SoET Research Day, 2024

Waveguide Light Development

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Problem Statement

The goal of this project is to create a more efficient, cost effective, and heat dissipating device that can be compared to a traditional solar cell. Tests will be needed to compare the power generation of different LED colors and configurations, as well as light transfer through 3D printed waveguides. A testing rig needed to be created to simulate the irradiance pattern of the sun in a lab environment to have a consistent method of experimental results.

Customer Background

The leading device to generate power from solar energy is a solar energy is a solar panel but they're an expensive solution for their inefficiency due to reflected light and heat build-up. Commercial panels are only between 13-24% efficient at converting light.

PV Technology		Conversion Efficiency Cell	Module
Crystalline	Monocrystalline silicon (Si)	27.6%	24.4%
	Multicrystalline Si	23.3%	20.4%
	Multi-junction Gallium arsenide (GaAs)	47.6%	38.9%
Thin film	Cadmium telluride (CdTe)	22.3%	19.5%
	CIGS	23.6%	19.2%
Emerging	Perovskite/Si tandem	33.7%	-
	Perovskite	26.0%	17.9%
	Organic	19.2%	13.1%

Figure (1): Solar Panel and Solar Panel efficiencies

Requirements

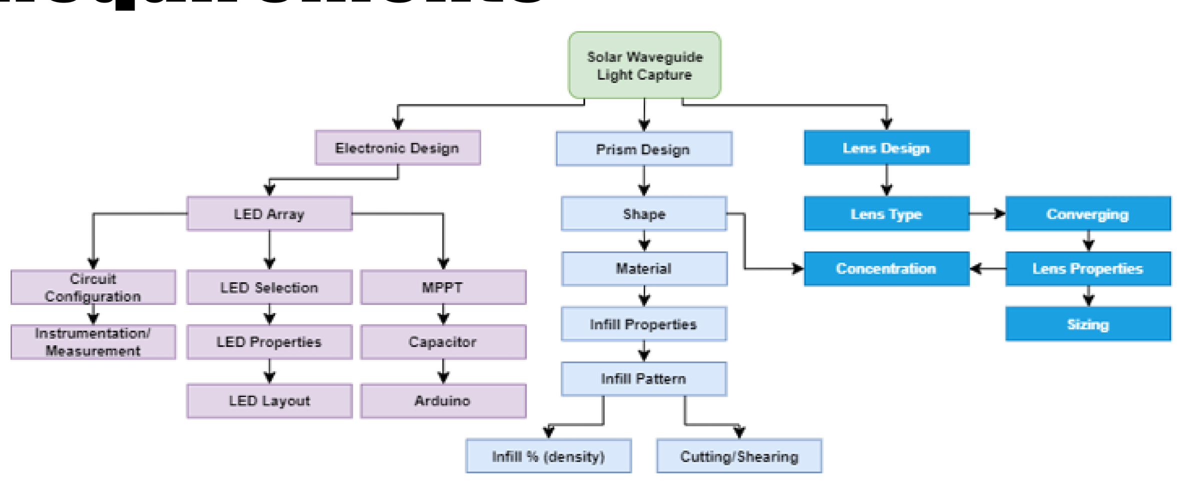


Figure 2: System breakdown for the interacting systems and components.

