Methods of Solar Cell Cooling

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Objectives

- Effects of Solar Cell Heating
- Methods of Solar Cell Cooling
  - Air/Water
  - Heat Pipe
  - Heat Sink
  - Fins
  - Thermal Radiation
- Conclusion

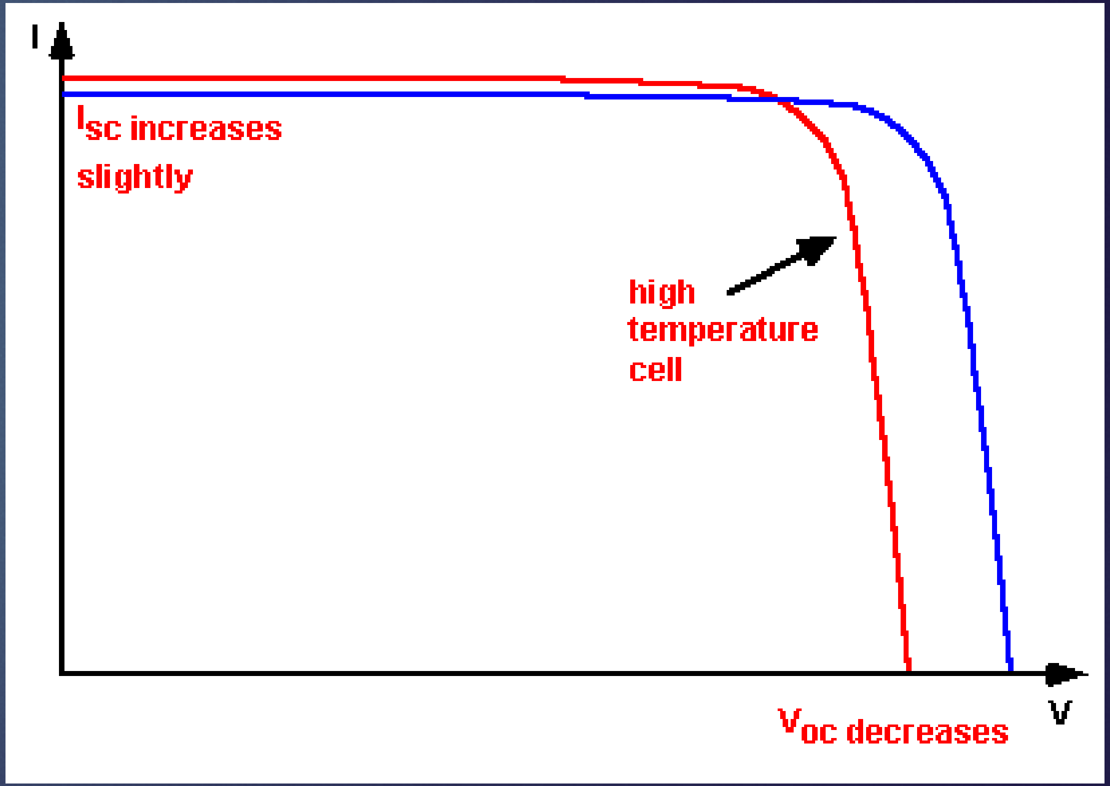
Solar Power Plant in Nellis, Nevada

Effects of Solar Cell Heating

- Wavelengths not absorbed in band gap are dissipated as heat
- Temperature rise excites electrons to higher energy states
  - Reduces band gap
  - Smaller band gap decreases open circuit voltage

