Without Filters (mW/cm^2)	1083	406	228	164
Power density with AM0 Filter (mW/cm^2)	646	242	136	98
Power Density with AM0 Filter (SUN)	4.8	1.8	1.0	0.7
Power Density with AM1.0 Direct Filter (mW/cm^2)	580	220	120	87
Power Density with AM1.5G filter (mW/cm^2)	634	238	134	96
Power Density with AM1.5G filter (SUN)	6.6	2.5	1.4	1.0

1600W Solar Simulator

Distance from Exit	10" 254 mm	20" 508 mm	30" 762 mm	36" 914 mm
Beam Diameter (Class B uniformity)	3.7" 94 mm	5.3" 135 mm	7" 178 mm	8" 203 mm
Area (cm^2)	69.4	143.1	248.8	323.7
Power Density Without Filters (mW/cm^2)	1460	548	308	221
Power density with AM0 Filter (mW/cm^2)	898	337	189	136
Power Density with AM0 Filter (SUN)	6.6	2.5	1.4	1.0
Power Density with AM1.0 Direct Filter (mW/cm^2)	810	300	170	130
Power Density with AM1.5G filter (mW/cm^2)	854	321	180	129
Power Density with AM1.5G filter (SUN)	8.9	3.3	1.9	1.3

2500W Solar Simulator

Distance from Exit	10" 250 mm	25" 630 mm	36" 910 mm
Beam Diameter (note: uniformity)	7" 180 mm	12" 300 mm	15" 380 mm
Area (cm^2)	250	730	1140
Power Density Without Filters (mW/cm^2)	320	110	70
Power Density with AM0 Filter (mW/cm^2)	200	69	43
Power Density with AM0 Filter (SUN)	1.45	0.5	0.3
Power Density with AM1.5G filter (mW/cm^2)	190	65	40
Power Density with AM1.5G filter (SUN)	1.9	65	0.45

7.5 kW Solar Simulator

The SS-7.5kW Solar Simulator uses three Sciencetech SS 2.5kW fully reflective Solar Simulators to provide up to 1 Sun of highly uniform illumination on a large area (30 x 30cm) target. The spectral distribution can be tailored to the user's needs with easily removed transmission and reflection filters. These filters provide combinations of solar spectra, UV or IR illumination, or other spectra for special applications.

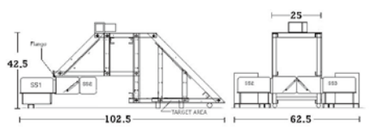
Highlights

Uniform Target Area 30cmx30cm at 1 Sun
Horizontal target, lamps
Adjustable power level
Fast electronic shutter (optional)
Optical feedback to stabilized output(optional)
Completely air cooled.

Version/ Model	Description
SS 7.5kW	Three-unit Solar Simulator

Technical Specifications

Total Output Power on Target	1 Sun (1000W/m2) when each unit runs at 95A
Uniformity	Constant within 2% over 30cmx 30cm field
Stability of power on target (Short term)	±1% after 30 minutes
Stability of power on target (Long term)	-20% (due to aging of lamp)
Mounting Options	Horizontal
Wavelength Control	Solar and Bandpass Filter
Dimensions (without power supply)	102.5" x 62.5" x 42.5” 260.35cm x 158.75cm x 107.95cm
Weight (approximate)	220 kg



Three Solar Simulator Units + Bean Folding Unit

Horizontal Mounting Dimensions of each unit

High Power Fully Reflective Solar Simulators for UV Applications

Sciencetech’s high powered fully reflective solar simulators can be used for UV applications by replacing the solar filters with UV filters. The smallest model is the 500W model, which approaches the power output of most conventional 1000W models on the market. Sciencetech also manufactures 1.0kW, 1.6kW, and 2.5kW models which are also noticeably more intense than competing models of the same power rating, especially in the UV spectral range. Sciencetech’s fully reflective solar simulators are ideal for UV applications due to their fully reflective design. Unlike conventional solar simulators that utilize light-losing focusing lens and diffusers to achieve uniformity, Sciencetech’s fully reflective solar simulators use only mirrors to “fold” the light from the arc lamp source to the target. This results in high uniformity without the intensity losses of conventional designs which is especially pronounced in the UV portion of the spectrum.

