

Executive Summary

Problem Statement

Reliable power delivery is difficult in environments where wiring or fuel transportation is impractical. Current wireless power solutions face limitations in practicality, distances, and system complexity.

Project Objective

This project aims to demonstrate wireless laser power transmission while evaluating efficiency limitations and optimizing power transfer through optical beam shaping and Maximum Power Point Tracking (MPPT).

Background

- Traditional wireless methods such as inductive coupling are limited to short distances, while microwave transmission suffers from power spread and safety concerns.
- Laser-based power transmission offer a direct solution, enabling precise, long distance energy delivery with a compact system design. Efficiency may be limited by atmospheric conditions, non-uniform illumination, and beam overlap

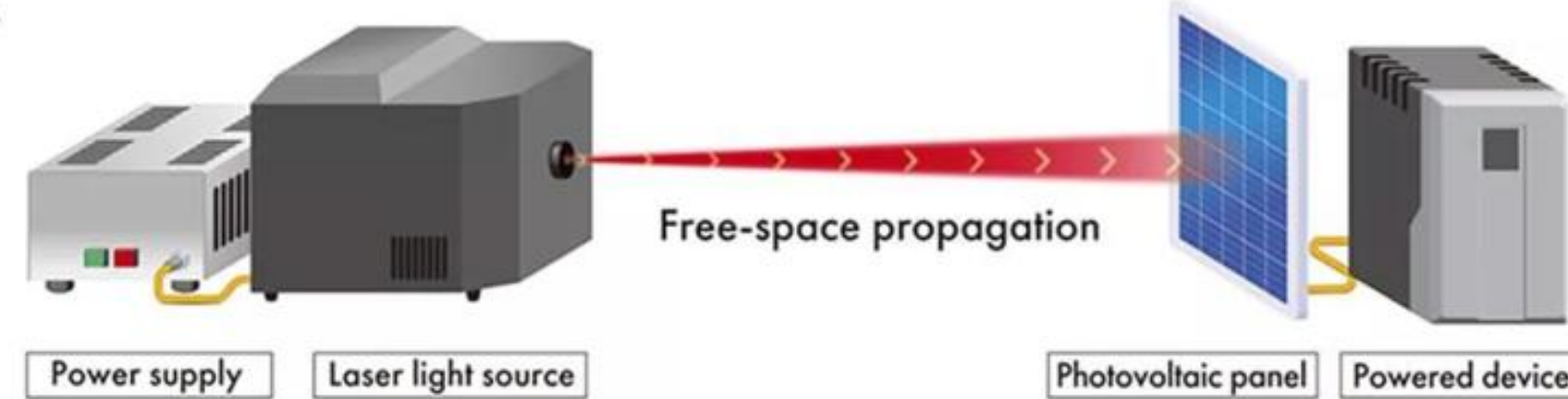


Figure 1. Laser Power Transmission (1)

MATLAB Simulation

- Simulink model of laser-based PV system
- Adjustable parameters and MATLAB scripts analyze wavelength-dependent efficiency
- Thermal modelling based on input irradiance
- MPPT control with boost converter maximize output across varying loads
- Outputs: IV curves and conversion losses

