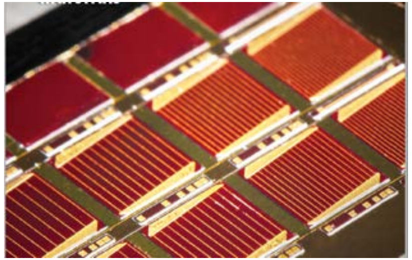


Selection and Use Considerations for Laser Power Photovoltaic Receivers

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

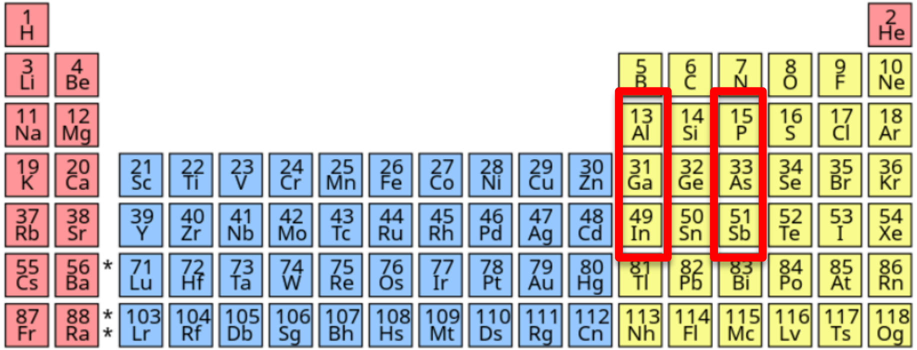
III-V Semiconductors for Laser PV receiver

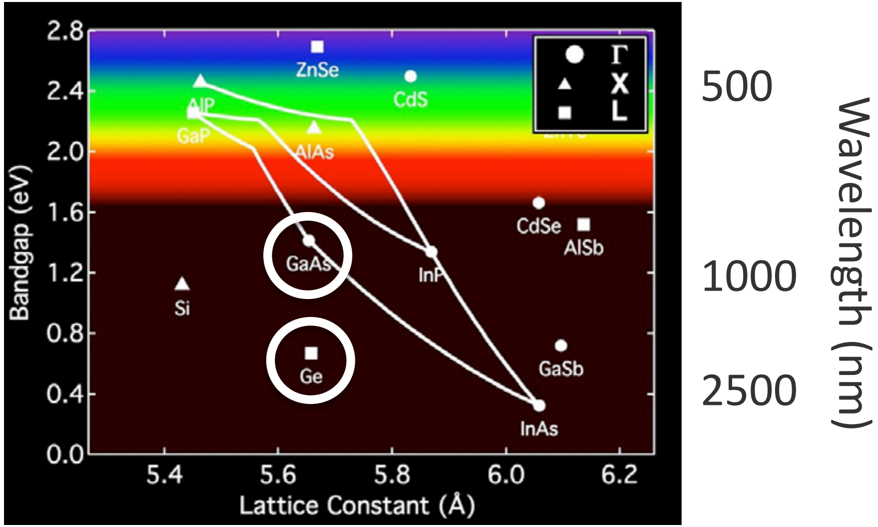
III-V semiconductor PV devices based on GaAs and InP are

- 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 (λ = 600 – 2500 nm)
- λ >870 µm is more complex ("metamorphic growth")

- Cost reduction projects underway



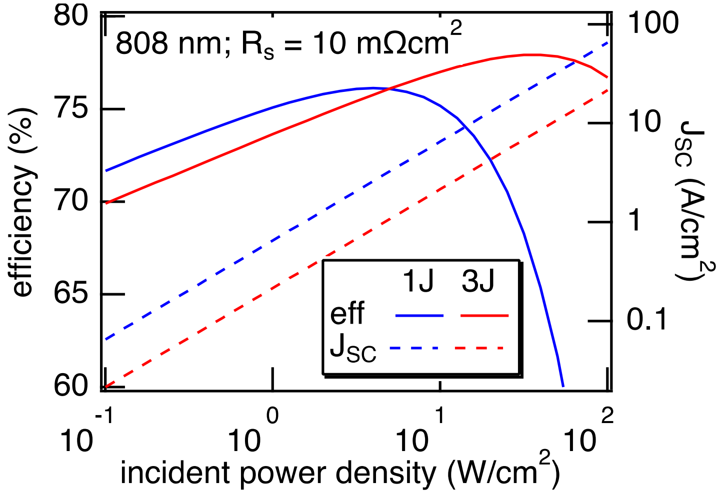


Irradiance

Want to be able to handle high laser power

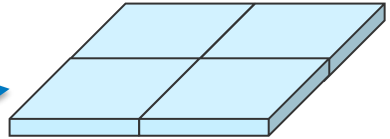
→ Much higher PV cell currents than solar cell (Example: 10W/cm^2 of 808nm light generates ~6 A/cm^2 current, at ~1V!)

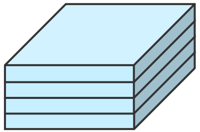
→ Potentially large I^2R series resistance losses – must design PV to mitigate



Mitigation:

- Make individual PV cell areas small, and interconnect in series… and/or…
- Share current amongst multiple junctions in vertical configuration



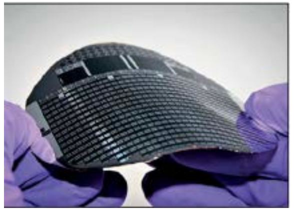


Both strategies are employed in practice

State of the Art – prominent examples

Laboratory: Fraunhofer ISE

- 68.9% PV receiver efficiency under 11.4 W/cm^2 of 858 nm light, at 25°C
- GaAs
- Area = 0.054 cm^2



Helmers et al, Phys. Status Solidi RRL, p.2100113 (2021)

Commercial: manufacturers including Broadcom, Spectrolab, and Azur Space

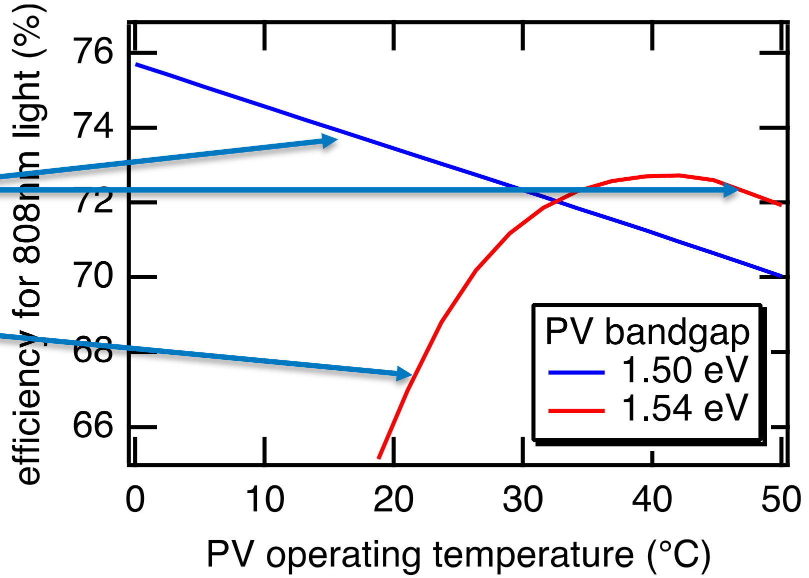
- > 50% PV receiver efficiency, depending on operating conditions
- Multijunction
- Various configurations available

Temperature Dependence

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

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