UVA and UVB Wavelengths Definition

Please note that the wavelength definition of UVA and UVB in the COLIPA sun screen testing community is slightly different from the general scientific community.

General Definition

UVA 315nm-400nm
UVB 280nm-315nm

Sunscreen definition

UVA 320nm-400nm
UVB 290nm-320

Highlights

- Fully reflective design means minimal UV loss and spectral distortion
- 500W, 1000W, 1600W and 2500W models available
- Xenon base arc lamp light source
- Selection from a wide range of UV filters
- For use in sun screen testing
- For use in photo-lithography (timed exposure)
- 120VAC cooling fan

Built-in Filter Holder inside Beam Homogenizer

The filter holder inside the beam homogenizer has room for two filters mounted in series. The filters are first mounted onto a frame and then inserted into the holder. The filters are 76 x 76mm (3" x 3") to cover the entire beam diameter. Generally two filters in series are required to isolate the UVA or UVB spectral regions. To eliminate the IR radiation, a plane mirror inside the solar simulator beam homogenizer is replaced with a hot mirror.

Types of UV Filters

The UV solar simulator without any filters provides a broadband white light source that ranges from UV to IR light. Hence, filters are required to eliminate the visible and IR light portions such that only UV light remains. There are various types of UV filters available, although they can be generally classified into two applications, for use in sun screen testing and for use in photolithography. Each application requires a different region of the UV spectrum so Sciencetech has separated its UV filter selection into different group accessories by application. Since all such filters work with the UV solar simulators, the user can purchase UV filters from both groups.

Beam Diameter

The target spot diameter is preset at the factory between 50mm (2”) to 203mm (8”) diameter, but it can be re-adjusted. Please specify target spot diameter when placing a purchase order.

Performance Example

The following values are based on a 1.6kW solar simulator n a 150mm (6") diameter spot without UV Enhanced Coating Optics. Actual performance should be better.

- Broadband power without filters 230mW/cm^2
- UVA region is approximately 16.5mW/cm^2
- UVA+B region is approximately 20mW/cm^2

Version/ Model	Description
SSUV0.5KW	0.5kW Model with Power Supply
SSUV1.0KW	1.0kW Model with Power Supply
SSUV1.6KW	1.6kW Model with Power Supply
SSUV2.4KW	Three-unit Solar Simulator

Solar Cell Testing

Version/ Model	Description
SSIVT-20Wcont	20W/1A IV Tester for Continuous Solar Simulator
SSIVT-20Wpulse	20W/1A Tester for Flash Solar Simulators
SSIVT-60Wcont	60W/3A Tester for Continuous Solar Simulator
SSIVT-60Wpulse	60W/3A Tester for Flash Solar Simulators
SSIVT-10Apulse	1000W/10A Tester for Flash Solar Simulators

Test Software & Reference Cells

Software for the SSIVT measurement system can be purchased separately. SCISPIV.exe is the primary module Two other components, SCIRUNIV and SCIRUNQE, provide screen output for monitoring I-V or QE operations, available separately or bundled with SCISPIV. These interface and control programs are designed for operation with Keithley 2400 series sourcemeters.

Main features:
• Does not require Windows
• Has its own user interface
• Requires RS-232 port (COMM 1 preferred, 1-4 okay)

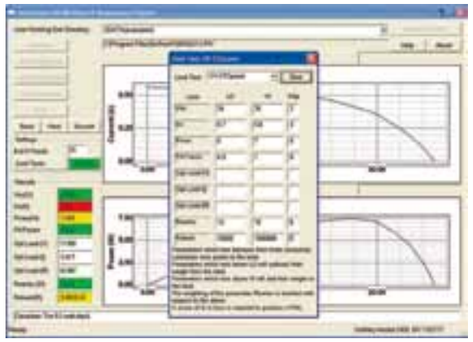
The software runs in the background, communicating with the Keithley instrument to:
• Operate flash systems
• Control the state of the solar cell during QE and SR measurements
• Measure the reference cell and temperature during I-V measurements
• Generate and operate the I-V measurement procedure
• Allow customer calibration of a reference cell
• Collect and write data to files readable by the inter face programs