Req. #	DESIGN REQUIREMENTS	DESIGN TARGETS	VALIDATION
	RATIONALE		
1	Works in real outdoors enviornment (works with sunlight (1000W/m^2 irradiance) in robust setting	Power successfully generated and stored outside in solar conditions	Successful generation and storage >= device inside
	The project must be able to work in the sun as the sole purpose is a competitor to a solar panel. Successfully replicating and creating the system better than the previous years work will show it has opportunity for commercialization in a robust manner.		
2	Transport irradiation to power device (LEDs/capacitors/etc.)	Power LEDs/capacitor with energy generated from sunlight	LED lights up, capacitor charges
	The goal is to generate energy but the energy must be useable so LEDs being powered or a capacitor charging show that we are getting		
3	The effective area we utilize is larger than the active area	dimensionally consistent with a traditional solar panel, but utilizing rays from larger area	Measure irradiance with and without amplificationa and note increases in efficiency
	We want our project to be able to ustilize a larger effective area by concentrating the light onto our waveguide active area to utilize more light than just the active area would receive normally		
4	Cost efficiency compared to traditional methods	Design a system that can compete cost effectively to a traditional solar cell	Cost of generated system less tha that of standard solar cell
	System does little good if 100% efficient but costs 10x as much as normal. It needs to be low cost with a high efficiency		
5	Match IV curves of solar panel and battery	Successfully match the IV curves of tradtional solar storage	Compare our curves to tradition pv system
	As discussed with Mauricio and Dipak, IV curves can show us a maximum achievable area which is equivalent to the power ahcievable using specific equipment. We need to make sure that IV curves can match that of the traditional method to get the most out of our system that aligns with traditional solar methods.		
6	Design something smaller that can be scaled effectively	Build something that works upscaled	Works upscaled
	While we are far away from the commercialization of the project, manufacturing processes need to be kept in minc as it would do no good to create a device that can't be scaled through manufacturing methods. Our project needs to be scalable on a commercial setting.		
7	Modularity	Design system to where each 3 subsystems can be researched independently to come together into a greater whole	Each system has a goal that can be achieved separate to the performance of the rest of the system. (greater light conversion, absorption, storage
8	Ability to provide multiple simulations and their results to guide our designs as well as prove the simulated results align with the experimental results	Show data simulated in ANSYS and replicate data experiementally	Same efficiencies from simulation as experimentally and results to show
	Our project is very big on simulations this year and a goal of that is to guide our designs going forward. Furthermore, a big aspect is to make sure that our simulations are matching our physical reality and that we are able to achieve the same results as the simulation so that we arent being gudied incorrectly or find out our methods are incorrect at measuring efficiecny from the light refraction		

Figure 3: Requirements Matrix

Experimentation and Concepts

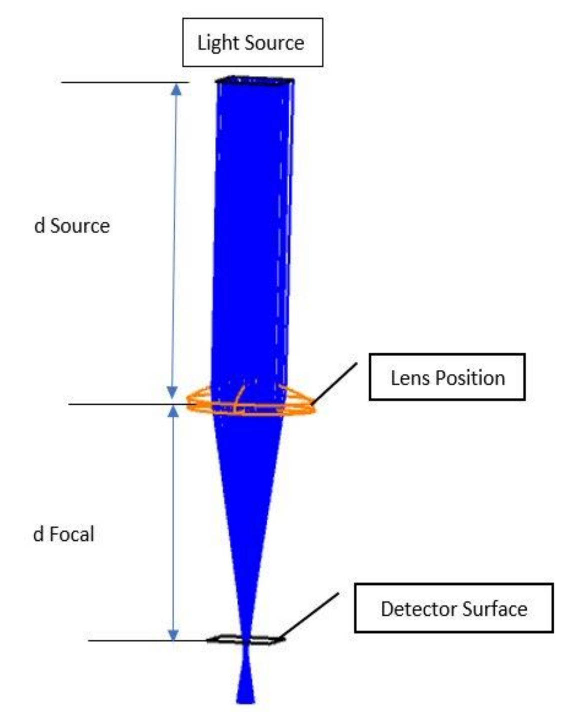


Figure 4: Zemax OpticStudio testing layout with labeled features.

$P = I * V$
P = power
I = current
V = voltage

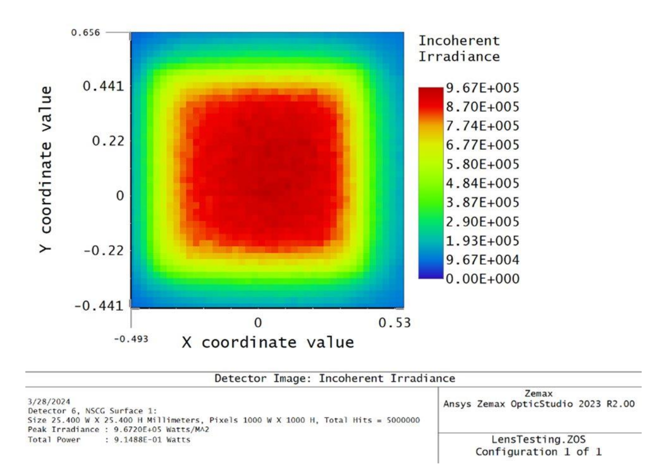


Figure 5: Detector surface within Zemax OpticStudio.

