OUR Journal: ODU Undergraduate Research Journal

Volume 9 Article 10

2022

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Recommended Citation
VanHuss, Raines A. (2022) "The Development of an Inexpensive Alternative to Industry Solar Simulators," *OUR Journal: ODU Undergraduate Research Journal*: Vol. 9, Article 10.
DOI: 10.25778/q7bj-es55
Available at: https://digitalcommons.odu.edu/ourj/vol9/iss1/10

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Cover Page Footnote

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The Development of an Inexpensive Alternative to Industry Solar Simulators

By Raines VanHuss

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ABSTRACT— Solar cells are a prominent renewable energy source used in the twenty-first century. In order for the technology to grow, research lab equipment is needed to measure and characterizes these cells. This report covers solar simulator devices and proposes an alternative design solution to lessen the cost of solar cell lab equipment. Common household light sources were tested by generating I-V characteristics using an amorphous silicon solar cell. The light bulb that generated the best I-V curve was selected and then tested for the optimal distance between the light source and the solar panel. The alternative solar simulator was then tested at the optimal distance by the generation of I-V characteristics and light spectrum. These results will be compared to an industry-standard solar simulator: the Newport LED Solar Simulator LSH-7320. The experiment conducted in this report and its findings' intentions are to motivate more research in designing low-cost solar simulators with the hopes of allowing developing countries to start utilizing solar cell technology.

Keywords: Solar simulator, Solar energy, Renewable energy, Research, Electrical engineering, Amorphous silicon, Solar cell, Developing countries, Photovoltaic

I. Introduction

Solar panels have become one of the most popular renewable energy resources in the twenty-first century. In order to develop new technology related to solar power, the photovoltaic (PV) cells have to be tested and characterized to better understand design constraints. In order to test PV cells, solar simulators are purchased to generate I-V characteristic curves in engineering and science labs. However, these machines are expensive which means that it is hard for developing countries to test and use solar systems as a power source. In order to remedy this dilemma, one research team has purposed a low-cost LCD projector as a working solar simulator [1]. In this report instead of using an LCD projector, the design will substitute everyday light bulbs and fixtures as the light source to test PV cells. Four different lightbulbs have been tested using a spectrometer and generating I-V characteristic curves on a solar cell. The results provide data that can be used to build low-cost solar simulators to further develop solar technology that can be utilized by a broader range of constituents.

II. METHODOLOGY

The physical design of the solar simulator was based on the industrial device used in research facilities. Specifically, the Newport LED Solar Simulator LSH-7320. This device is used to generate and record precise and accurate data for PV cells. The basic design is a light source overhanging a platform. The solar cell is placed on the base and connected using probes to a digital logging multimeter. Computer software is then used to gather data and generate I-V graphs. Figure 1 shows the Newport LED Solar Simulator utilized in this experiment. This device and its specifications will be used to compare the low-cost version developed.

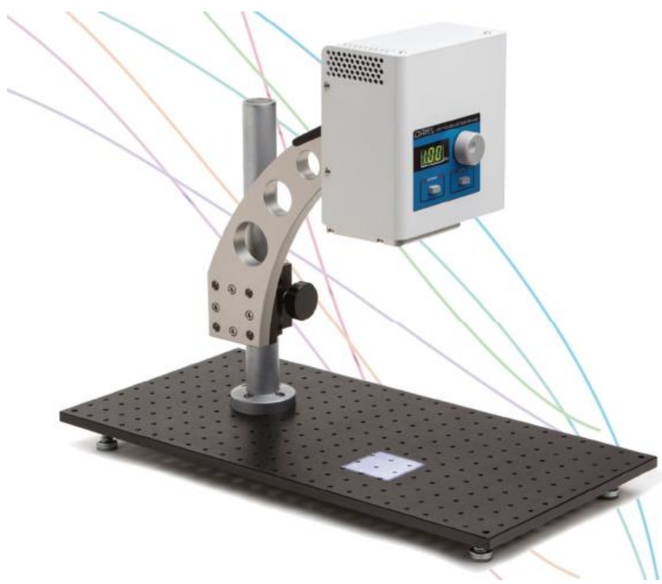

Figure 1: Newport LED Solar Simulator LSH-7320

The physical design of the low-cost solar simulator features a weighted base attached to a tall metal rod. The light source consisted of a store-bought 100 W rated light fixture that has the correct connectivity to be plugged into a standard wall outlet. The fixture was prebuilt with an attaching arm that could be adjusted. It was then clamped to the metal rod and secured with rubber bands. The height of the light fixture can be adjusted to the optimal height away from the solar cell. The initial height was set to 18 cm above the base as a starting point for testing. Figure 2 displays a diagram of the low-cost simulator that was tested.