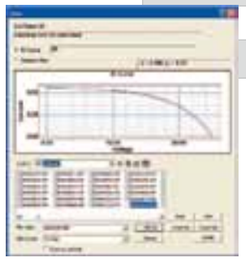
Sciencetech also offers calibrated reference cells for use in IV, QE and SR measurements. These reference cells include a platinum resistance thermometer which eliminates the need for an A-D board and special software. An adapter is required for use of a reference cell and temperature sensor with a Keithley sourcemeter.

Reference cells for use with flash systems are also available with in-house calibration. This cell does not require a temperature sensor adaptor.

(Use of reference cells with Keithley 2600 series sourcemeters is discouraged as these systems lack the hardware for the control and temperature adapters).

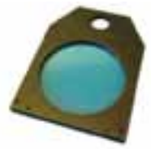
SSIVT Software Screenshots





Version/ Model	Description
SCISPIV	Testing software
SCIRUNIV	I-V Screen module
SCIRUNQE	QE Screen module
SCIRUNIV + SCIRUNQE	Combined Screen modules
	Continuous reference cell
	Flash reference cell

Air Mass Solar Filters



The following removable filter combinations are available. They are to be inserted into the filter holder inside the beam conditioner through the access panel to simulate various light conditions on earth and in space. At minimum, the AM0 filter is required to mimic space conditions with no atmosphere. These filters can be used separately or in series.

Version/ Model	Description	Size
AM0	Simulates the solar spectrum under space conditions	3” x 3” 76 x 76mm
AM1.0	Simulates the DIRECT solar spectrum on the ground when the sun is directly overhead	3” x 3” 76 x 76mm
AM1.5D	Simulates the DIRECT solar spectrum on the ground when the sun is at 48.2°zenith angle	3” x 3” 76 x 76mm
AM1.5G	Simulates the terrestrial solar spectrum on the ground when the sun is at 48.2°zenith angle	3” x 3” 76 x 76mm
		6”x6” 150x150mm
		for PSS06
AM2.0	Simulates the DIRECT solar spectrum on the ground when the sun is at 60.1°zenith angle	3” x 3” 76 x 76mm

Specialty Filters

UV blocking Filter

This 3" x 3" filter eliminates over 99% of all UV wavelengths below 400nm, but allows Visible and IR light (up to 2000nm) through. Unfortunately, its transmission efficiency in the Visible range is only 85%. This filter can be purchased with the correct mounting frame for use in Sciencetech SF150, SS150 and SS (500,1K,1.6K) solar simulators as well as inside the 3" FH filter holder.

IR Absorbing Water Filter

IR absorbing water filters protect downstream optical components from IR thermal damage by absorbing all infrared light between 1000-3000nm. When filled with distilled water, it absorbs nearly 100% of all IR light in this spectral range while allowing approx. 98% of all visible light between 350-700nm through. It also absorbs little UV light between 200-350nm as nearly 80% of all UV light is transmitted through. All Sciencetech IR absorbing water filter models have a re-circulated water jacket to cool the filter itself making it excellent for high power applications. Sciencetech offers IR filters in both aluminum and stainless steel models. Aluminum filters are used where only distilled water is used. Stainless steel filters are used when the absorbing media is water, copper sulfate or nickel sulfate

Hot Mirror for UVApplications - 3 x 3 Inches

This 76x76mm (3” x 3”) hot mirror filters out IR light to remove thermal heat on the target. However, standard hot mirrors also remove UV light as a side-effect which means it cannot be used in UV applications. This special hot mirror removes IR light between 730-1100nm while preserving UVA and UVB light (280-400nm) in addition to visible light. This filter is ideal for Sciencetech UV solar simulators where the filtering of thermal heat on the target is desired and preservation of UVA and UVB light is required.

