

Simulation of Solar Irradiation

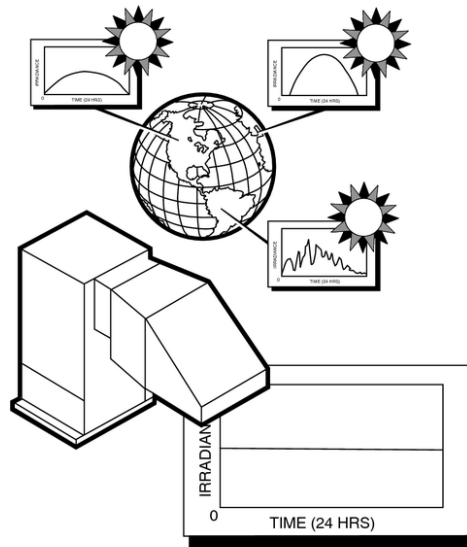


Fig. 1 Simulators let you simulate various solar conditions any time of the day, during any weather condition.

Oriel® Xenon Arc Lamp Solar Simulators

Newport's Oriel® Solar Simulators provide the closest spectral match to solar spectra available from any artificial source. The match is not exact, but better than needed for many applications. For the closest match possible, choose a [Oriel Sol3A Class AAA Solar Simulators](#) these maintain an extremely tight uniformity, output stability and spectral match, as required by the photovoltaic cell manufacturers for testing PV cells.

Fig. 2 shows the optics of the Oriel Simulators. The xenon arc lamp at the heart of the device emits a 5800K blackbody-like spectrum with occasional line structure. The small high radiance arc allows efficient beam collimation. The system design features low F/# collection, optical beam homogenization, and filtering and finally, collimation. The result is a continuous output with a solar-like spectrum in a uniform collimated beam. Beam collimation simulates the direct terrestrial beam and allows characterization of radiation-induced phenomena.

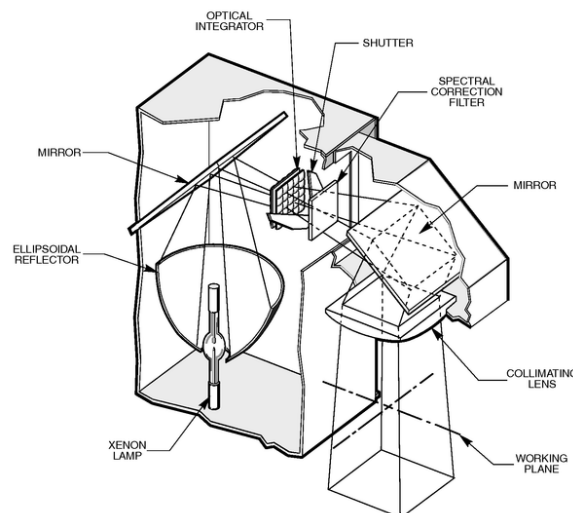


Fig. 2 Cut-away view of an Oriel Solar Simulator.

Beam Size Sets Irradiance Level, Not The Spectrum

Our simulators are available with several beam sizes. The magnitude (sun value, total irradiance in W m^{-2} or spectral irradiance at any wavelength in $\text{W m}^{-2} \text{nm}^{-1}$), but not the shape of the spectral curve, depends on the beam size. That is, the shape of the curve of any Oriel Solar Simulator with the same Air Mass filters is essentially the same.

Example

The 91192 kW (4 x 4 inch) Solar Simulator, with AM 0 filter has a typical integrated irradiance of 3575 W m⁻² compared with the "1 sun" value of 1367 W m⁻² of the AM 0 standard. The 91191 (2 x 2 inch) Simulator, with the same AM 0 filter, has a typical integrated irradiance of 13400 W m⁻².

Output Control

You can reduce the magnitude of the simulator output by 15% using the power supply controls, and by more than 80% by adjusting lamp position and using optional apertures. Using apertures improves the output beam collimation.

The Role of the Filters

The xenon lamp spectrum differs from all solar spectra because of the intense line output in the 800 - 1100 nm region. We use our AM 0 filter to reduce the mismatch, but no reasonably economical filter can remove the line structure without severe modification of the remainder of the spectrum. The relevance of the residual infrared mismatch depends on the application. Our AM 1, AM 1.5 and AM 2 filters also modify the visible and ultraviolet portion of the spectrum for a better match to the standard solar spectra. Many photobiological and photovoltaic applications require very close simulation of the solar ultraviolet. For PV cell testing, we offer [Oriel Sol3A Class AAA Solar Simulators](#), which use a proprietary filter to minimize the mismatch.