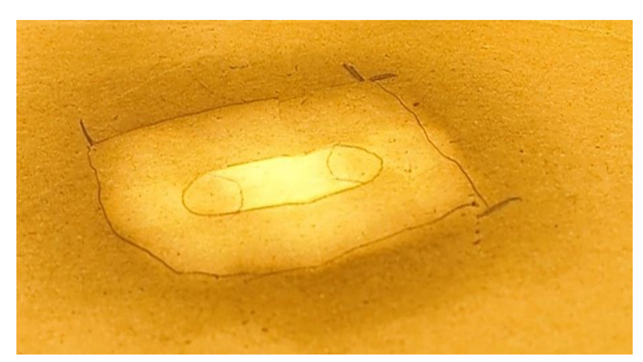


Figure 6: The outlined concentration area and illuminated area during focal point adjustment tests.

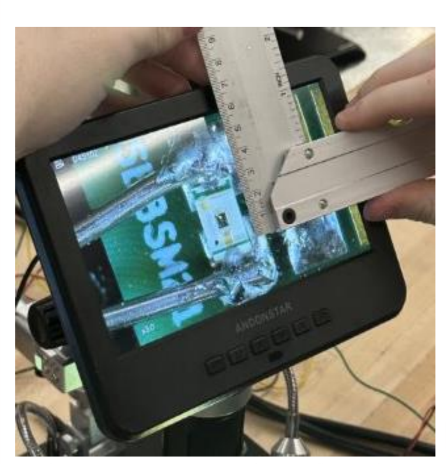


Figure 8: Measuring of Active vs. Inactive Area: ~13%:87%

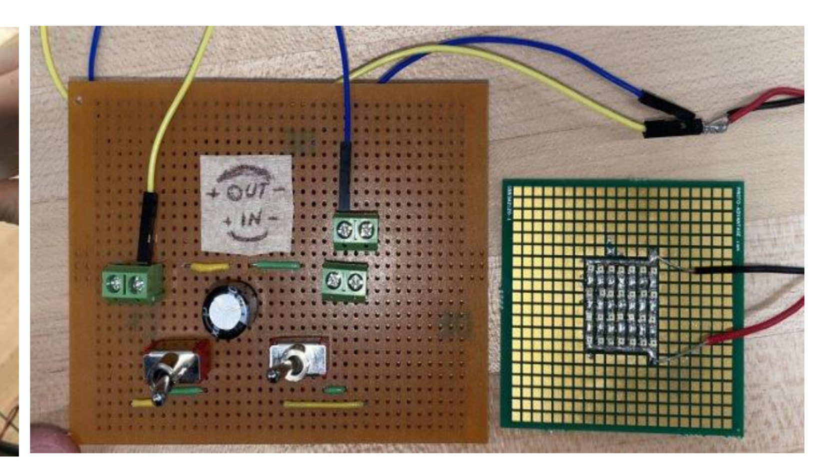


Figure 7: IR Array Connected to Charging Capacitor

Final Design

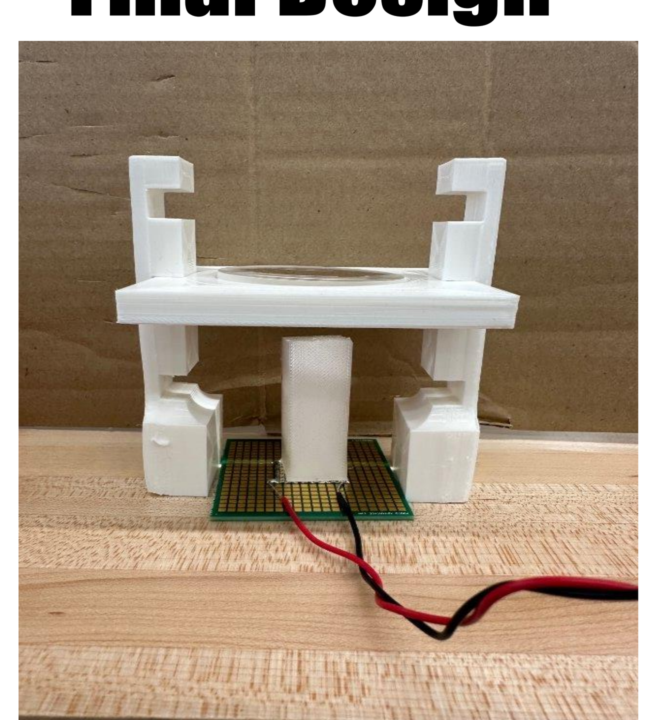
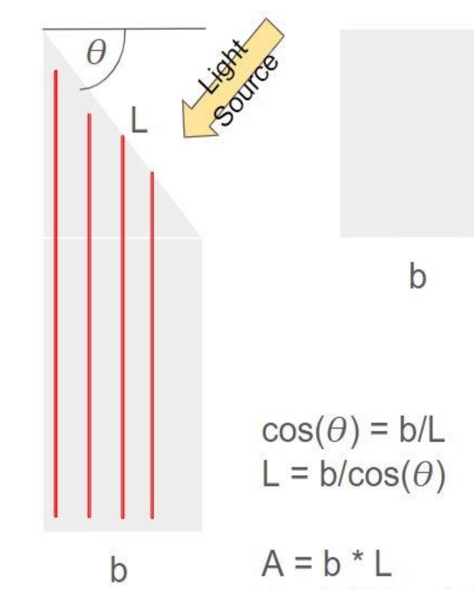


Figure 9: The lens, 3D Geometry, and LED array all held together by a printed holder