Band Pass UVA+B filter

Only the 290-400nm UVA and UVB portion of the ultraviolet spectrum is required for SPF (Sun Protection Factor) sun screen testing. Isolating UVA+B rays is achieved by using a Schott WG320 UVC blocking filter in series with a Hoya U330 visible and infrared blocking filter. These two filters eliminate all other wavelengths.

This is the industry's accepted method (COLIPA compliant) for isolating UVA+B wavelengths in SPF sun screen testing. Sciencetech's Band Pass UVA+B Filter is essentially these two filters arranged in series.

The cost below includes the 3" frames for use with Sciencetech SS series fully reflective solar simulators or 1" frames for use with the Sciencetech SF-150 solar simulator. Warning! Please note that when used in Sciencetech 500W, 1000W, 1600W, 2400W solar simulators it is necessary to place a dichroic filter before these filters to remove the heat generated by the arc lamp, otherwise the U330 filter will crack.

Band Pass UVA Filter

The ultraviolet spectrum is divided into UVA, UVB and UVC sub-spectral regions. The UVA portion of the spectrum as defined by the SPF (Sun Protection Factor) testing industry is 320nm-400nm. To isolate these UVA wavelengths, the Hoya U330 filter and Schott WG335/WG345 filter are used in series. The Hoya U330 filter is used to eliminate visible and IR light while the Schott WG335/3mm or WG345/1mm filter is used to eliminate UVB and UVC light. Sciencetech Band Pass UVA Filter is essentially the combination of these two filters.

The cost below includes the 3" frames for use with Sciencetech SS series fully reflective solar simulators or 1" frames for use with the Sciencetech SF-150. Warning! Please note that when used in Sciencetech 500W, 1000W, 1600W, 2400W solar simulators it is necessary to place a dichroic filter before these filters to remove the heat generated by the arc lamp, otherwise the U330 filter will crack.

Version/ Model	Description
UVBlock	UV Blocking Filter
01-8711 12/2-SS	IR Absorbing Water Filter
HM-UVAB-3x3SS	Hot Mirror for UV applications
UG11WG320x1	U330 & WG320 filters (1 inch with frame)
UG11WG320x3	U330 & WG320 filters (3 inch with frame)
UVAB-1inch	U330 &WG335/WG345 filters (1 inch with frame)
UVAB-3inch	U330& WG335/WG345 filters (3 inch with frame)

Large Neutral Density Filters

A Neutral Density Filter is used to uniformly reduce the amount of light across the visible and near-IR spectrum that pass through it (350-2000nm). This glass substrate 76 x 76mm (3" x 3") square neutral density filter is designed for use with Sciencetech's fully reflective "SS" solar simulators (150- 2500W) and Sciencetech's SF150 solar simulator. Its high cost is due to its metallic reflective material off which the unwanted light is reflected back to the light source rather than being absorbed. This is important in high energy applications such as solar simulation. The cost includes a frame for mounting the filter inside Sciencetech's Solar Simulator internal filter holders. The list below is only a partial list of OD values available. If you are interested in other optical density values speak to an application specialist

Version/ Model	Description
OD0.1	Optical DensityOD = 0.10 = 79.49 %T
OD0.3	Optical DensityOD = 0.30 = 50.12 %T
OD0.4	Optical DensityOD = 0.40 = 39.81 %T
OD0.6	Optical DensityOD = 0.60 = 25.12 %T
OD0.8	Optical DensityOD = 0.80 = 15.85 %T
OD1.0	Optical Density OD= 1.00 = 10.0%T
OD1.3	Optical Density OD= 1.30 = 5.01%T
OD1.5	Optical Density OD = 1.50 = 3.16 %T

Spare Xenon Lamps

Version/ Model	Description	Service Life (Hours)
100-150XOF	150W for SF150	1,200
100-150XOF-SS	150W for SS150	1,200
100-500XOF	500W	2,000
100-1.0kXOF	1000W	1,500
100-1.6KXOF	1600W	2,000
100-2.5KXOF	2500W	2,000

Electronic Shutter

An arc lamp is not designed to be frequently turned off and on and doing so dramatically lowers its service life. In addition, each time it is turned on the power supply needs to ignite it with a 20,000V+ spark. Therefore, an electronic shutter system inside the beam homogenizer is available to control exposure time. Please note that the shutter cannot be closed for long periods of time while the arc lamp is on because the high intensity beam can damage it. The Electronic Shutter is computer controlled with an activation time of <150ms.

