Selection and Use Considerations for Laser Power Photovoltaic Receivers

A primer for the PV user, not the PV expert
Some similarities to a solar cell, and some significant differences

Daniel Friedman and Don Jenket
National Renewable Energy Laboratory
7-23-2021
III-V Semiconductors for Laser PV receiver

III-V semiconductor PV devices based on GaAs and InP are
• Efficient
• Can handle high power densities
• Designable for laser wavelength of choice
• Robust, stable
• Lengthy heritage for space solar PV

• Bandgaps from ~0.5–2 eV ($\lambda = 600 – 2500$ nm)
• $\lambda > 870$ µm is more complex ("metamorphic growth")

• Cost reduction projects underway
Irradiance

Want to be able to handle high laser power
→ Much higher PV cell currents than solar cell
  (Example: 10W/cm² of 808nm light generates ~6 A/cm² current, at ~1V!)
→ Potentially large I^2R series resistance losses
  – must design PV to mitigate

Mitigation:
• Make individual PV cell areas small, and interconnect in series... and/or...
• Share current amongst multiple junctions in vertical configuration
Both strategies are employed in practice
State of the Art – prominent examples

Laboratory: Fraunhofer ISE
- 68.9% PV receiver efficiency under 11.4 W/cm² of 858 nm light, at 25°C
- GaAs
- Area = 0.054 cm²

Commercial: manufacturers including Broadcom, Spectrolab, and Azur Space
- > 50% PV receiver efficiency, depending on operating conditions
- Multijunction
- Various configurations available

PV efficiencies generally increase with decreasing temperature (~ Carnot)... ... Until the PV no longer absorbs the laser wavelength!

This sudden efficiency drop with temperature is due to the laser light being monochromatic – very different than for solar cells

→ Consider the entire range of operating temperatures when choosing your PV cell-- design for the lowest temperature you care about
Future Developments

• Ultra-high performance especially at bandgaps other than 1.42 eV (870 nm)

• Cost reduction
SUMMARY:
Operating conditions including irradiance and cell temperature must be accounted for.

Very high efficiencies demonstrated for small GaAs devices.

Potential for significant future advances in
- performance especially for other wavelengths
- cost

Thank you

www.nrel.gov  NREL/PR-5900-80548

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.