Automated Modeling of 3D Solar Cell Concentrators

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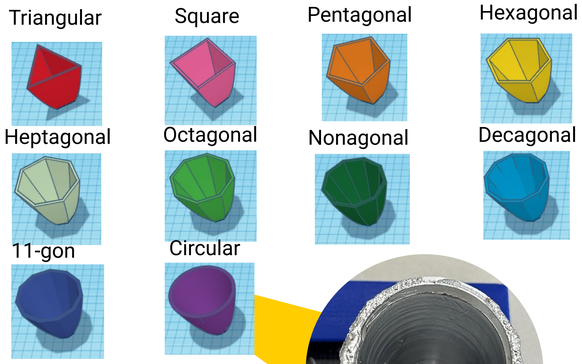
Introduction

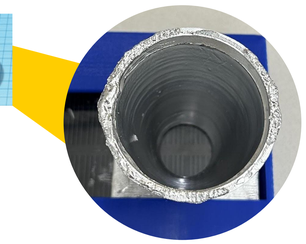
- Solar energy is a rapidly growing energy source, particularly with green initiatives
- We aimed to determine the ideal solar cell concentrator shape among various polygonal compound parabolic constructions
- We developed two methods of solar tracking to further improve solar cell efficiency

Methods

We used OpenSCAD (parameterized, script-based CAD tool) to develop the 3D concentrator models using bash script

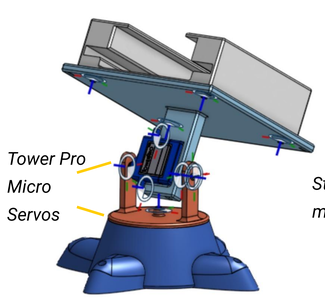
N-sided polygonal compound parabolic 8.0X concentration concentrators shown below, all 1 cm radius of bottom aperture and 6 cm tall



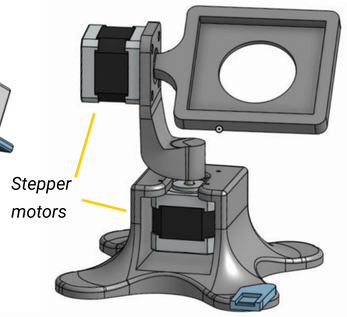


Smoothed and coated circular parabolic concentrator

Dual Axis Solar Tracking Systems



Photoresistor Method

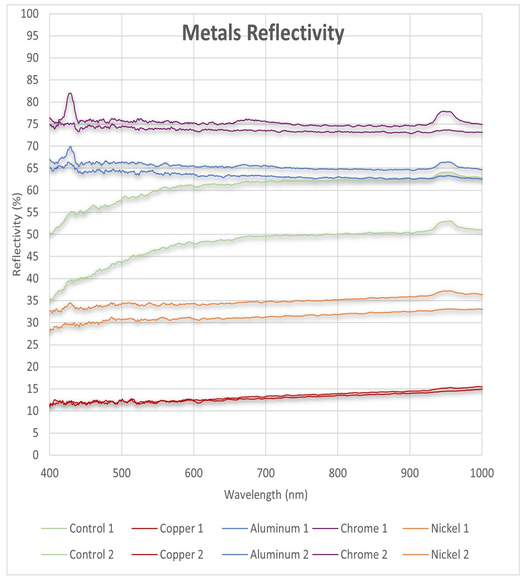


Sun Tracking Method

Coating and Ray-tracing

We chemically smoothed the 3D printed concentrators using X2C 3D print coating before coating them in reflective metal coating. Chromium, aluminum, copper, and nickel were tested on sample squares for reflectivity, as shown in figure A below. Chromium proved to be the most reflective and thus we coated our final concentrators with it.

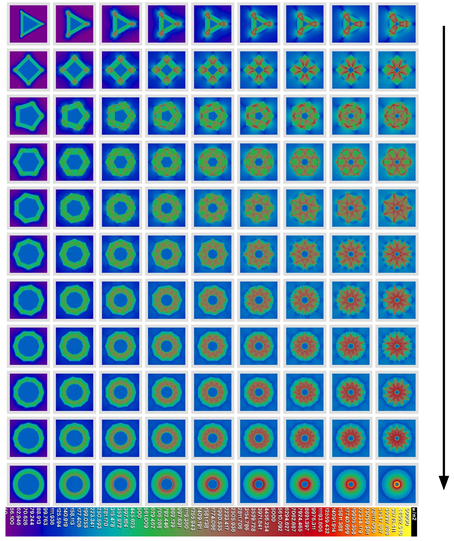
Figure 1



Above shows the reflectivity percentages of the four different metal coatings at corresponding wavelengths on the solar spectrum.

Figure 2

Radiance Ray-tracing of Each N-Sided Compound Parabolic Concentrator



Results

Our experimental results of measuring each solar cell concentrator's short circuit density aligned with our observed theoretical pattern with an increasing number of sides for a given concentration ratio achieving a higher value and thus better observed efficiency.

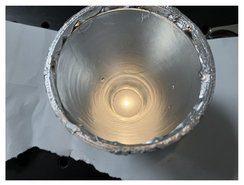
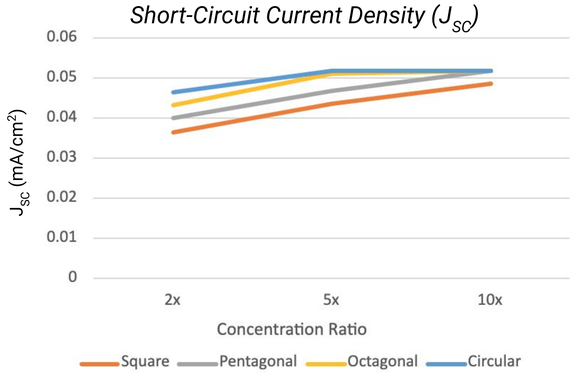


Figure 3

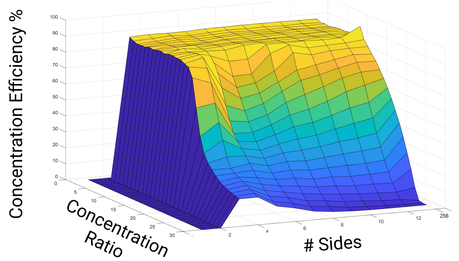
Short-Circuit Current Density (J_{SC})



Conclusions

Through my team's investigation of the ideal design for solar cell concentrators, we devised a way to automate the 3D modeling process of these concentrators with our OpenSCAD program. In this way, other researchers looking to easily and efficiently develop concentrator 3D models can use our program as a tool in their own research or applications.

Figure 4
Radiance Ray-Tracing Results (With 256-Sided)



Acknowledgments

Thank you to my lab members for making this experience possible and always entertaining, and to my mentor Dr. Toor, graduate students Dan and Rezwan, and super cool guys Nick and Caleb for their guidance. I'm also glad to have spent time with the RA's and made so many good memories ☺️

References

1. **Cooper, T., Dähler, F., Ambrosetti, G., Pedretti, A., & Steinfeld, A. (2013).** Performance of compound parabolic concentrators with polygonal apertures. *Solar Energy*, *95*, 308–318. https://doi.org/10.1016/j.solener.2013.06.023
2. **Rincón, E., Lentz, A. (2009b).** *New solar air heater based on Non-Imaging Optics for High-Temperature applications*. https://doi.org/10.1115/es2009-90306

Link to research brief

MATLAB Code

IOWA