Version/ Model	Description
SSES-SS150	For the 150W Fully Reflective Solar Simulator
SSES-SS1kW	For High Powered SS Fully Reflective Simulators

High Speed Shutter

The external version of the 600-VS25 shutter can be used with Sciencetech small beam SF150 Solar Simulator. The 600-VS25 series high speed shutter is computer controlled via Sciencetech's PCI A/D data acquisition board. The shutter has its own power supply, electronics module, and cable that connects it with the Sciencetech PCI A/D data acquisition board. It has a 25mm diameter aperture, minimum exposure time is 6ms (40Hz), and maximum exposure time is several minutes. Time to open is 3ms.

Version/ Model	Description
600-VS25-INT Solar	High Speed Shutter (Solar Simulator Version)

Variable Focus

Every time the illumination target size changes the reflective mirrors inside the solar simulator that direct the light from the source to the target need to be refocused. Although this can be performed manually, the procedure is a hassle should the user need to change the target size frequently. The solar simulator would need to be shut down and have each internal mirror re-adjusted to support a different target size. With this variable focus option, re-adjusting the internal mirrors of the solar simulator is performed through a single knob without having to shutdown the solar simulator. This feature can also be used to vary illumination intensity by spreading the light over a larger area or concentrating the light into a smaller area. This variable focus option readjusts the focal plane after the beam goes through the segmented mirror that folds the light from the outer ring to the central dark spot in order to produce uniform illumination of the target.

Version/ Model	Description
SSVF-SS	Variable Focus Mirror Assembly

Alignment Package

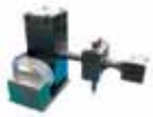
Sciencetech Solar Simulator System Alignment Kit: it includes (1 sun calibrated alignment Silicon detector, laser and holder, UV protection glasses, Sciencetech multimeter) Can be used on all Sciencetech's Solar Simulators.

Version/ Model	Description
SSAKF-01	SSAKF-01

Beam Turning Assembly for SF150 Solar Simulator

A beam turning assembly can be mounted to the output port of a Sciencetech SF150 Solar Simulator to redirect the light downwards onto a horizontal table top. This beam turning assembly is placed after the filter holder. Without this beam turning assembly, the light would shine towards a vertical wall surface. It consists of a flat UV enhanced mirror mounted on a 45° angle and is located after the lamp housing's collection lens at the output port. An optional cold mirror version is available to eliminate IR Light and thermal heat on the sample.

Version/ Model	Description
CTBT /b-SF150	With Regular Mirror
CTBT c/UV -SF150	With Cold Mirror
CTBT-B-SS1kW	With Regular Mirror



Downward Facing Vertical Stand for Fully Reflective Solar Simulators

This vertical stand enables the high powered model SS fully reflective solar simulator to project its output beam downwards onto a horizontal illumination table which makes it ideal for solar cell testing. The beam is projected down onto a built-in sample platform where the sample, such as a solar cell, can be placed. The stand assures the distance between the output port of the solar simulator to the sample platform produces duces exactly 1 SUN intensity (100mW/cm2 using an AM1.5G filter or 136mW/cm2 using an AM0 filter) onto a 5" diameter area for an SS-500W, 7" diameter for an SS-1000W, and 8" diameter for an SS-1600W.

Version/ Model	Description
DFS-SS150	for SS150
DFS-SS0.5KW	for SS0.5KW
DFS-SS1.0KW	for SS1.0KW
DFS-SS1.6KW	for SS1.6KW
VertOp SS1Kmount	for SSUV

Light Intensity Stabilizer

The Light Intensity Stabilizer is a microprocessor based, stand alone unit. It comes with a light sensor, coupled to the light source with a fibre optic cable for electrical isolation. The unit is easy to install/operate, and it is used to monitor the light intensity of a solar simulator. It corrects intensity fluctuations caused by a change in environmental or power conditions by automatically adjusting the power supply output in real time to maintain the same light intensity level. The optical feedback unit uses relative intensity comparison to maintain light levels.