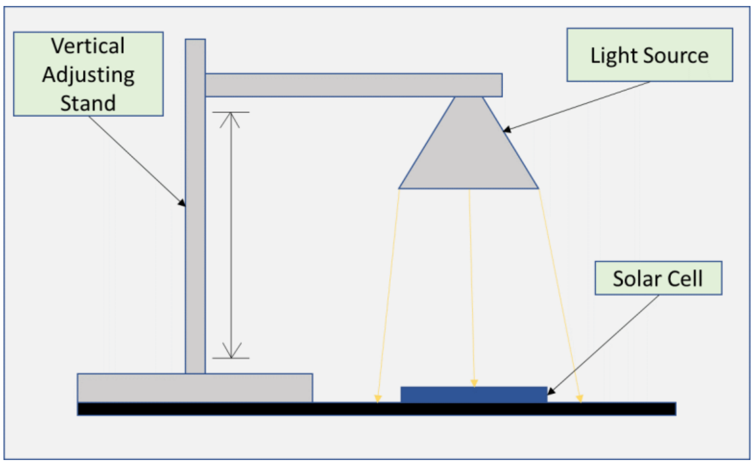

Figure 2: The diagram shows the low-cost solar simulator, including the metal stand, light source and solar cell base.

After the physical design was agreed upon, the testing equipment was needed to generate the I-V characteristics. Two multimeters were used. The voltage was measured by a FLUKE 107 digital multimeter, and the current was measured using a KLEIN TOOLS MM600. To vary the resistive value, a GME Resistive Decade Box was used. The box contains switches to simulate resistive values from 1 ohm to 10 million ohm. Probe wires were used to connect the multimeters properly, voltage in parallel, and current in series. In order to connect the solar cell to the circuit, alligator clamp wires were used. Figure 3 shows the testing setup used. Please note that the fuse box was not included in the design in order to cut unnecessary cost. The solar cell was connected directly to the red and black probes going into the fuse box.

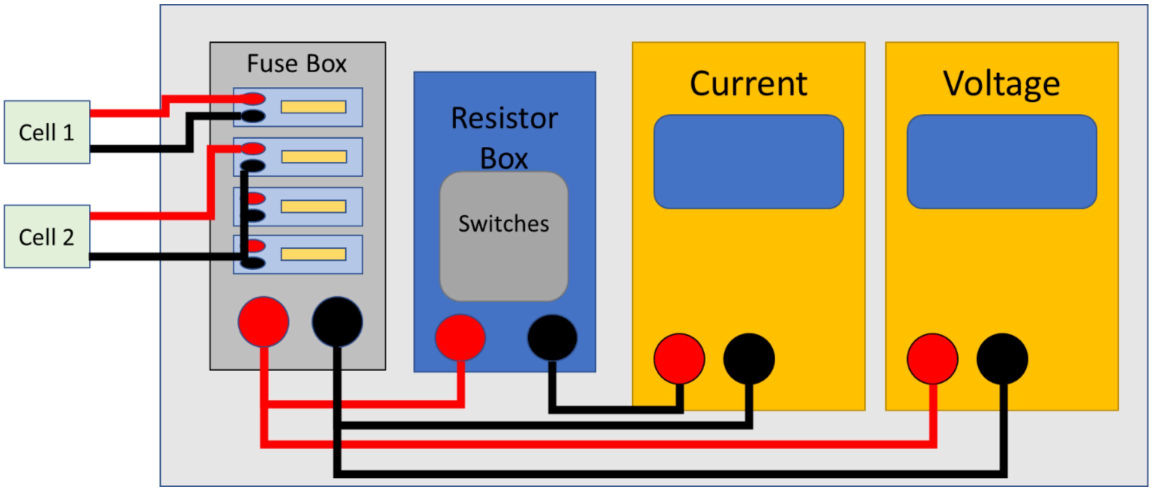

Figure 3: The testing setup contains two digital multimeters: one connected in series for current and one connected in parallel for voltage. The resistor box was used to simulate different resistive loads.

