ESC Cost Effective Solar Simulator

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Background and Purpose

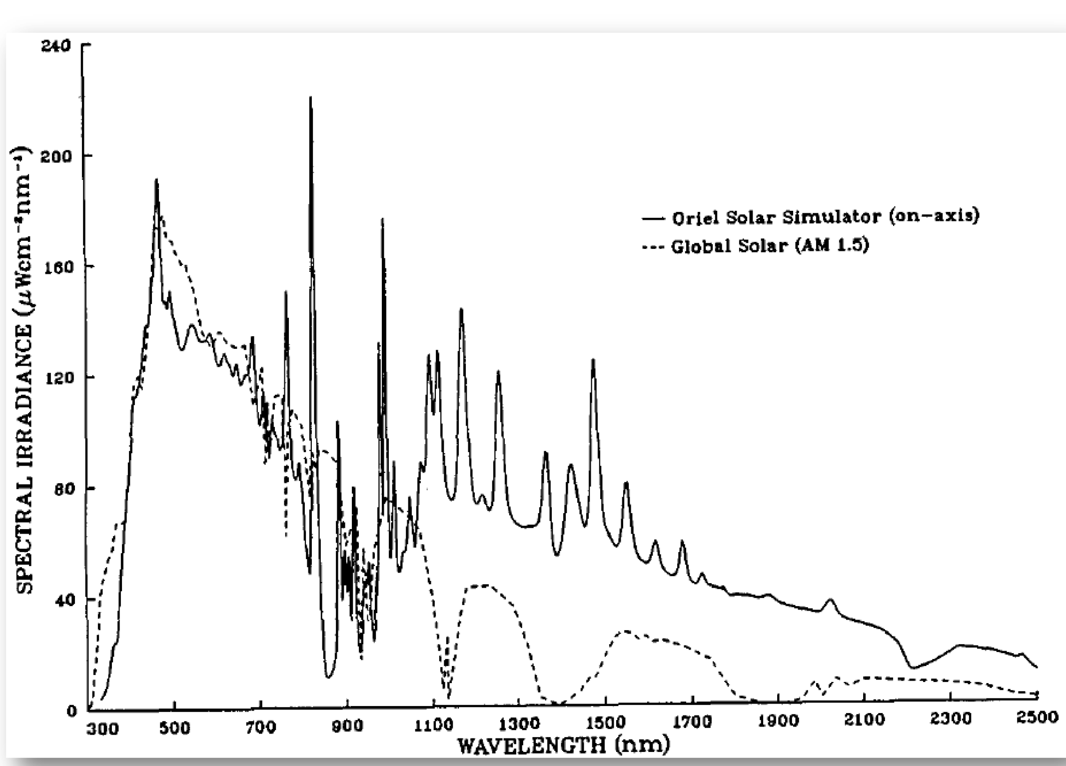
Solar simulators have been in use for half a century. A solar simulator allows us to test solar systems independent from current weather conditions and time of day, which allows for accelerated solar research. They have been used by a variation or groups, from NASA simulating extraterrestrial conditions to horticulturalists accelerating growth of plants. Commercially available solar simulators are mostly intended for photovoltaic cell characterization. A few specific systems can test either solar thermal or concentrated photovoltaic but there is no single system that can test all different kinds of solar power systems

The goal of the ESC Advanced Solar Simulator is to be able to test all types of systems with the highest accuracy to the three main solar characteristics.

- Spectrum: 300nm to 2500nm range
- Intensity: 1000 W/m^2 $\pm$5% across the area
- Angular Div.: $\pm$0.267º or 0.533º from direct beam collimation
- Test: Solar Thermal, Concentrated Solar Power (CSP), Photovoltaic (PV), Concentrated Photovoltaic (CPV)

Methods

The design for the solar simulator is meant to meet the requirements stated above. The geometry is a 2kW Xenon arc lamp placed inside a parabolic 24" diameter parabolic reflector. The lamp is offset of the focal point to adjust for a more even intensity distribution. A Xenon arc lamp is the most common source for solar simulators because of availability and the closeness to the terrestrial spectrum. Different filters or material can be used to adjust the fit of the Xenon spectrum to the desired solar spectrum.



Olson and Parker's[1] experimental Xenon arc lamp characterization.

The lights can be arranged in either an aligned or offset pattern to compensated for the geometry required. Intensity and light distribution is affected by the distance the test plane is away from the light source. This is because of the angles created by the parabolic reflector of a source which is not at the focal point. A maximum half angle of 2.47º is calculated for these experiments.