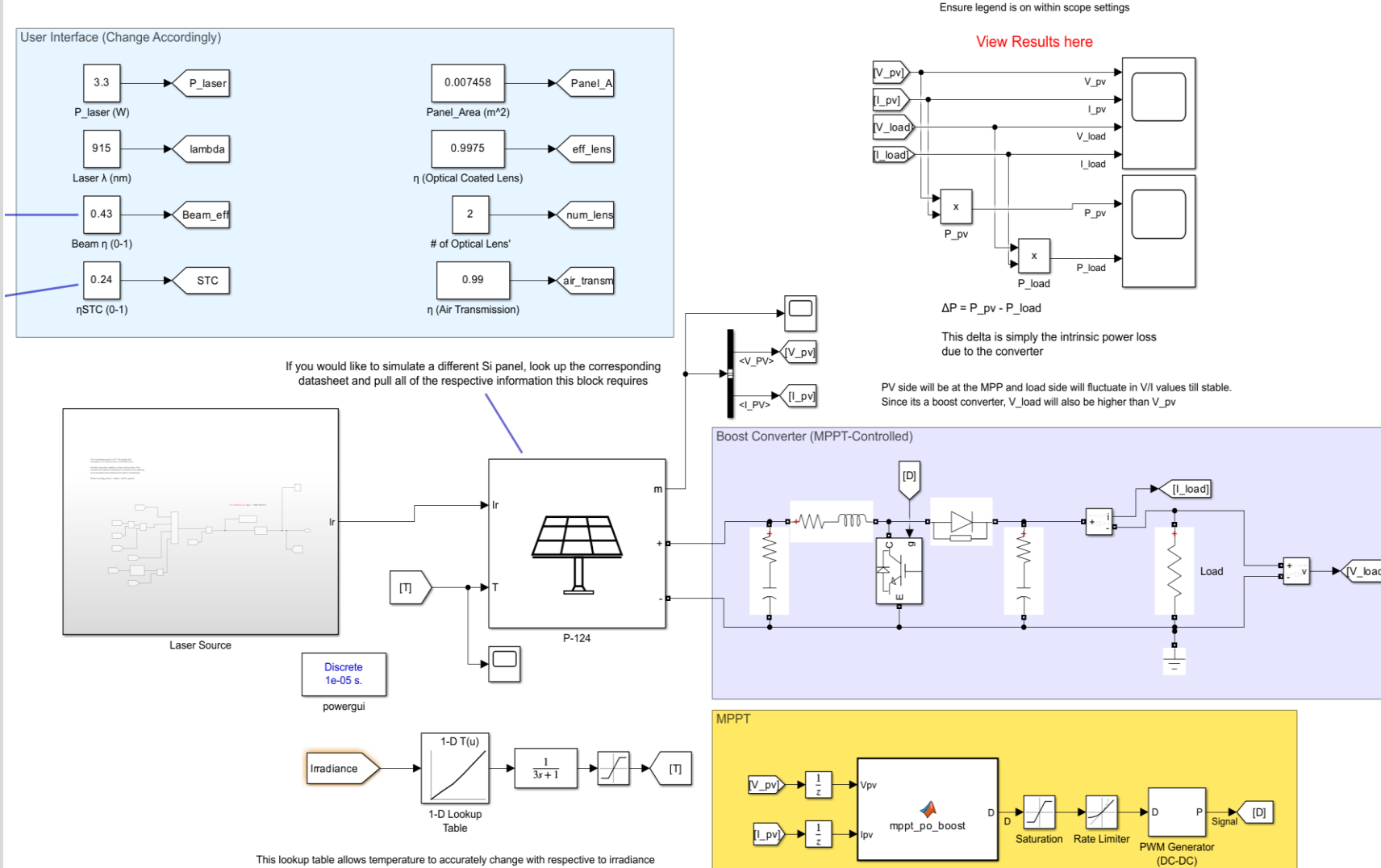


Figure 2. MATLAB Simulink Layout

Experimental Setup

