Solar simulation basics

Solar radiation
The sun is a spherical source 1.391.400 km in diameter located 149.600.000 km from the earth. From our vantage point we see a beam of light with an angle of collimation of approximately 0.5° (of full angle). The total irradiance value at the atmosphere, the solar constant is about 1370 Wm^{-2}, equivalent to 1 "sun".

When viewed from outer space without atmospheric absorption the sun's spectrum approximates a 5900 K full radiator with spectral lines superimposed. The irradiation outside the atmosphere is called the Air Mass Zero (AM 0), indication no atmospheric absorption.

Our atmosphere causes substantial absorption and scattering throughout the spectrum. Scattering is strongest at lower wavelengths. The absorption is particularly strong in the UV due to ozone, and in the IR due to water vapor and carbon dioxide. The frequent changes in clouds, aerosols and water vapor result in changes in the spectrum seen on the ground.

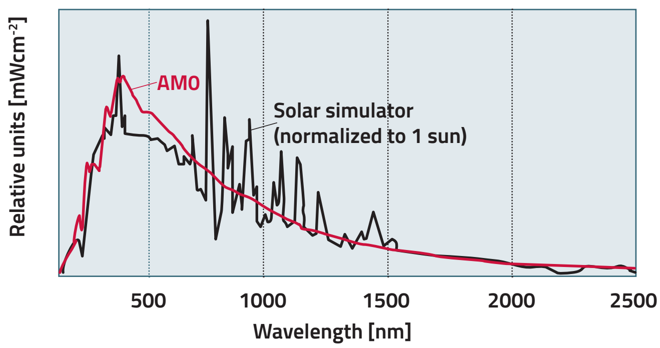
Direct radiation comes straight from the sun, diffuse radiation is scattered from the sky and from the surroundings. The total radiation on the ground has direct scattered and reflected components and is called global radiation.

The irradiance on the surface with the sun at the zenith is said to be an Air Mass 1 (AM 1) spectrum. The sun at 30° from the horizon, (60° from the zenith) doubles the path and gives an AM 2 spectral distribution. The sun at 48,2° from the zenith is called AM 1.5 spectrum.

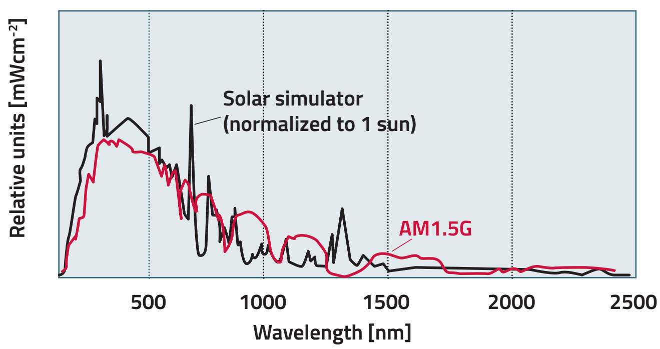
The direct irradiance curves represent radiation falling on a surface normal to the direction to the center of the sun in a collection cone angle of 5.8°. The global irradiance curve represents radiation collected over 2 steradians (a hemisphere) and includes both direct and diffuse light.

Standard spectra
Reference standards have been established because of the wide variation in solar irradiance. The American Society for Testing and Materials (ASTM) published three spectra, AM 0, AM 1.5 Direct and AM 1.5 Global on a sun facing surface 37° from the horizontal. The curves are from the data in ASTM standards E-490-00 for AM 0 and G-173-03 for AM 1.5. The spectral sets were also adopted by the IEC (International Electrotechnical Commission).

Air mass filters
For an Air Mass Zero (outer space) solar spectrum the Xenon lamp is filtered to reduce the excessive power from the Xenon lines in the infrared from 0.8 to 1.0 microns. The Xenon lamp also shows some excessive power in the 0.25 to 0.35 region. For the terrestrial solar spectrum the ultraviolet below 0.4 microns and the infrared must be further attenuated by filters. We offer an AM 0 for extra terrestrial spectra and an AM 1.5G filter for global terrestrial spectra. (See figures)



Air mass 0. Total irradiance from 250 - 2500 nm is 130 $mWcm^{-2}$



Air mass 1.5 Global. Total irradiance from 250 - 2500 nm is 95 $mWcm^{-2}$

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Solar simulation basics

Simulation of sunlight
High pressure Xe arc lamps make excellent artificial sources to simulate sunlight. The high color temperature of the xenon lamps (6050 to 6350 K) is a close match to the solar temperature. This results in similar spectra in the UV and VIS although the lamp has some Xe emission lines in the near IR. The Xe lamp spectrum must be filtered to match various atmospheric conditions. Our simulators include filters to tailor the spectrum and give good matching to standard spectra. The matching is better in the UV and VIS than in the IR.

Spectral match
Any simulator does not accurately match the sun's spectrum and the spectrum of the simulator changes somewhat with lamp age and system. Of course the terrestrial solar spectrum itself varies greatly with sun altitude and with atmospheric constituents. Care should be taken to measure the beam power in the primary spectral region of interest in order to reduce the effects of this mismatch. For example, for visual applications a sensor corrected to match the photopic curve (i.e. the sensitivity of the eye) should be used. For solar cell applications, using a calibrated cell of similar spectral sensitivity helps correct for the spectral mismatch. For total power measurement a laboratory thermopile with quartz window calibrated in power per unit area (w/m²) whose response is essentially independent of wavelength can be used. Collimation

The sun illuminates the earth with light that is parallel to ±0,25°. Generally simulator collimation angles are higher (from ±3° to ±6°). For irradiation of flat areas this effect is usually negligible. Take car that the sensor used to measure the simulator beam accepts the wider collimation angle.

Photovoltaic testing
ASTM and IEC provide norms for photovoltaic testing and devices which classify simulators on the basis of spectral match, non-uniformity and temporal instability of irradiance into three classes: A, B and C (ASTM E927-05; IEC 60904-9).

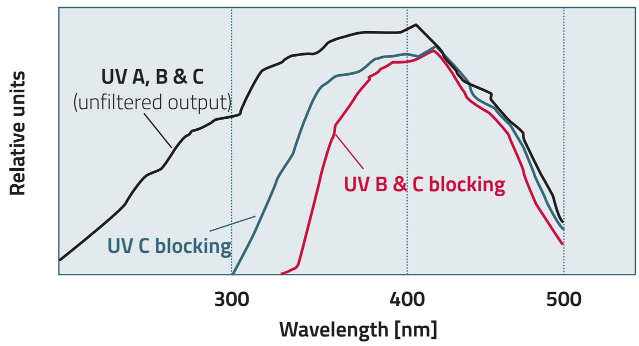
Our simulators meet class B or C specification for uniformity and stability and class A for spectral match. By the way, outdoor sunlight does not meet spectral requirements for an ASTM class A simulator!

UV simulators
We offer enhanced UV sources as simulators with the spectral distribution modified to reduce the visible and IR regions of the sun spectrum.

The UVA and UVB regions are of particular interest because natural sunlight includes UVA and UVB radiation.

Our UV simulators come with a dichroic mirror which selectively reflects the UV radiation from the Xe lamp and transmits the visible and infrared radiation. The VIS and IR is converted to heat at a heat sink behind the dichroic mirror. The remaining VIS and IR radiation (less than 20% of the original VIS and IR) are transmitted to the output along with the UV radiation.

Further filtering can be accomplished at the output by using UVC or UVB/C blocking filters (see figure).



These units are useful for work requiring a very intense UV without the complications of visible and infrared heating. This is especially important for biological work on live subjects.

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