Testing



$\cos(\theta) = b/L$
$L = b/\cos(\theta)$

$A = b * L$
$A = b^2/\cos(\theta)$

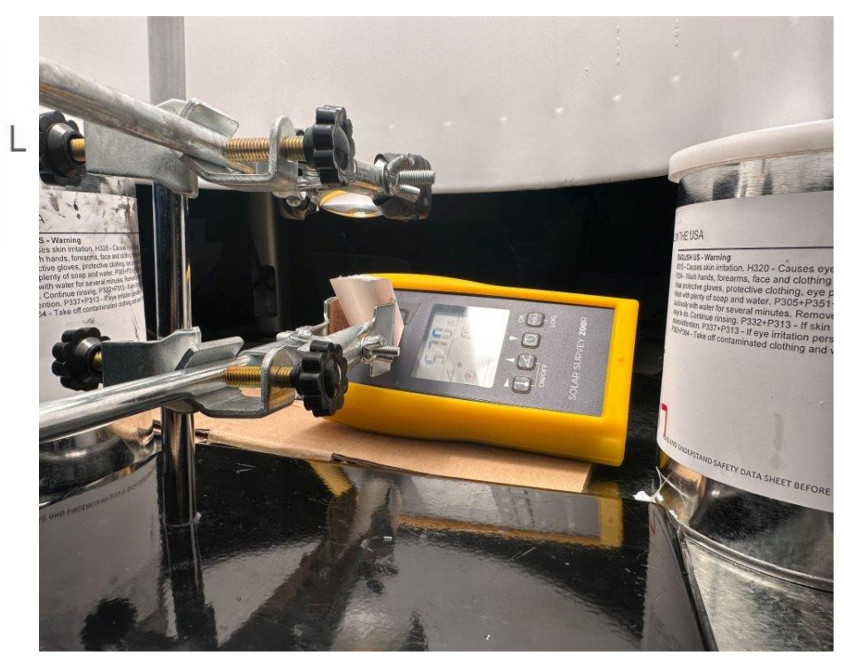


Figure 10 & 11: Testing setup for surface area tests

Figure 12: Testing of 0° angle

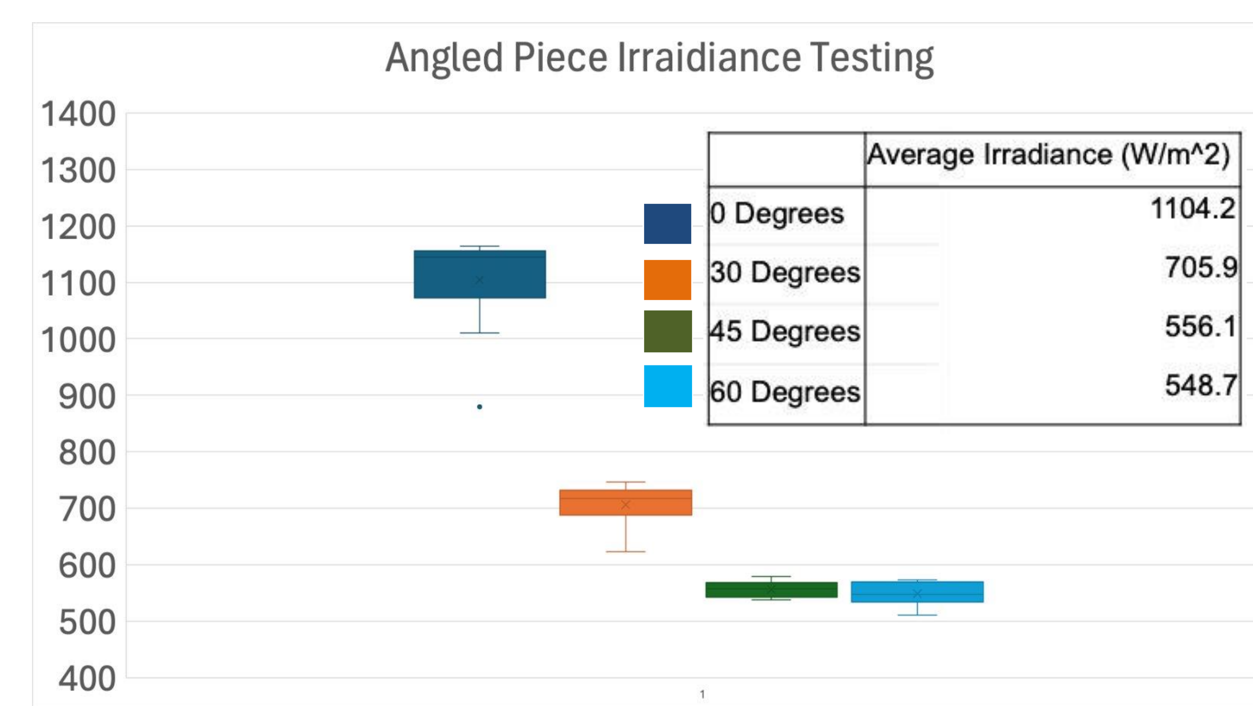