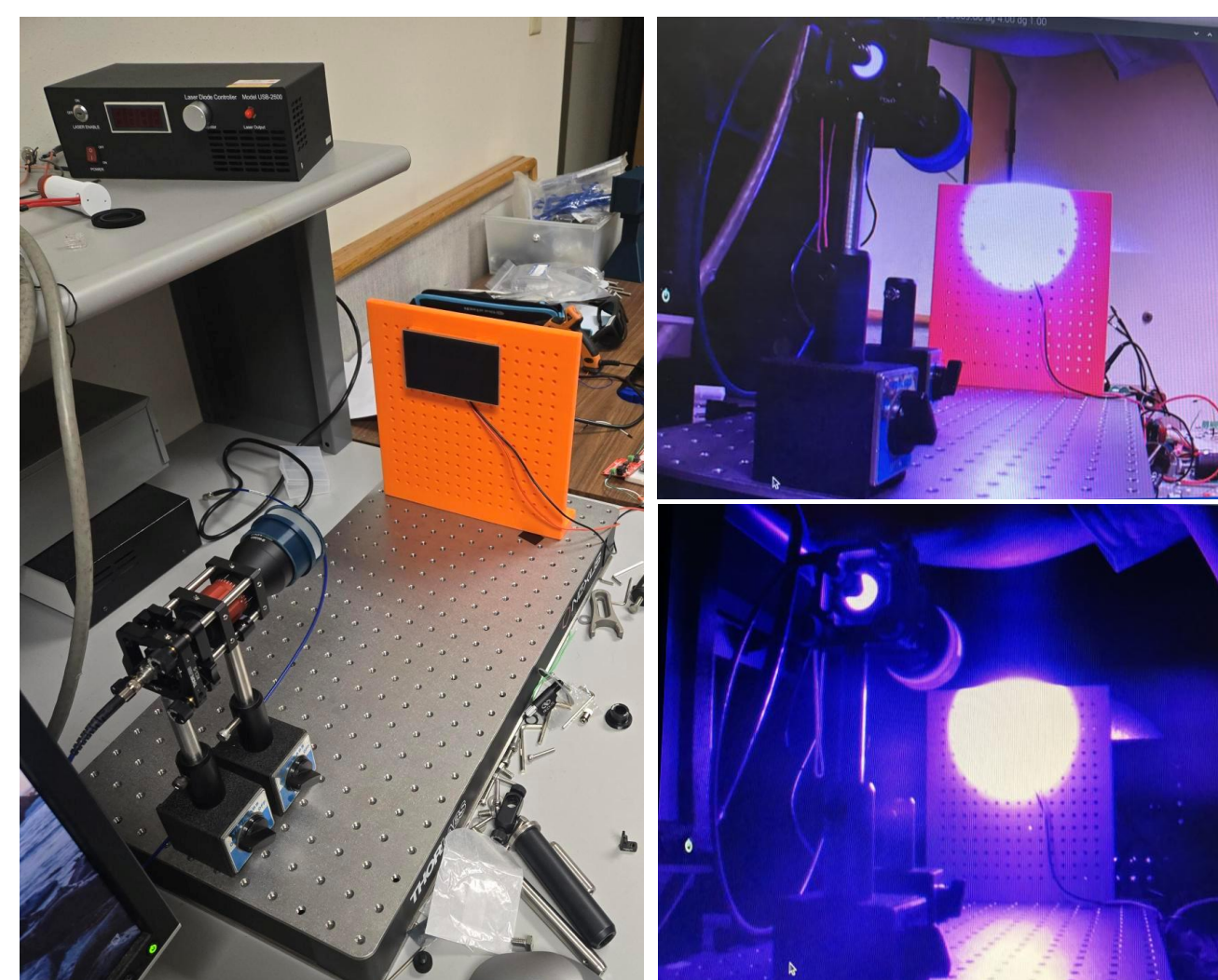
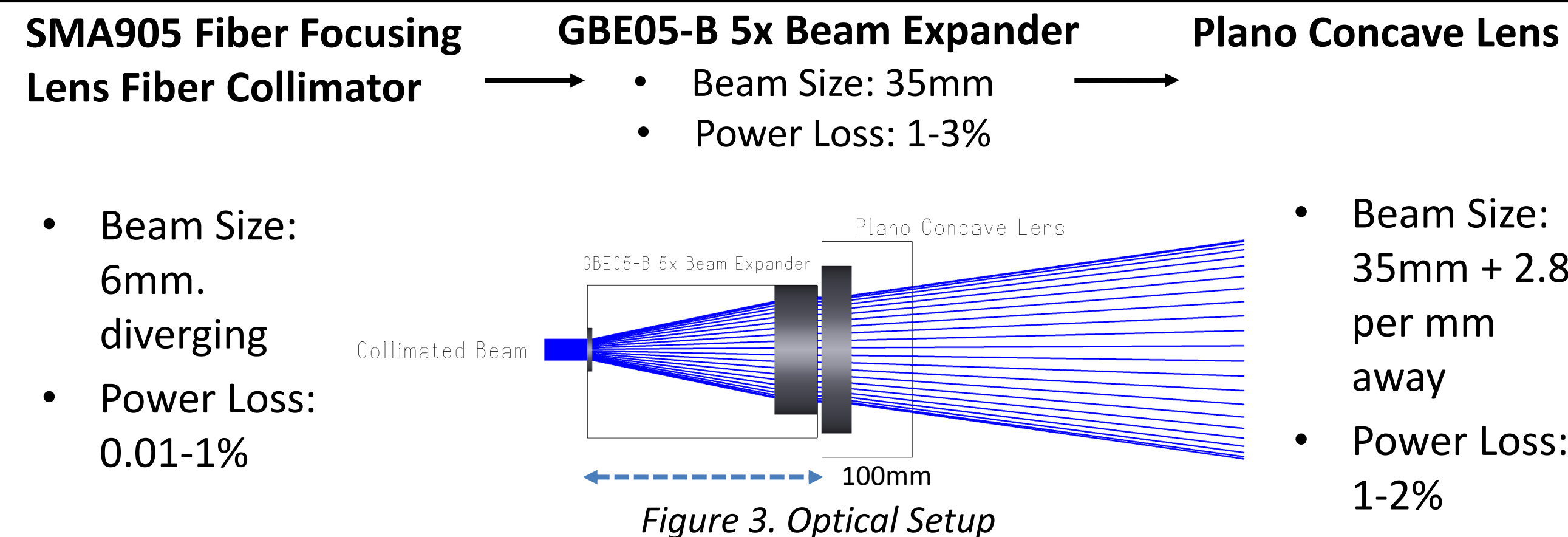