The last components needed for the build was light bulbs of different wattage and a solar panel. For testing, a small amorphous silicon cell made by Panasonic Battery (AM-5412) was used. This cell should function as a typical solar cell and was tested with the Newport Solar simulator for comparison data. Four light bulbs were considered for this project: a 22 W LED, a 9 W LED, a 72 W incandescent, and a 60 W halogen. Each bulb contains similar brightness levels and should provide a fair comparison. All light sources were kept under 100 W to accommodate the wattage limit on the light fixture. In addition, low wattage allows for less energy consumption making this build a lower cost compared to using projectors or other light-emitting devices.

III. Analysis and Results

The first test included deciding which light bulb would produce the best I-V characteristics curve from the given solar cell. Each bulb was used as a light source with the same cell, and I-V curves were created using the testing setup. The load resistance parameters started from 10 ohms to 500 kilo ohms. In order to decide which light bulb provided the closest light to the solar simulator, the I-V curve with the maximum current was selected. When testing solar cells, the max voltage remains mostly stable with sufficient light to generate the photovoltaic effect. Current flow is affected by the intensity of light connecting with the panels. Figure 4 shows the results for the four different light sources tested on the solar panel. While the LED bulbs consumed less wattage, the current values generated were lower than the rest of the bulbs. The best performance bulb based on maximum current was the halogen 60 W which narrowly outperformed the Incandescent 72 W. All bulbs were tested 18 cm away from the solar cell. This measurement stretched from the surface of the solar cell to the edge of the light fixture.

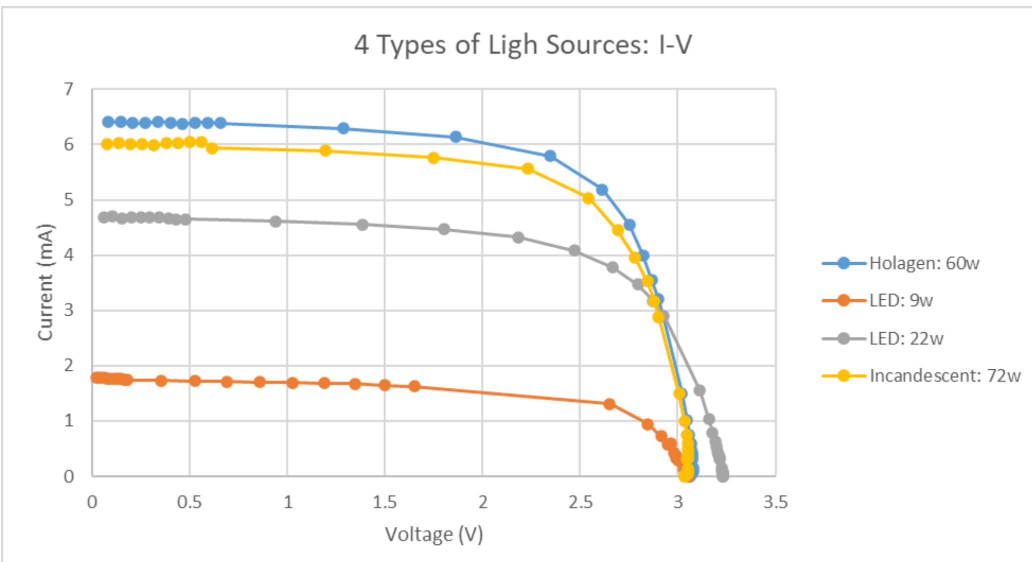

Figure 4: This graph shows the I-V characteristics generated from an amorphous silicon solar cell that was exposed to four different light bulbs. The results were judge based on max current achieved.