$$MPP = FF * I_{SC} * V_{OC}$$

MPP: Maximum Power Point, FF: Fill Factor



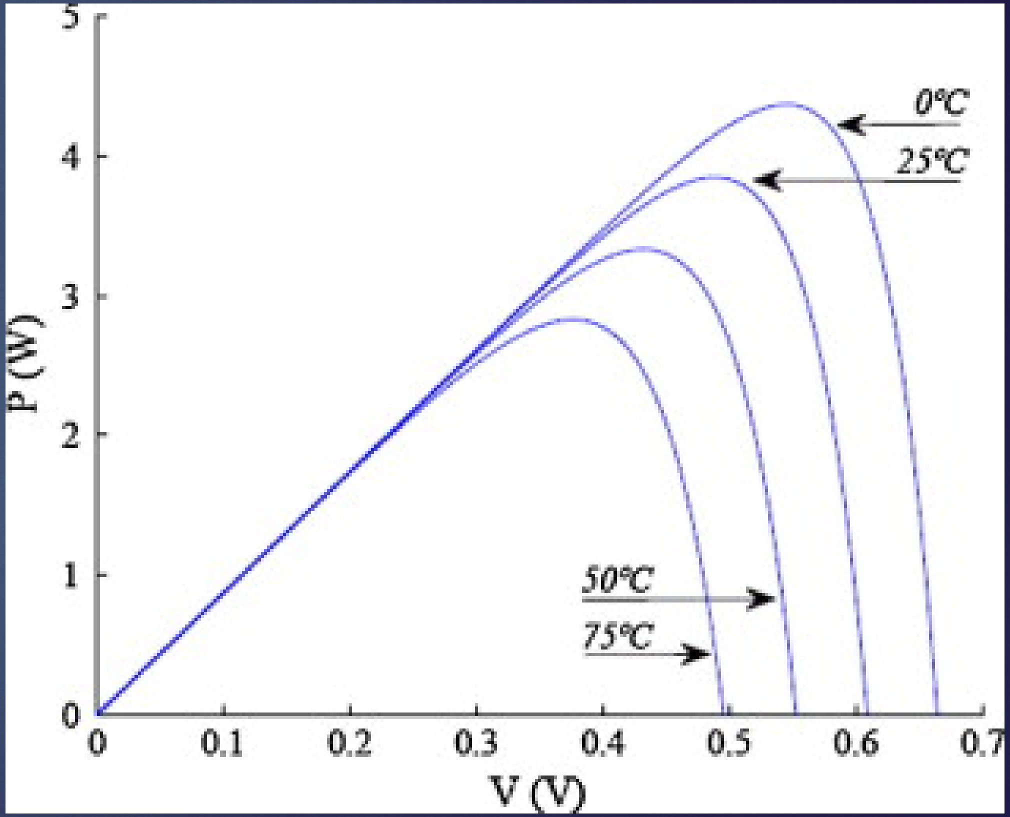
I-V Curve with effects of temperature rise

Effects of Solar Cell Heating

- Typical solar cell operating temperature: 50ºC to 55ºC
- Temp. ↑ 1ºC leads to Efficiency ↓ 0.45%
- Reduces output power and efficiency
- Reduces reliability, lifespan of device

$$\eta_e = \frac{P_{E\,out}}{P_{in}} = \frac{V_{mpp} I_{mpp}}{GA}$$

Efficiency equation: G = solar radiation



P-V curve with effects of ranging temperatures

Method 1: Air/Water

- Air and water are used as mediums of cooling
- Passive air or water cooling methods are insufficient for concentrated solar cells
  - Ex: 400x concentration can raise temperatures to 1200ºC without cooling