Figure 4. System Setup

- Laser source** coupled into optical fiber for controlled beam delivery
- Fiber collimator** converts diverging output into parallel beam
- Beam expander** increases beam diameter to improve panel coverage
- Plano-concave lens** introduces controlled divergence with distance
- PV panel** converts incident light into electrical power for MPPT controlled load with V-I sensor measurements
- IR Pi camera** visualizes the 915nm beam for alignment and verification

Experimental Test Plan

Silicon's PV spectral response peaks near ~900-1000nm. A 915nm laser was selected here to maximize photon to electron conversion efficiency.

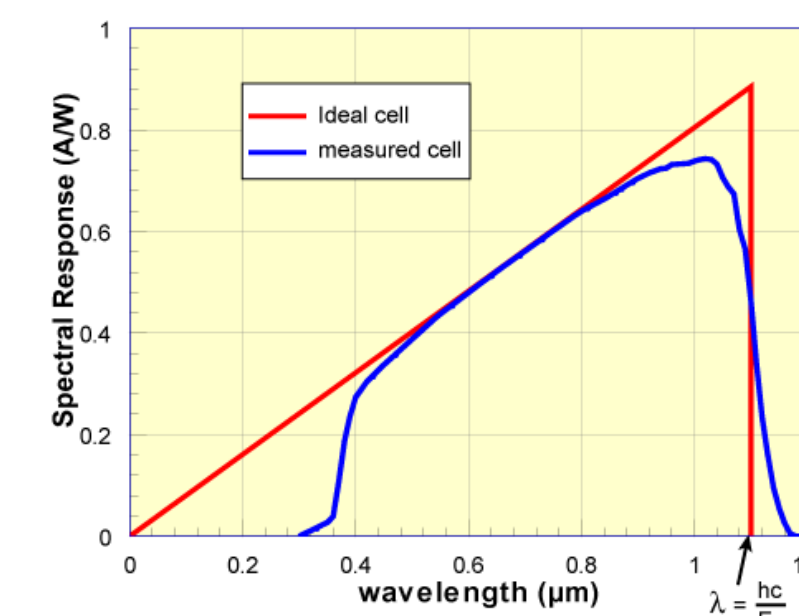


Figure 5. Silicon Spectral Response (2)

Maximum Power Point Tracking (MPPT) identifies the optimal V-I point of the PV system; this maximizes power, especially under non-uniformity.