Comparing Simulators' Spectra with Standard Solar Spectra

It is helpful to consider the solar spectral and simulator curves as having both a shape and magnitude. The easiest single number specifying the magnitude is the total irradiance, the integral of the curve.

$$\text{Total irradiance of standard} = \int E_{\text{std}}(\lambda) d\lambda$$

$$\text{Total irradiance of simulator} = \int E_{\text{sim}}(\lambda) d\lambda$$

For the AM 0 standard curves this value is the solar constant, 1367 W m⁻², equivalent to "1 sun." We measure the total irradiance in W m⁻² for our simulators by integrating the spectral data with a calibrated broadband meter. For some applications, it is preferable to compare the integrated irradiance over a limited spectral region. For silicon photovoltaic research the integrated irradiance from 200 - 1100 nm, the sensitive range for these devices, is a better basis for comparison of the magnitude of a simulator irradiance with that of the corresponding standard curve.

If you know the spectral response of the effect you wish to create R_λ , then comparing the effective exposure rates, the integrated product of the solar and simulator spectra, with the responsivity curve, gives a better measure of how the simulator relates to standard solar exposure.

$$\text{Effective exposure rate} = \int E_{\text{std}}(\lambda) R_\lambda d\lambda$$

For the standard curves

$$\text{Effective exposure rate using the simulator} = \int E_{\text{sim}}(\lambda) R_\lambda d\lambda$$

Temporal Behavior of Simulator Output

The sun is a relatively constant source, though the terrestrial irradiance level and spectrum changes with daily and annual cycles and with unpredictable atmospheric conditions. Our simulator power supplies have superb regulation against line or load changes and internal filtering to reduce short-term noise and ripple. Even so, the output of our simulators falls gradually and the spectrum changes slightly as the lamp ages (see Fig. 3). Changes in local temperature can affect the simulator output by a few percent. We can provide initial test data (on a special order basis), but recommend regular measurement of total or relative simulator output for long-term assurance of irradiation level.

We select and age our filters, and the design locates them in a moderate intensity zone of the beam. With these and other precautions we find no significant post-processing filter heating or filter aging effects. For precise quantitative work, you should stabilize the output in the spectral region of interest using the optional Light Intensity Controller. For repetitive monitoring, as in a quality assurance application, a standard test cell can be simpler than spectroradiometry for monitoring simulator performance and stability. (Note that changes in radiometer responsivity in the UV due to radiometer filter or detector changes can imply that the simulator output is changing. The UV irradiance of some of our simulators can quickly change untreated filter transmittance and UV detector spectral responsivity.)

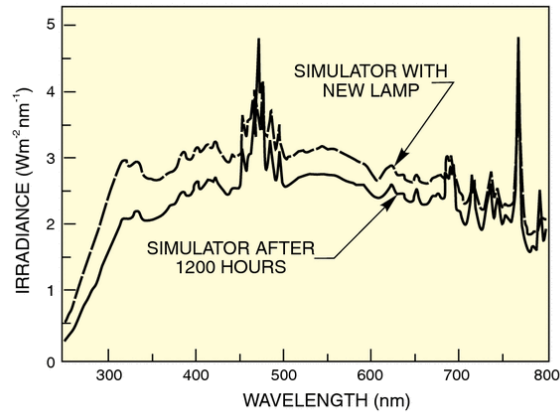


Fig. 3 Actual spectral irradiance of a Solar Simulator with a new lamp, and a lamp after 1200 hrs. (Light intensity controller was not used.)

Simulation with Other Kinds of Lamps

Solar simulators based on lamps other than high pressure xenon arcs produce spectra that are poorly matched to the solar spectrum (with the exception of the impractical carbon arc simulator).

Simulation with Tungsten Lamps

The brightest tungsten lamps operate at color temperatures of 3200K (the solar spectrum has a brightness temperature of 5600 - 6000K depending on the spectral region). Filters allow you to modify the tungsten lamp spectrum for a reasonable match to portions of the solar spectrum. The low UV and shortwave visible output prevents an efficient match in these key regions. You can use a filtered tungsten lamp for a good match to the infrared solar spectrum.