The next step in the testing process was to adjust the distance between the light source and the solar cell. To find the optimal distance between the source and cell, the halogen bulb was placed 20 cm away and then slowly decreasing in one cm increments until 5 cm. While this occurred, the testing setup was used to measure the current generated by the cell over a 3k ohm load resistance. Shown below, figure 5, provides the optimal distance between the bulb to solar cell, which was found to be 10 cm. In either case, increasing the distance or decreasing the distance proved to lessen the current generated by the solar cell.

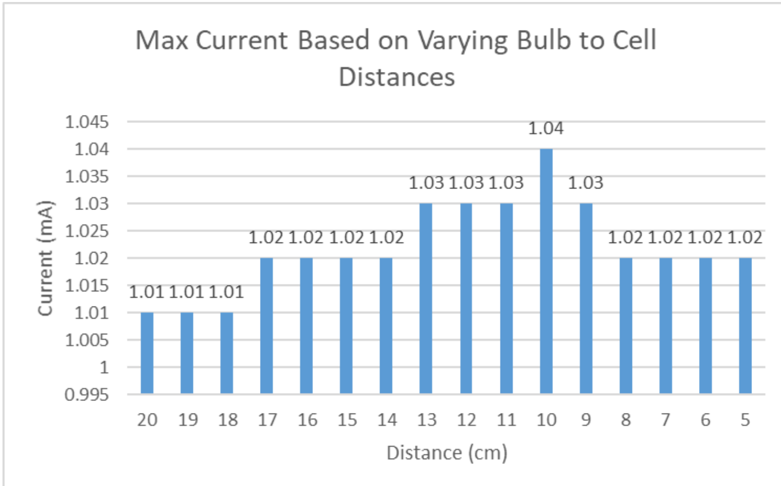

Figure 5: This bar graph shows the varied distance from the halogen light source and the solar panel. The optimal distance was found to be 10 cm.

Once the optimal distance was found, the Newport Solar Simulator and the low-cost solar simulator needed to be compared on two fronts: I-V characteristics simulated and light spectrum. To test the light spectrum, the SPECTRA-1 by Kvant was used. This device is pre-calibrated and provides automatic light spectrum measuring software. It is connected to a Windows PC using USB and comes with fiber optic sensor and cable. Figures 6 and 7 show the resulting measured light spectrums. The results showed that the Newport Solar Simulator has greater light intensity around the lower wavelength spectrum and the halogen bulb has average light intensity across the spectrum but with lower intensity compared to the simulator. The results of both light spectrum tests show slight resemblance between the two, but the specially designed bulb in the Newport device outperforms the halogen bulb in the lower wavelengths. Overall, the midrange intensity of the halogen bulb's light spectrum allows it to be more similar to the industrial grade device.