Version/ Model	Description
FS-02	Optical Feedback Unit

Plug Style

Sciencetech electrical devices can be configured with a variety of different electrical plug styles for compatibility with various international electrical outlet standards. The styles available are: NEMA 5-15 115VAC (North America, ROC), NEMA 6-15 240VAC (North America), NEMA L6-15 240VAC (North America), Type E 240VAC (Continental Europe), Type G 220VAC (China, UK, Singapore, Hong Kong), Type M 230VAC (India), Type F 220VAC (South Korea). Please specify which plug style you require at the time of ordering. Price differs for machine and style, contact a Sciencetech representative for details.

Step-Up Voltage Transformer

Sciencetech 1000W, 1600W arc lamp sources and solar simulators require 230-240VAC electrical service. If your lab does not have a 240VAC electrical outlet as in most North American laboratories, you can use a 120VAC- 240VAC step-up voltage transformer to power 240VAC devices with a 120VAC electrical outlet. However, this set up transformer will require a 30 Amp 120VAC circuit.

Version/ Model	Description
VTrans	Step-Up Voltage Transformer

Output Fiber Bundle Attachment

This option mates a 12" flexible fiber bundle or 39" flexible liquid light guide to the output port of an SF150 Solar Simulator such that the light can be channeled through a fiber to illuminate a small point. The fiber bundle or liquid light guide has a collimating lens at its output tip to reduce the divergence of the beam . There are two fiber bundle choices available, one with quartz fibers to preserve the UVA and UVB light and one with glass fibers for only visible and IR light transmission. The liquid light guide is a special IR enhanced version that preserves both visible and IR light but does not transmit UV light. Please note the fiber bundles and liquid light guide distorts the spectrum of the solar simulator light.

Version/ Model	Description
FBO-Q412	1/4” Diameter Quartz Fiber Bundle x 12”
FBO-G412	1/4” Diameter Glass Fiber Bundle x 12”
FBO-LLG8x39	8mm Diameter Liquid Light Guide x 39”
FBOHP	Output Hand Probe Attachment

Water Recirculating Cooler and Sample Cooling Pad

This adjustable temperature cooler is designed to keep a sample from overheating under intense light by placing a water cooling pad underneath it. This water cooling pad not only cools the sample to ambient room temperature, but also monitors its exact temperature. This cooling system is an external unit designed to dissipate up to 700W of heat through a fan cooled radiator system, which is enough to cool samples illuminated by 1600W solar simulators. The cooler displays the sample's current temperature in either celsius or Fahrenheit. The temperature of the sample can be adjusted by setting the cooler's internal radiator fan speed which is also displayed on the cooler. If the current temperature wanders above a "warning" preset value, an alarm will go off. The cooling pad temperature is monitored by a thermo sensor wire which can be embedded between the cooling pad and the sample itself.

Version/ Model	Description
130-REC-std	Flat Cooling Pad
130-REC-cuvette	Cuvette Cooling Pad

Temperature Controller Thermoelectric Element for PV Cell Holder Assembly

For accurate thermoelectric temperature control, a low cost, high power temperature controller with excellent temperature stability (±0.1°C). This controller features PWMcontrol and comes with a 1kohm RTD sensor.

Highlights

- Adjustable DC output voltages: 3, 7, 12, and 14 V (PWM) with maximum output current of 10A
- Control temperature range: 0°C to 100°C
- Temperature sensor: 2-wire PT1000 RTD
- Universal input power: 110/220VAC, 50-60Hz
- LED display of measured value and set point value
- Proportional, integral, and derivative terms adjustable
- 8.5 A, 15.4 V thermoelectric element

Version/ Model	Description
EGV-1410	Temperature Controller Thermoelectric Element