Power Beaming Validation for Space-Based Solar Cells:
Survey of Laser Power Beaming Experiments

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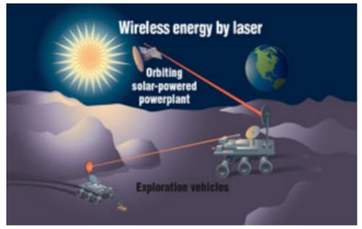
Abstract

Initially, the goal of this project was to conduct an experiment using a triple junction solar cell and three LEDs of different wavelengths to attempt to replicate research that predicted a laser power beaming efficiency of 51.15 %. Due to unforeseen circumstances, this experiment was not able to be performed and the project changed directions towards a literary survey of articles on laser power beaming experiments. This project describes research into the topic of laser power beaming with the purpose of surveying past experiments and identifying viable options for the future. Power beaming has excellent potential for space applications such as the ability to beam power when a spacecraft or lunar rover is in eclipse. This would increase operational time as well as reduce the necessary resources to complete the mission. The variety of successful experiments in this analysis that have potential for future development due to meeting the criteria of power density, efficiency, and more parameters, are the technology that may make these discussed capabilities possible.

Introduction

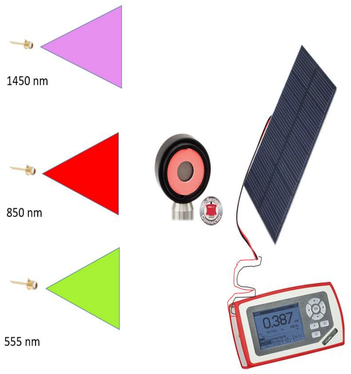
Power is incredibly important to a spacecraft and is a limiting factor in missions and capacities. Laser power beaming opens opportunities for power in space and could lead to something such as a spacecraft beaming power to another spacecraft or rover in lunar eclipse to sustain power and reduce the need for batteries. Efficiency of power beaming is the driving factor in future implementation as a high efficiency is necessary for use of this innovative technology.



Methods and Transition

- Experiment consisted of 3 LEDs of wavelengths 1450 nm, 850 nm, and 555 nm , a photodiode power sensor, a multi-meter and a triple junction solar cell.
- Connect the LEDs to a power source and beam variable power to the solar cell
- Record power in by using a photodiode power sensor and power out using a multi-meter and with those numbers, calculate the efficiency

- ❑ Unforeseen circumstances caused a shifting in approach from the experiment to a survey of 22 published laser power beaming papers
- ❑ The survey would analyze efficiencies and power densities to better understand the history and future of laser power beaming



Results and Discoveries

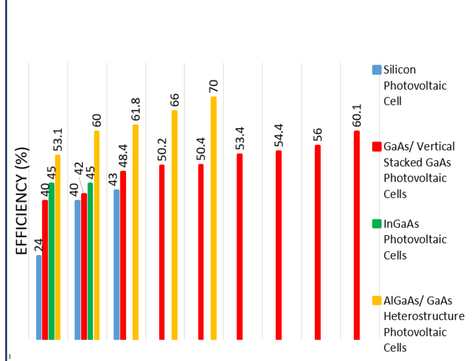
SI Photovoltaic Cells
- Lower efficiencies with still high power densities
- Limited use in space with the development of multi-junction cells
- Cheaper type of cell, but with spacecraft, high end is better

GaAs and GaAs vertically stacked cells
- Most commonly tested material
- Strong correlation between efficiencies and power densities
- Both vertical stacking and cooling of GaAs led to higher efficiencies
- High achieved efficiencies of 60.1% and 54.4% using stacking and cooling

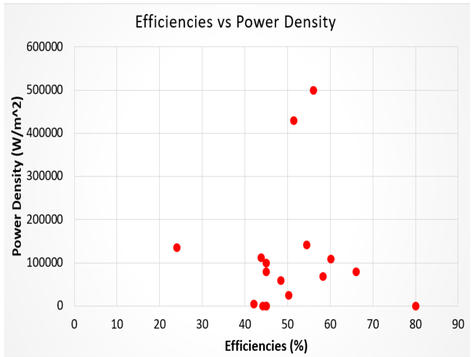
InGaAs
- Less experiments with material
- With a power density less than the sun's, 45% efficiency was achieved
- With increasing power densities, efficiencies may increase
- A very promising material for future tests

AlGaAs and GaAs Heterostructures
- Consists of multiple layers of different GaAs or AlGaAs based elements
- Very high efficiencies of 60-70% with high power densities as well
- In comparison with just GaAs cells, heterostructures perform more efficiently at lower power densities

- ❖ Efficiencies are misleading without looking at power density
- ❖ Power density from the Sun at the edge of the earth's atmosphere is 1300 W/m^2
- ❖ High power densities like those in some of these experiments around 60,000 W/m^2 would be impractical and too costly in terms of power usage
- ❖ Temperature is also a key factor in keeping efficiency high as the lower the temperature, the more efficient the photovoltaic cell



Efficiencies of experiments by materials



Efficiencies with varying power densities

Conclusion

- Advancements in laser power beaming may simply take more advanced technology than exists in order to balance power density and efficiency
- Temperature and power density play a very important role in power beaming and should be analyzed in every future experiment
- Only using one wavelength might hinder the optimization of the efficiencies and the effects of multiple wavelengths should be explored

The Way Forward

- Designs such as vertically stacked GaAs photovoltaic cells and heterostructures should be explored further as their efficiencies were consistently high
- Continued surveys or new research and experiments are vital towards finding designs with potential for the future

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