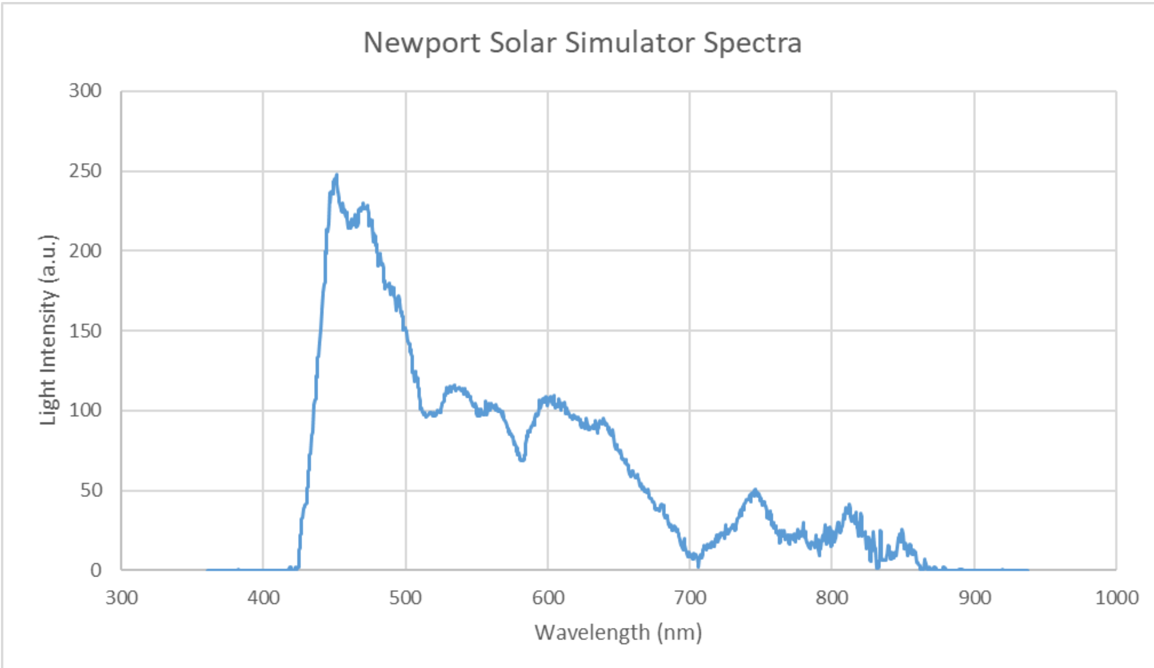

Figure 6: Shows the measured light spectrum for the Newport Solar Simulator. The results shows that the simulator features higher light intensity in the lower wavelengths and lower intensity in the higher wavelengths. Wavelength is measured in nm and intensity uses arbitrary units.

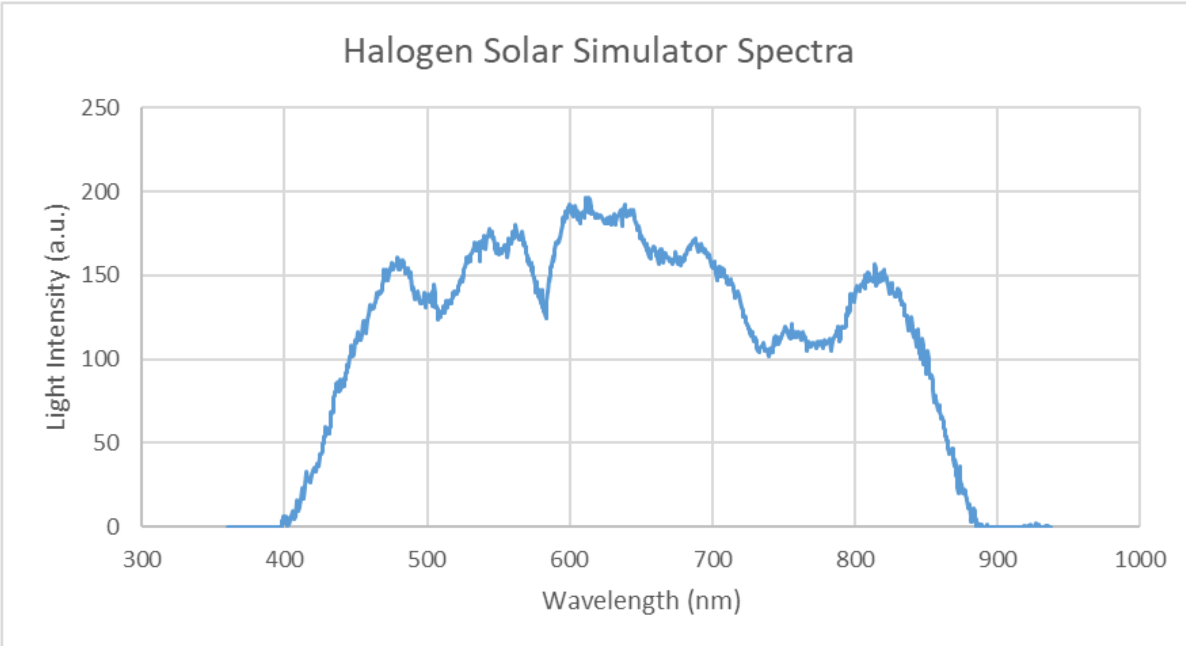

Figure 7: Shows the measured light spectrum of the low-cost solar simulator. The results shows that all of the wavelengths contained similar light intensity levels, except in the lower wavelengths. Wavelength is measured in nm and intensity uses arbitrary units.