Figure 14: Testing Results for different angled setups

Figure 13: Testing of 90° piece bend

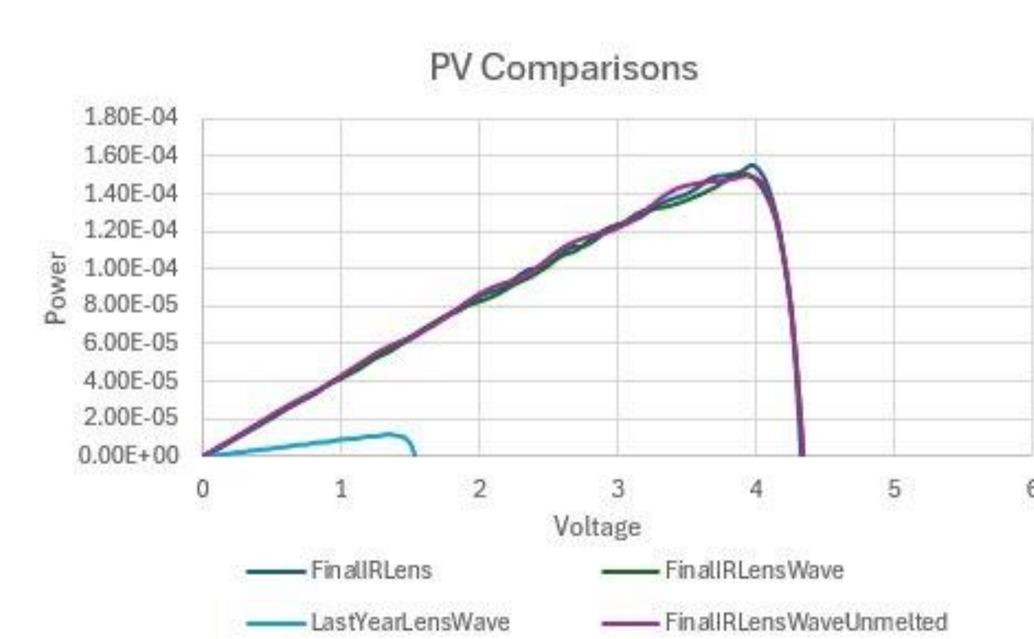


Figure 15: Power vs. Voltage Comparison of Various Waveguides

Max power using last year's design: 0.0000117 W
Max power using this year's design: 0.000149 W