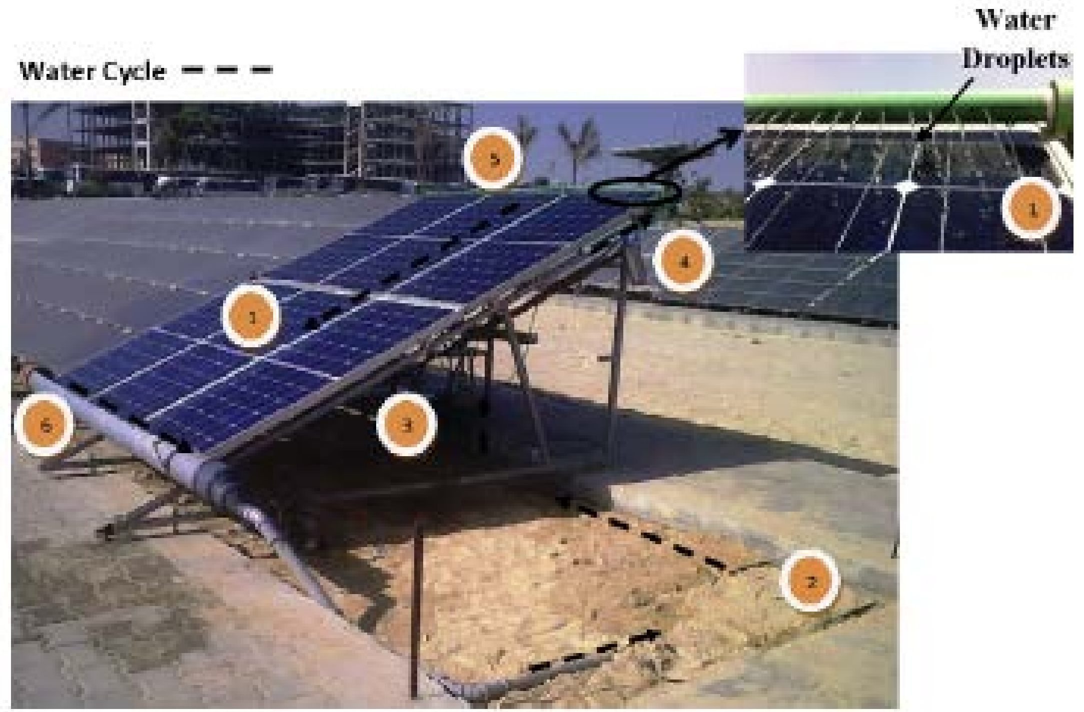
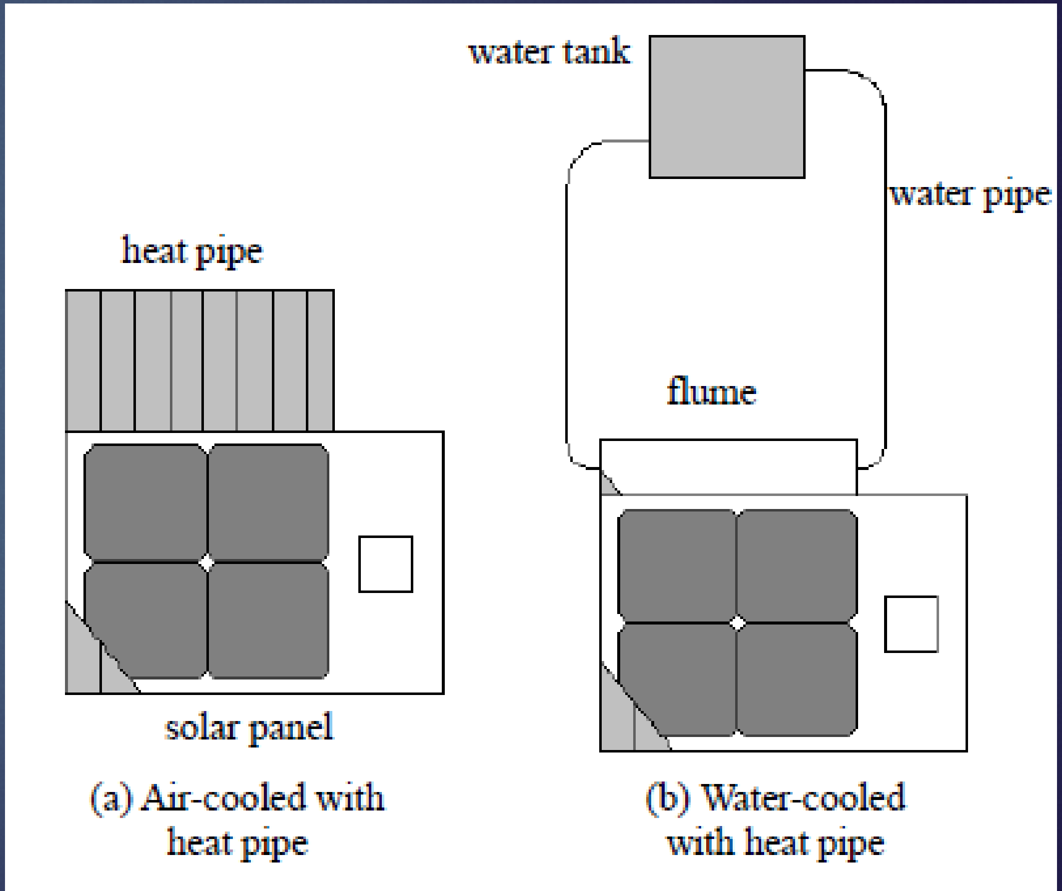