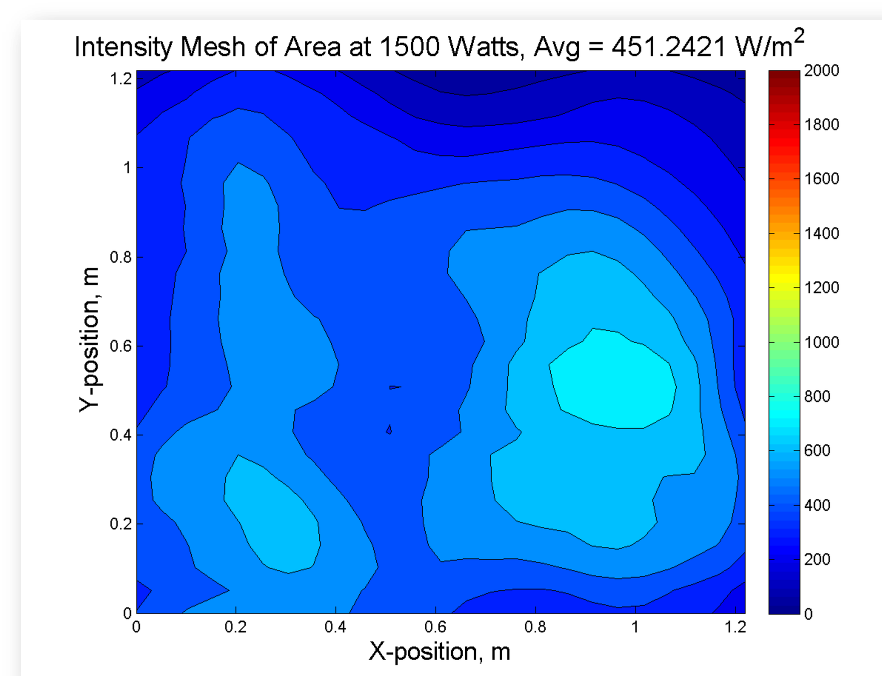
Pyrheliometer on Traverse

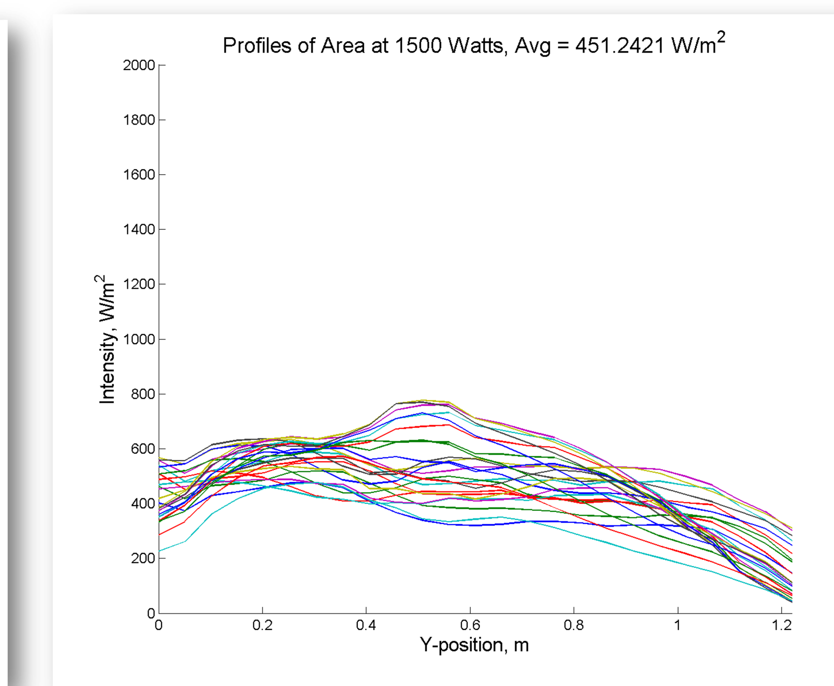
Lamp Array

An Eppley Normal Incidence Pyrheliometer (NIP) is used to measure the overall intensity of the spectrum at grid points with a 1.22 m by 1.22 m (48'' x 48'') area. The pyrheliometer only measures direct beam radiation, $\pm$2.5º and it measures the total intensity across the solar spectrum.

