

# Oriel® Sol3A™ Class AAA Solar Simulators



## Sol3A Advantages

- Output beam sizes 2x2", 4x4", 6x6", 8x8", and 12 x 12"
- Factory certified Class AAA CW systems
- Calibration certificate validating Class AAA performance for all 3 standards
- Long-lived, highly reliable instruments designed specifically for 24/7 production environments
- Easy lamp replacement
- Non-reflective black finish reduces stray light
- Temperature sensors and interlocks ensure operator safety
- Improved optical design for maximum spatial uniformity
- Improved working distances accommodate larger samples
- Universal AC mains operation
- CE certified



Leveraging over 40 years of experience in light source and power supply design, Newport's Oriel® brand is proud to introduce the latest innovation in solar simulators – the Oriel Sol3A™ Class AAA Solar Simulator family. The product family includes:

- |                                  |                                |
|----------------------------------|--------------------------------|
| Model 94123A = 12"x12" Beam Size | Model 94043A = 4"x4" Beam Size |
| Model 94083A = 8"x8" Beam Size   | Model 94023A = 2"x2" Beam Size |
| Model 94063A = 6"x6" Beam Size   |                                |

All Oriel Sol3A simulators are certified to IEC 60904-9 Edition 2 (2007), JIS C 8912, and ASTM E 927-05 standards for Spectral Match, Non-Uniformity of Irradiance, and Temporal Instability of Irradiance. By convention, Class AAA is reported with the first letter representing Spectral performance, the second letter Uniformity of Irradiance, and the third letter Temporal Stability. The Oriel Sol3A simulators all use a single lamp design to meet not one or two, but all three performance criteria without compromising the 1 Sun output power, providing true Class AAA performance. The Oriel Sol3A uses a black non-reflective finish to minimize stray light and incorporates captive screws for all panels requiring user access to facilitate lamp replacement, alignment, and filter changes. Safety interlocks prevent inadvertent exposure to UV light. The Oriel Sol3A rugged design is backed by the Newport Corporation's world wide organization.

## WHY CLASS AAA?

Photovoltaic (PV) cell research and manufacturing are evolving at an amazing rate, with new technologies like thin film processes, tandem junction and multi-junction cells, organic thin films and dye sensitized cells all requiring careful evaluation of their performance. The old designation of "Class A" solar simulators had become standard in most test laboratories and manufacturing environments, but the definition of Class A has degraded to mean a system that is capable of meeting any one (typically spectral match) of the three performance parameters called out in the test methods. In October 2007 the IEC revised the method used to evaluate the performance of a solar simulator. The new standard calls for quantifying and reporting the performance of each of three performance criteria separately. A solar simulator is now measured as class A, B, or C for Spectral Match, Non-Uniformity of Irradiance, and Temporal Instability of Irradiance. The new Sol3A solar simulators have been designed to meet Class A performance for all 3 of the test requirements, Spectral Match, Non-Uniformity of Irradiance, and Temporal Instability of Irradiance as called out by IEC 60904-9 Edition 2 (2007) edition, JIS C 8912, and ASTM E 927-05.

By ensuring measurement uniformity that allows results comparability and traceability, Class AAA systems reduce binning variability of photovoltaic cell testing as compared to so called Class A, Class B or non-classified sources. This performance consistency allows for precise comparison of performance data for researchers engaged in developing novel solar materials.

Newport Corporation puts each Oriel Sol3A™ through rigorous testing for all 3 standards (IEC, STM, and JIS) to insure compliance and supplies a certificate of calibration for all three standards.

# Oriel® Sol3A™ Class AAA Solar Simulators

## DEFINING CLASS AAA PERFORMANCE STANDARDS

Photovoltaic standards mandate that Class AAA solar simulators meet demanding requirements in three key performance areas: spectral match to the solar spectrum, spatial non-uniformity of irradiance, and temporal instability of irradiance.

