CPV (Concentration Photovoltaics)

- What is CPV?
- Why CPV now?
- How?
- Business
What is CPV?

FP = Flat panel (Silicon)
CPV = Concentration Photovoltaics

Concentration factor $C_g$
What is CPV?

- Generation of electricity: potential cost ($/KW-h) reduction
  - Fewer cells (A/C_slot)
  - More efficient cells (38% vs. 22%)

Challenges

- The increased system complexity\(^1\) can compromise the potential cost reduction

\(^1\) Efficient optics, heat sinks, two-axis sun-tracking, alignment, installation...
What is CPV?

Key points

Optical efficiency $\times$ cell efficiency

High-efficiency concentration cells can be up to 500 times more expensive than 1-sun cells (per unit area). Cell area must be strongly decreased ($C$)

Optics, tracker, heat sinks

Only direct radiation (90-65%) is usable

\[
\text{cost} = \frac{\text{cells cost} + \text{other costs}}{\text{energy}} = \text{solar radiation} \times \text{efficiency}
\]
What is CPV?

**Trade-off:** \( \text{CAP} = \text{concentration} \ C_g \times \text{acceptance angle} \ \alpha \)

**Key points**

- **Large \( C_g \)- low \( \alpha \)**
  - Accepted rays
  - \( 2\alpha \)
  - CPV
  - Solar cell

- **Low \( C_g \)- large \( \alpha \)**
  - Accepted rays
  - \( 2\alpha \)
  - CPV
  - Solar cell
What is CPV?

- Trade of concentration $C_g$ - acceptance angle $\alpha$

Large $C_g$ - low $\alpha$

Low $C_g$ - large $\alpha$

**Key points**

Difficult aiming

Easier aiming (and more!!) large $\alpha$
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Why CPV now?

- **Increased need for renewable energy sources**
  - Global warming: increased funds from governments
  - Increase demand of oil and resulting oil prices
  - Rising economies: China and India will keep oil prices high

- **Silicon solar cells not keeping up with demand**

- **Flat panel solar uses more (costly) commodities**

- **Short term goals:** availability (there is a bubble of interest!)

- **Long term goals:** CPV to demonstrate its cost competitiveness with non-renewable sources
<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Type of cell</th>
<th>Cell efficiency</th>
<th>Type of optics</th>
<th>Concentration ratio</th>
<th>Concentration ratio</th>
<th>Aiming tolerance</th>
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<tr>
<td>USA</td>
<td>MJ</td>
<td>35%</td>
<td>26%</td>
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<td>32%</td>
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<td>±0.8°</td>
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<tr>
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<td>2 mirrors</td>
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<td>±0.8°</td>
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<td>32%</td>
<td>Curved Fresnel</td>
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<tr>
<td>US</td>
<td>Silicon</td>
<td>26%</td>
<td>26%</td>
<td>Fresnel + SOE</td>
<td>400x</td>
<td>±0.8°</td>
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</tr>
</tbody>
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Why CPV now?

- **CPV companies: lack of acceptance syndrome**
  - Optics requires high accuracy.
  - Assembling is expensive because fine adjustments become compulsory.
  - Efficiency decreases significantly from single unit to an array. Optical mismatch.
  - Efficiency increases significantly when the cells are bigger.
Why CPV now?

Record Cell Efficiencies

42.8% DARPA Very High Efficiency Solar Cell (VHESC) program

Boeing-Spectrolab monolithic MJ cells

Triple junction concentrator solar cells achieved multiple world records since ’01 from ~30% to 40% during the last decade
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Desired CPV system attributes

- High optical efficiency → limited number of optical elements
- High concentration → decreasing cell cost
- Long term durability → is energy, not power
- High acceptance angle → relaxes optical, mechanical requirements
- Irradiance uniformity → cell efficiency and durability
- Low cost → mass producible components
- Compactness → transportation costs
Why large acceptance angle?

Conventional CPV system
\[ C_g = 1000x, \alpha = \pm 0.6^\circ \]

SMS device
\[ C_g = 1000x, \alpha = \pm 1.75^\circ \]

Difficult aiming...
High accuracy - High cost

Easier aiming...
Low accuracy - lower cost
How?

**Why large acceptance angle?**

- Decreases structure stiffness
- Relaxes optics accuracy (low cost)
- Simplifies assembly
- Easier array installation
- Reduced maintenance
- Potential for higher concentration
- Reduced mismatch losses → **System Efficiency!!!**

Cost-effective + large-scale implementation!
How?  

• With LPI

New cells: ↑efficiency & ↑cost

Circular aperture

Square aperture

Present Fresnel lens-based systems

Present parabolic dish-based systems

LPI-Solar
• With LPI

  • Patented record-breaking technologies
    • SMS devices achieve the largest $\alpha$ for a given $C_g$
  • Sorties into cost-cutting strategies: same manufacturing/installation processes as conventional devices but less tight (easier tolerances)
  • 20 years experience
    • Design, Optics manufacturing, Materials, Processes, Supporting/tracking structures, Sealing, Protection, thermal management...