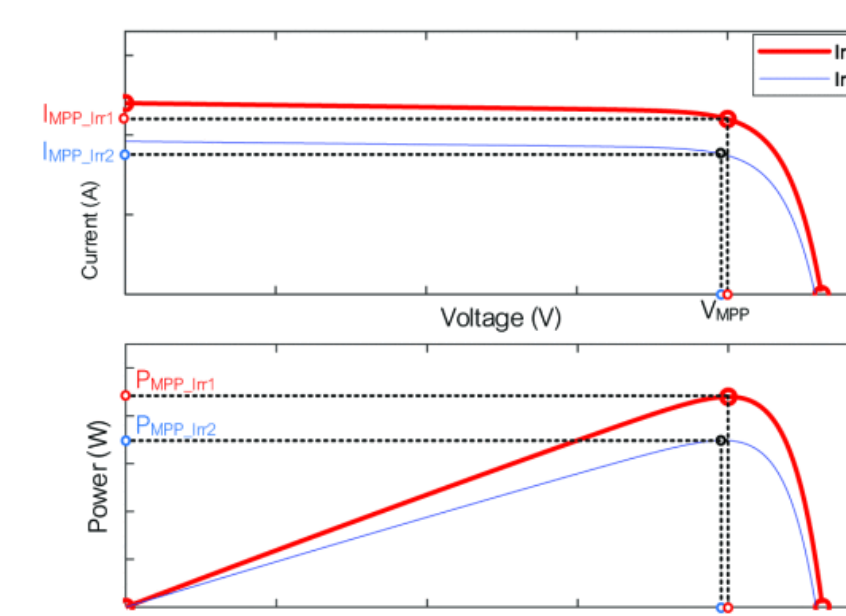


Figure 6. MPPT (3)

PV panels consist of series connected cells, making them sensitive to non-uniform illumination, leading to current bottlenecks in the series chain.

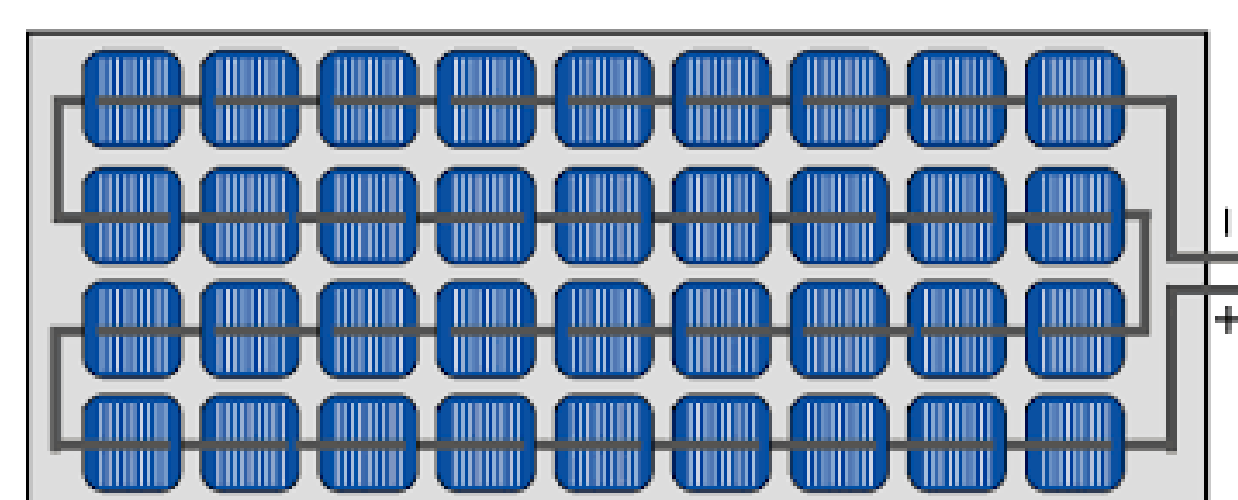


Figure 7. Series-Connected Cells (4)

Beam expansion solves non-uniformity by improving coverage, reducing mismatch loss and improving overall power extraction.