There are three standards that define solar simulator performance.:

- IEC 60904-9 Edition 2 (2007) Photovoltaic Devices – Part 9: Solar Simulator Performance Requirements
- JIS C 8912-1998, Solar Simulators for Crystalline Solar Cells and Modules
- ASTM E 927-05 (2005) Specification for Solar Simulation for Terrestrial PV Testing

**Table 1 Class AAA Standards and Specifications**

Organization	IEC	JIS	ASTM
Performance Parameter	60904-9-2007	C 8912	E92-05
Spectral Match (fraction of ideal percentage)	0.75 - 1.25	0.75 - 1.25	0.75 - 1.25
Non-Uniformity of Irradiance	2.0%	<±2%	2%
Temporal Instability	0.5% STI <2.0% LTI	<±1%	2%

## SPECTRAL MATCH

The standards define the spectral match of a solar simulator as a percentage of the integrated intensity in 6 spectral ranges (listed in Table 2). Any deviation from the specified percentages must then lie within a range that determines the class of the simulator. For Class AAA, this range is 0.75 to 1.25 times the ideal percentage.

## INTERNATIONAL STANDARDS FOR SOLAR SIMULATION SPECTRAL DISTRIBUTION

The reference spectral distribution of sunlight at global Air Mass 1.5 is defined in ASTM G173-03 and IEC 60904-3. Although these tables include the spectrum from 280nm to 4000nm, for classification of solar simulation systems, this is restricted to the wavelengths from 400nm to 1,100nm. This spectral bandwidth is defined in reference IEC 60904-9 and ASTM E927-05. The spectral match of the Sol3A is classified for the range of 400-1100nm.

To ensure that the Oriel Sol3A™ Solar Simulator falls reliably within this range, Newport uses a proprietary, highly stable spectral correction filter. This proprietary filter can withstand the very high intensity from the lamp without changing spectral properties. The result is the spectral output shown in Figure 1.

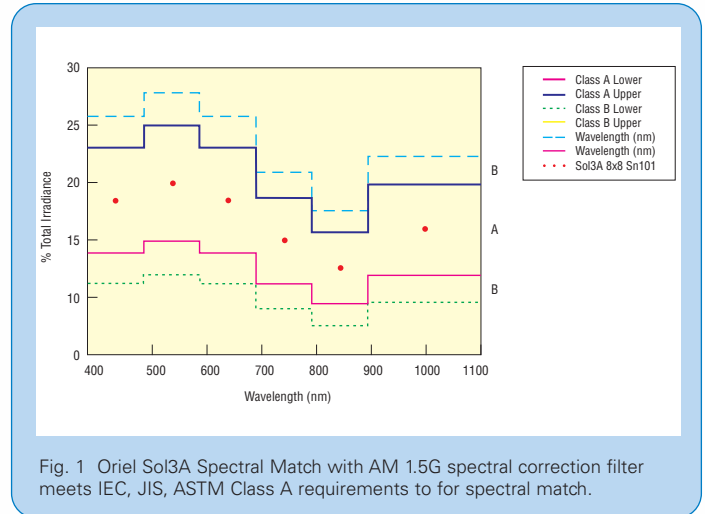


Fig. 1 Oriel Sol3A Spectral Match with AM 1.5G spectral correction filter meets IEC, JIS, ASTM Class A requirements to for spectral match.

## Spectral Match

**Table 2 Ideal Spectral Match Defined by IEC Standards**

Spectral Range (nm)	Total Irradiance Range (%)	Ideal %
400 - 500	13.9 - 23.1	18.5
500 - 600	15.1 - 25.1	20.1
600 - 700	13.7 - 22.9	18.3
700 - 800	11.1 - 18.5	14.8
800 - 900	9.2 - 15.3	12.2
900 - 1100	12.1 - 20.1	16.1

## SPATIAL UNIFORMITY OF IRRADIANCE

The irradiance uniformity over the work area is the most difficult Class AAA requirement to achieve and maintain. Hot spots can lead to significant errors in measured cell efficiency and can cause inaccurate binning of cells. The Class AAA spatial non-uniformity performance standard is designed to minimize the impact of hot spots and has a very stringent requirement of  $\leq 2\%$ . The plot below shows the uniformity of the irradiance across a typical simulator working area. Each unit will come with a plot of irradiance non-uniformity. The working distance ranges for each simulator are listed in Table 3.

## SOL3A WORKING DISTANCES

Table 3 Working Distances

Model	Size	Working Distance Range (Inches)
94023A	2 x 2 (51 x 51)	12.0 ±0.5
94043A	4 x 4 (102 x 102)	4.0 ±0.5
94063A	6 x 6 (152 x 152)	5.0 ±0.5
94083A	8 x 8 (203 x 203)	15.0 ±0.5
94123A	12x12 (300 x 300)	12.0 ± 0.5

## ORIEL CLASS AAA SOLAR SIMULATOR KEY COMPONENTS

### Illuminator Housing

The illuminator housing provides a safe enclosure for the lamp. Its powder coated flat black finish provides a durable surface that also minimizes stray light. It is equipped with safety interlock systems to ensure operator and system safety. Panels containing user serviceable components use captive screws that require no tools for ease of removal and replacement. Integral fan(s) provide forced air-cooling to maintain optimal lamp, optics and housing temperature. The Sol3A housing utilizes a design which allows the head orientation to produce a downward, sideways or upwards facing beam on the 2x2 or 4x4 models. Contact your Sales Engineer for details.