Precent Increase in power: 1173%

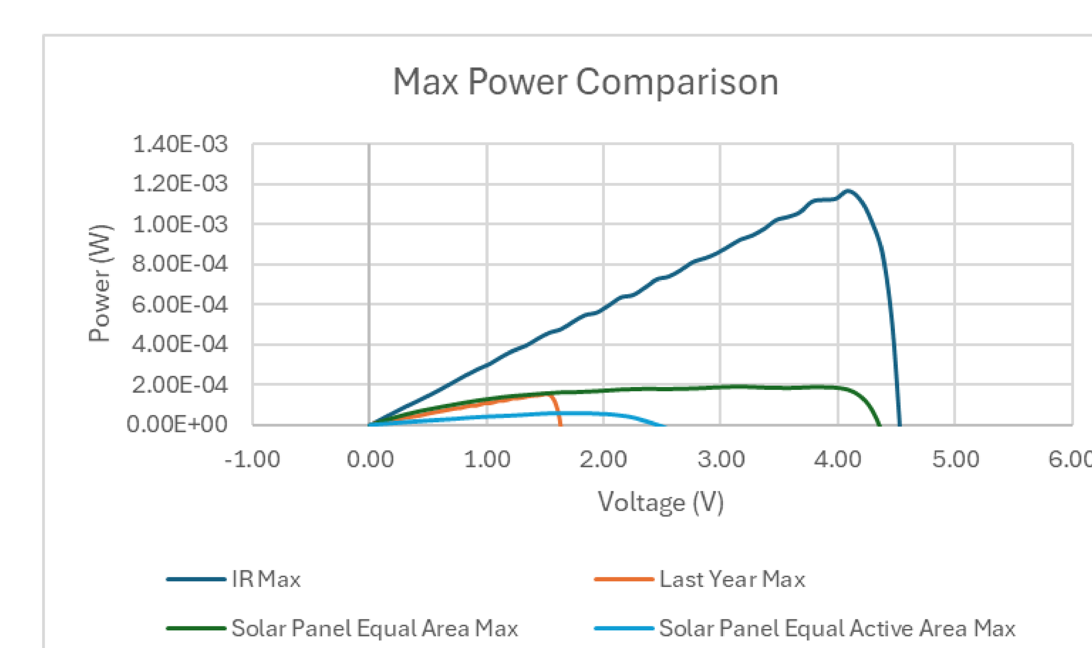


Figure 16: Max Power Comparison of Array vs. Solar Panel

Max Power Equal Active Area Solar Panel: 0.0002
Max Power Equal Active Area IR Array: 0.00117
Percent Increase in Power Generation: 485%