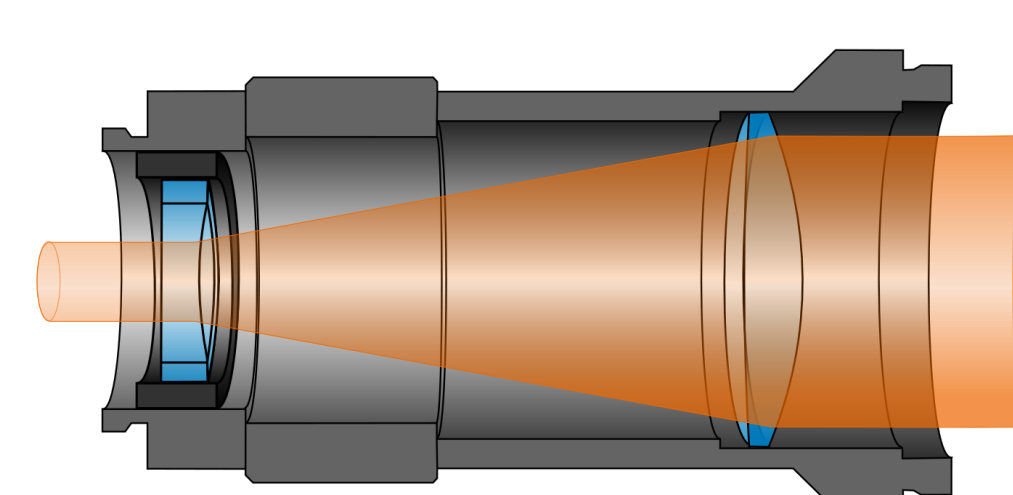


Figure 8. Beam Expansion (5)

Experimental Results

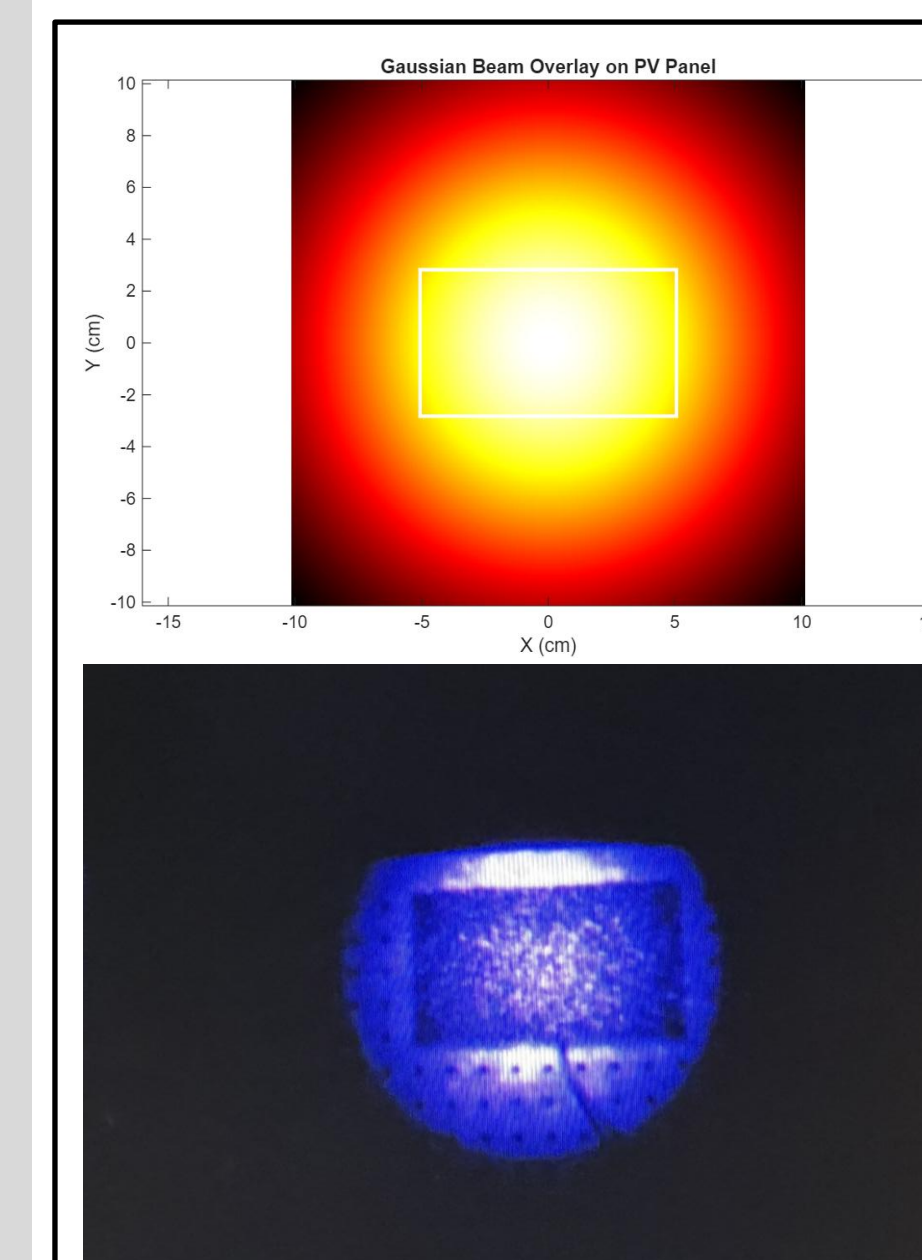
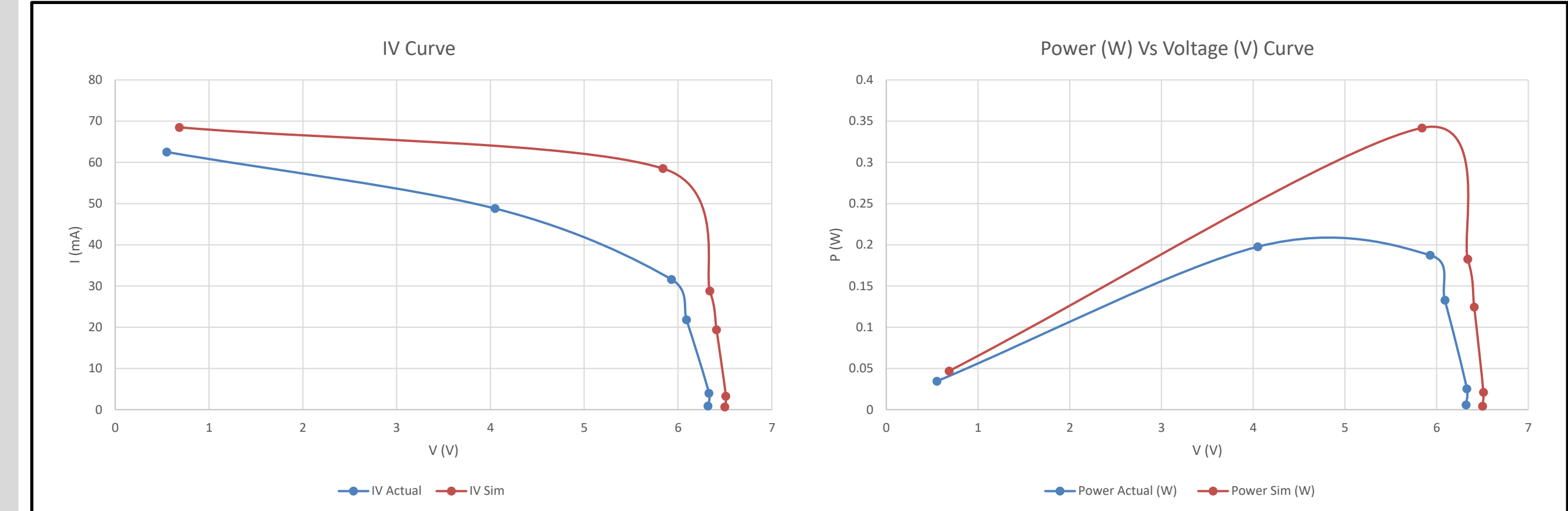