### Integrated Shutter

The Oriel Sol3A Solar Simulator includes an upgraded shutter for production-environment operation. The newly designed shutter for the Class AAA systems is a rugged, single-blade shutter designed for >1 million cycles. Historically, our real-world performance has exceeded 10 million cycles on units in the field for many years. The shutter has a minimum exposure time of 200 ms and can be controlled via a contact closure or logic level input, or a convenient push-button switch on the illuminator housing.

### Xenon Arc Lamp

The Oriel Sol3A Solar Simulator source is a CW system. This enables testing of all cell materials unlike flash-lamp based systems that are limited by the response time of the material allowing the cell to be soaked at a constant light level prior to testing. The lamp is an ozone-free xenon short arc lamp. We certify each source with the supplied lamp. For continuous production environments, we suggest purchasing replacement lamps and an alignment palette to ensure Class AAA compliance as lamps are replaced.

### Air Mass 1.5G Filter

The combination of lamp and air mass filter produces the characteristic Class AAA spectra. Our Air Mass 1.5G Filter retains its optical properties under the conditions encountered without degradation of the filter.

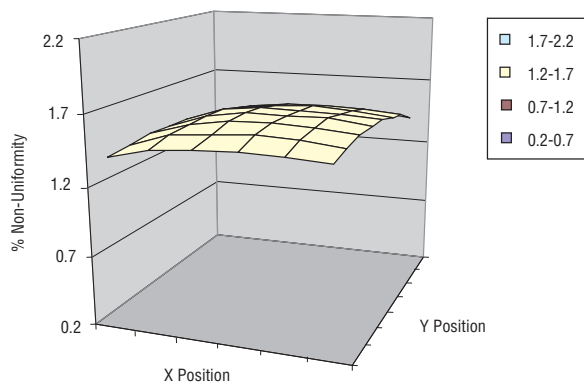


Fig. 2 Measured Uniformity of a 2x2" Oriel Sol3A Solar Simulator.

## TEMPORAL INSTABILITY

Temporal Instability is the third performance parameter of Class AAA standards. It requires that the output light be stable over time in order to ensure that the lamp fluctuations do not distort the measurement of solar cell efficiency. Oriel's Sol3A easily meets the requirements for temporal instability as defined by the IEC, ASTM, and JIS standards. The IEC 60904-9 (2007) has the most stringent requirements for short term instability with a maximum allowable level of 0.5%. Figure 4 shows a typical instability response for an Oriel Sol3A utilizing a 50 millisecond data acquisition time.

Elapsed Time (sec)	60
No. of Data Points	1200
% Instability	0.369

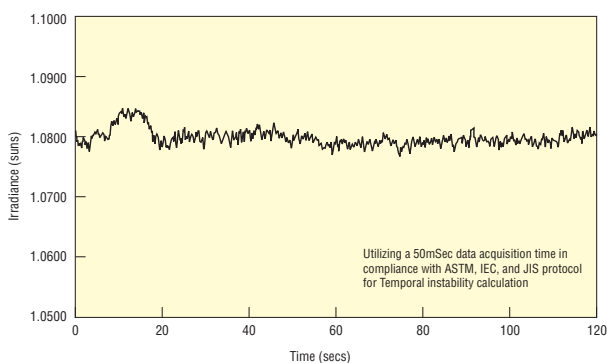


Fig. 3 Typical Output Variation of a 1.6 kW Oriel Sol3A Solar Simulator Over Time.

# Oriel® Sol3A™ Class AAA Solar Simulators

## Power Supply

The Oriel regulated power supply incorporates over 40 years of experience in high voltage power supply design to provide constant electrical power to the xenon lamp. The power supply is CE compliant and features universal AC mains operation for use anywhere in the world. Lamp usage can be monitored in accumulated hours from the power supply, because it is important to replace the lamp at the end of its rated life to maintain the minimum 1 sun output and spectral characteristics. The lamp's output will significantly decrease and change spectrally with continued use beyond its rated life.