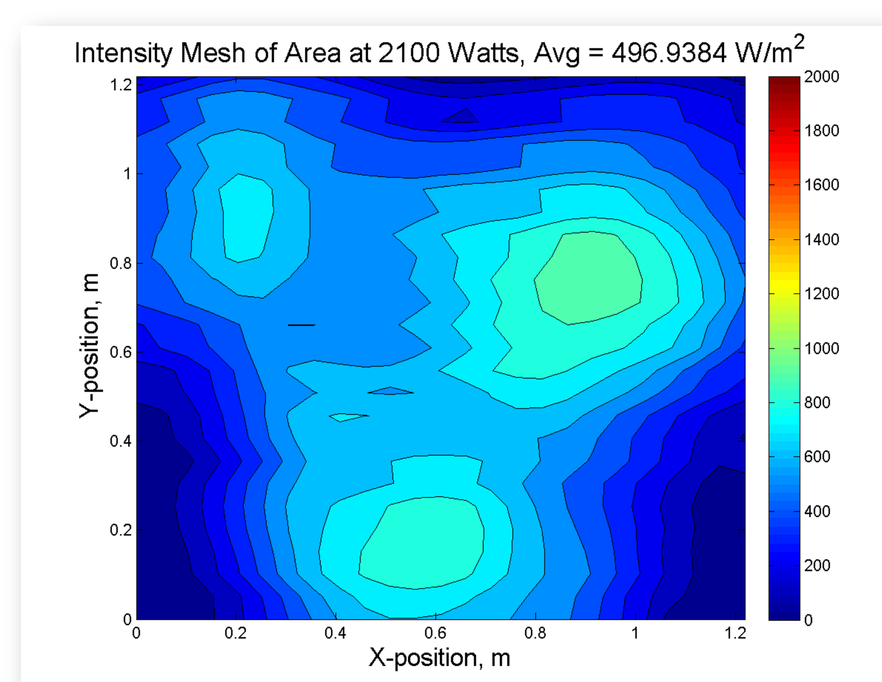
Results

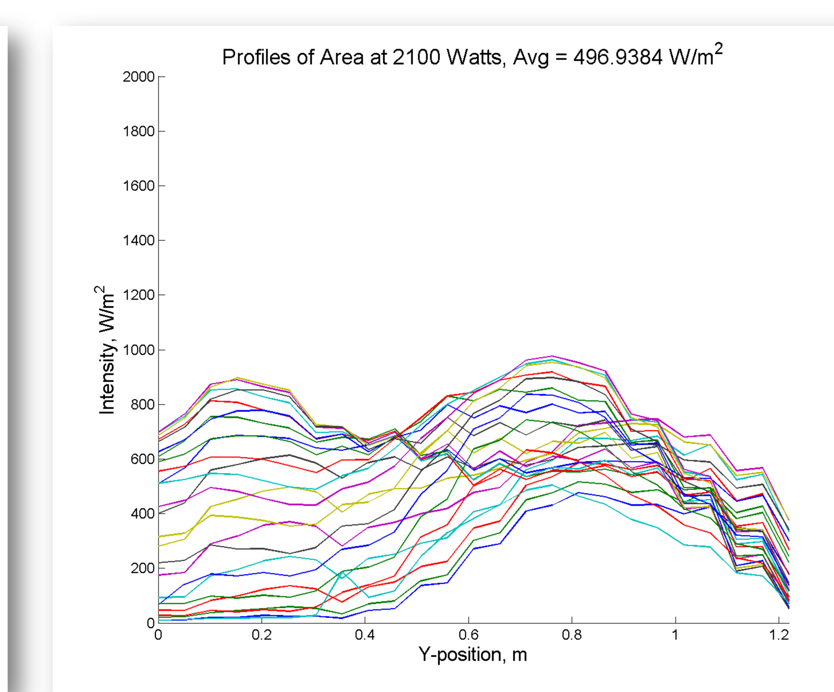
Data is collected with LabView and plotted in MATLab as a 3D mesh and 2D slices. Tests were done with both a 4-lamp array (aligned) and a 3-lamp array (offset).





Data With 4-lamp Array





Data With 3-lamp Array

The standard deviation with the 4-lamp array is about 146.3 W/m^2 while the standard deviation without a reflector is 207.4 W/m^2 over the entire area. These experiments were performed with the test plan at 5.9 m (19.5 ft) away from the focal point. The light source is offset -11.1 mm (0.438 in.) from the focal point, where negative is closed towards the reflector.

Conclusions and Future Progression

The amount of light lost was greater than anticipated. Ideal alignment is very hard to achieve as well, this can also create unwanted intensity peaks. It has been found that light intensity from a 2kW Xenon arc lamp is too low to meet the 1000 W/m^2 requirement. An even intensity distribution is extremely difficult to accomplish with the current setup. To obtain the desired intensity, a higher power lamp is needed.

Possible solutions:

- 2.5kW Xenon arc lamp
- Adjust lamp position inside the reflector
- Obtain more effective reflector

For future work an accurate spectral measurement of the ESC Solar Simulator needs to be performed to determine if it matches solar spectrum. This can only be done once the intensity requirement is met.

Other options involving changing the geometry and components of the setup are also currently being investigated.

References

[1] Robert A. Olson and Jack H. Parker. Carbon Arc Solar Simulator. Applied Optics, 30(10), April 1991.