Fig. 4 shows typical solar spectrum and tungsten lamp spectrum. Filters may be used to modify the spectrum to make a reasonable, but inefficient match in the visible.

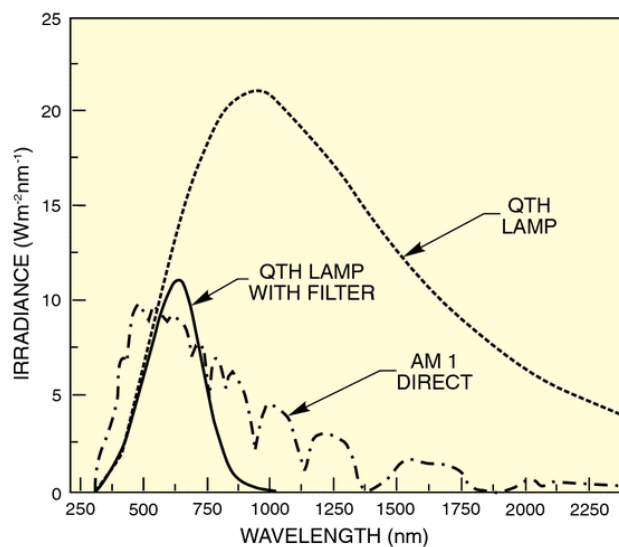


Fig. 4 Spectrum of a 3300K tungsten halogen lamp. Filtering removes a lot of the excess IR, but is inefficient and leaves a UV deficit.

Simulation with Mercury Lamps

There are many kinds of mercury lamps from low pressure lamps (germicidal) to high pressure short arc lamps. The strong line spectra in the ultraviolet prevent a close spectral match. You can successfully use these lamps to simulate solar UV for any application that is totally insensitive to source spectral distribution (i.e. having a flat action spectrum) and for some relative test. Most UV action spectra are far from flat, so results with mercury lamp simulators can be misleading.

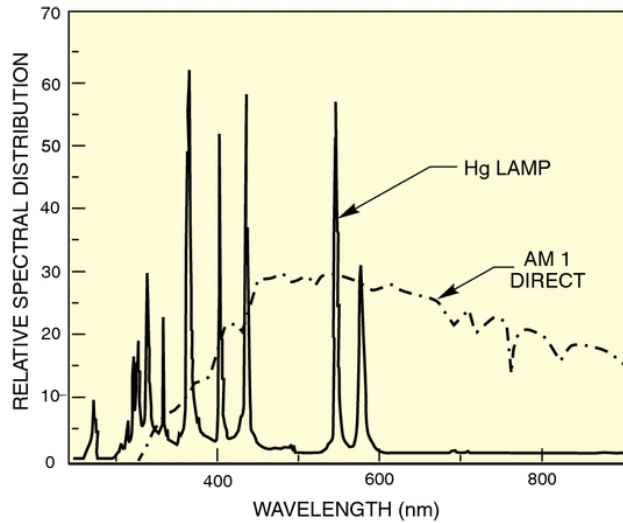


Fig. 5 Mercury lamp output and AM 1 direct solar spectrum.

Simulation with Metal Halide Lamps

Metal halide lamps are efficient sources rich in ultraviolet and visible output. Like mercury lamps, the spectrum is dominated by strong lines that invalidate quantitative data for most UV activated photoeffects.

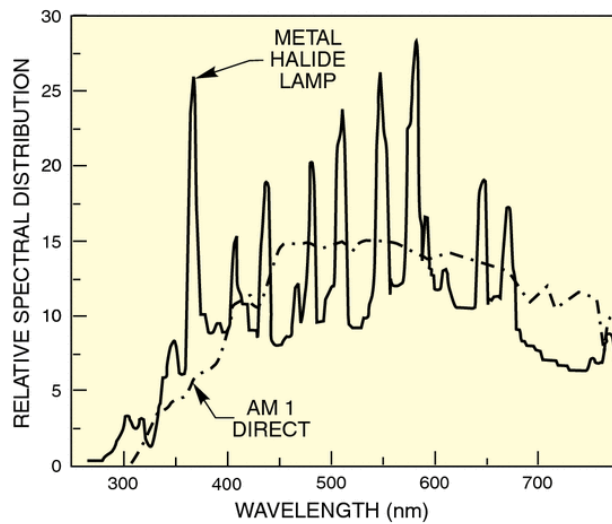


Fig. 6 Metal Halide lamp output and AM 1 direct solar spectrum.