## Maintaining the Oriel Sol3A Solar Simulator

Oriel Sol3A Solar Simulators maintain Class AAA compliance during the rated "performance lifetime" of the lamp. When the lamp is replaced, the instrument should be realigned to maintain Class AAA compliance. Irradiance uniformity is the most difficult Class AAA requirement to meet and maintain. In order to facilitate the measurements and adjustments necessary to maintain Class A uniformity, the Newport uniformity measurement tool (SOL-UMT) can be used to perform an automated test after lamp alignment following installation or replacement. The use of this tool can significantly reduce the time and effort required to maintain the Sol3A Solar Simulator within Class AAA specifications.\* Please contact a Sales Engineer for details.

\* Note: the use of these tools does not constitute re-certification of the system to Class A standards. For re-certification the entire Sol3A solar simulator must be returned to the factory. We recommend purchasing replacement lamps and certification at the time of purchase of the source. Contact a Sales Engineer for details.

## CLASS AAA SOLAR SIMULATOR SPECIFICATIONS

Model	94023A	94043A	94063A	94083A	94123A
Illuminated Area	2x2 inch (51x51mm)	4x4 inch (102x102mm)	6x6 inch (152x152mm)	8x8 inch (203x203mm)	12x12 inch (203x203mm)
Collimation Angle	<±4 °	<±4 °	<±3 °	<±2 °	<±1 °
Typical Power Output	100mW/cm <sup>2</sup> (1 Sun) ±20% Adjustable	100mW/cm <sup>2</sup> (1 Sun) ±20% Adjustable	100mW/cm <sup>2</sup> (1 Sun) ±20% Adjustable	100mW/cm <sup>2</sup> (1 Sun) ±20% Adjustable	100mW/cm <sup>2</sup> (1 Sun) ±20% Adjustable
Uniformity <sup>1</sup>	≤2 %	≤2 %	≤2 %	≤2 %	≤2 %
Uniformity Classification	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)
Temporal Instability <sup>2</sup>	≤0.5% STI ≤2.0% LTI	≤0.5% STI ≤2.0% LTI	≤0.5% STI ≤2.0% LTI	≤0.5% STI ≤2.0% LTI	≤0.5% STI ≤2.0% LTI
Temporal Instability Classification	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)	<b>A</b> (IEC 60904-9 2007) <b>A</b> (JIS C 8912) <b>A</b> (ASTM E927 - 05)
Spectral Match <sup>3</sup>	13.8% - 23.0% (400-500nm) 14.9% - 24.9% (500-600nm) 13.8% - 23.0% (600-700nm) 11.2% - 18.6% (700-800nm) 9.4% - 15.6% (800-900nm) 11.9% - 19.9% (900-1100nm)	13.8% - 23.0% (400-500nm) 14.9% - 24.9% (500-600nm) 13.8% - 23.0% (600-700nm) 11.2% - 18.6% (700-800nm) 9.4% - 15.6% (800-900nm) 11.9% - 19.9% (900-1100nm)	13.8% - 23.0% (400-500nm) 14.9% - 24.9% (500-600nm) 13.8% - 23.0% (600-700nm) 11.2% - 18.6% (700-800nm) 9.4% - 15.6% (800-900nm) 11.9% - 19.9% (900-1100nm)	13.8% - 23.0% (400-500nm) 14.9% - 24.9% (500-600nm) 13.8% - 23.0% (600-700nm) 11.2% - 18.6% (700-800nm) 9.4% - 15.6% (800-900nm) 11.9% - 19.9% (900-1100nm)	13.8% - 23.0% (400-500nm) 14.9% - 24.9% (500-600nm) 13.8% - 23.0% (600-700nm) 11.2% - 18.6% (700-800nm) 9.4% - 15.6% (800-900nm) 11.9% - 19.9% (900-1100nm)
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Working Distance	12 ±0.5 in.	4 ±0.5 in.	5 ±0.5 in.	15 ±0.5 in.	12.0 ± 0.5 in.
Lamp Power	450 W	450 W	1000 W	1600 W	1600 W
Input Power (Simulator)					
Line Regulation	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %



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Newport Corporation, Irvine, California and Franklin, Massachusetts; Evry and Beaune-La-Rolande, France and Wuxi, China have all been certified compliant with ISO 9001 by the British Standards Institution. Santa Clara, California is DNV certified.

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