The last test conducted utilized the amorphous silicon solar cell, the testing setup, and both of the solar simulators. I-V characteristic curves were generated using both light sources and the combined results are shown in figure 8. The Newport Simulator was able to deliver greater voltage and current readings overall compared to the halogen simulator. However, for comparing the price difference between each setup, the halogen simulator at the optimal distance generates a valid I-V characteristic curve and shows promise for low-cost solar simulators.

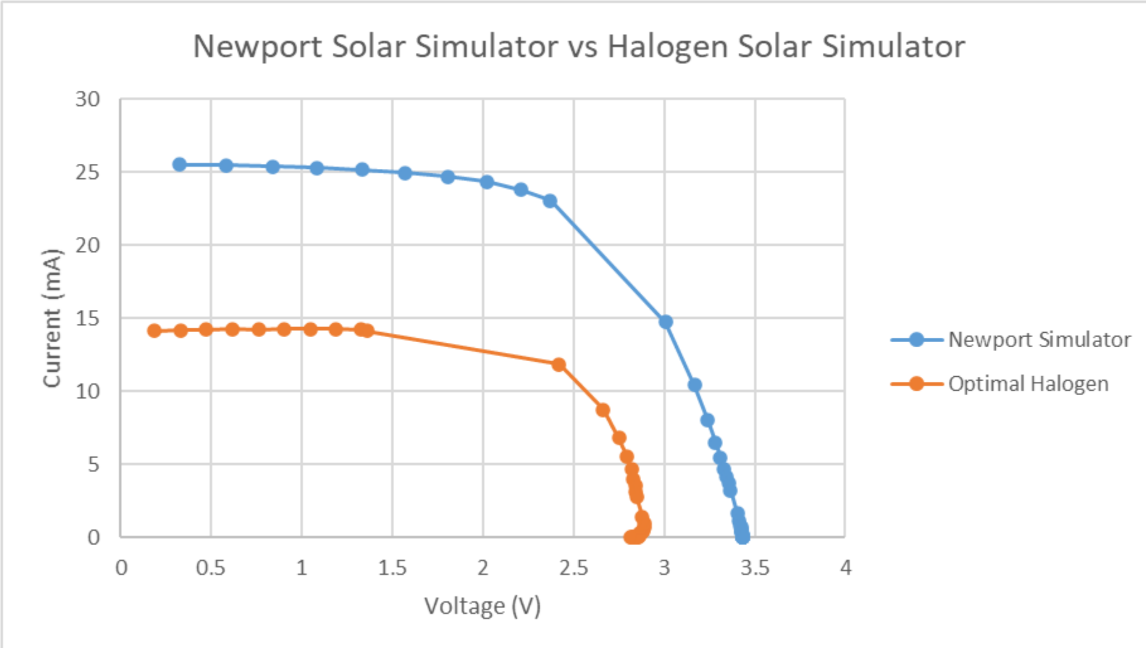

Figure 8: I-V curves are shown from both solar simulators. The results show that the Newport Simulator was able to generate a much more uniform curve with greater current and voltage values. However, the halogen bulb produces high current which also shows the characteristics of the solar.

IV. Conclusion

In conclusion, this project supports the idea of producing low-cost solar simulators and using them to test PV cells. This implementation is not to replace lab and industry use solar simulators but to show a side-by-side comparison of a lower-cost alternative. Based on the results of this experiment, the halogen light bulb produces light intensity through the light wavelength spectrum and has the ability to produce higher currents in amorphous silicon solar cells than LED and incandescent bulbs. Developing nations that are investing in and researching solar cells may find halogen light bulbs a cheaper alternative to purchasing thousands of dollar's worth of industry-standard solar simulators.

V. ACKNOWLEDGMENTS

I would like to thank the Office of Naval Research for purchasing the Newport solar simulator and supporting equipment. I would like to thank Dr. Hani E. Elsayed-Ali for his help in creating this project and overseeing its progression. Lastly, I would like to thank my mom who helped collect data for the I-V characterization of the solar cell.

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[1] Nuryadin, B. W., Nuryantini, A. Y., & Ramdhani, M. A. (2018). A solar simulator using a LCD projector for students' laboratory. *Physics Education*, *53*(5), 055021. https://doi.org/10.1088/1361-6552/aad4c2