Figure 9. Center Beam on PV

- Optimal distance of **44.5 cm** between Transmitter and Receiver
- ~**18.24%** power delivered to the panel
 - 604 mW delivered
- 253 mW** PV Output
- ~**41.89%** Efficiency

Table 1. Panel Output with 3.3W Laser

Resistance (Ω)	Voltage (V)	Current (mA)	Power (mW)
125	5.57	44.56	248.20
127.5	5.62	44.08	247.72
130 (MPP)	5.72	44.23	253.00
135	5.76	42.66	245.76
140	5.81	41.50	241.11

Conclusions

- Laser power transmission was successfully demonstrated by powering a low powered load using a 915nm laser module and the P-124 Silicon based PV panel.
- A maximum output of **0.253W** was achieved, below simulated expectations (~**0.35W**) primarily due to non-uniform illumination and beam overlap on the PV.
- The team found that proper alignment and better beam expansion improved performance of the system; paired with an MPPT controller, we were able to optimize the system to its current state.
- Future work includes improving beam uniformity by creating an autonomous alignment system using photoresistors and exploring higher efficiency PV-Laser pairings
- This team is sponsored by Weidong Zhou, and testing was performed at the UTA Nanofabrication building. A thank you to Professor Zhou for his insight and mentorship throughout the entirety of the project.

References

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