Figure 4 Experimental setup 1 – PV module, 2 – tank, 3 – pump, 4 – filter, 5 – nozzle and 6 – drain pipe.

Example of water spray cooling technique

Method 2: Heat pipe

- Heat pipe components:
  - Evaporator, Condenser
- Heat is vaporized in evaporator and transferred to condenser
- Condenser is cooled by air or water
- Convection is key

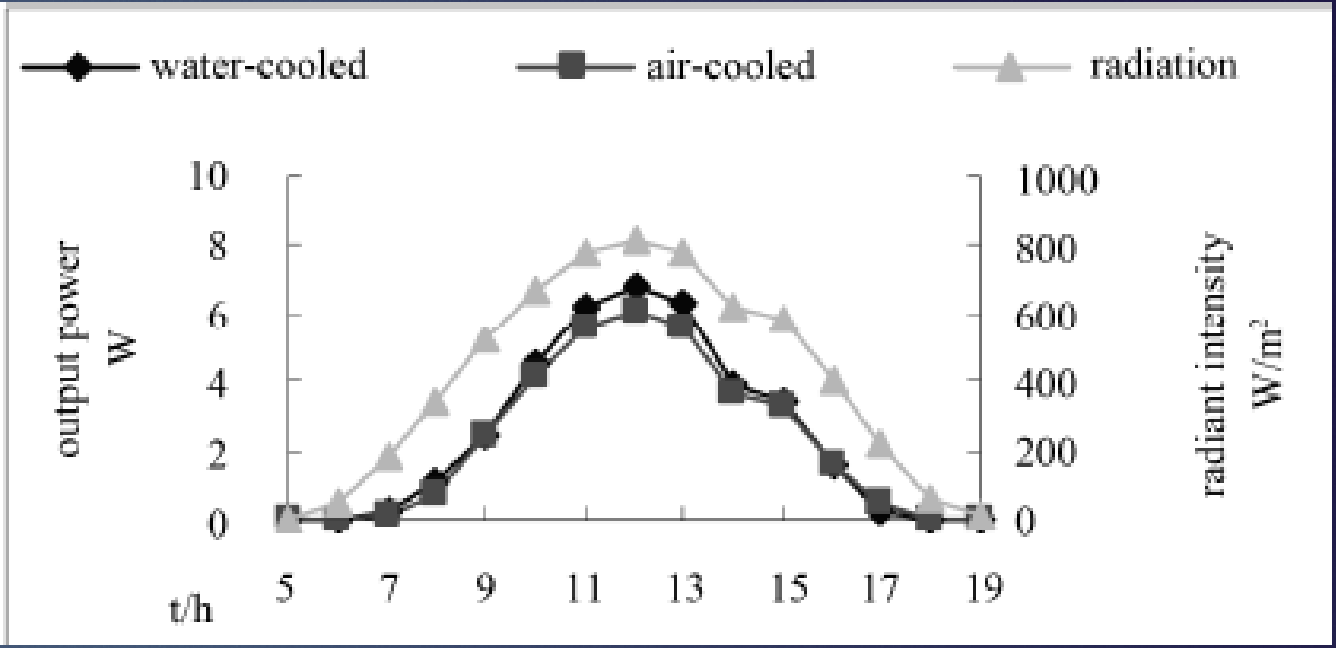


Solar panels with heat pipe cooling system

Method 2: Heat pipe

Experimental Results of Heat Pipe Cooling

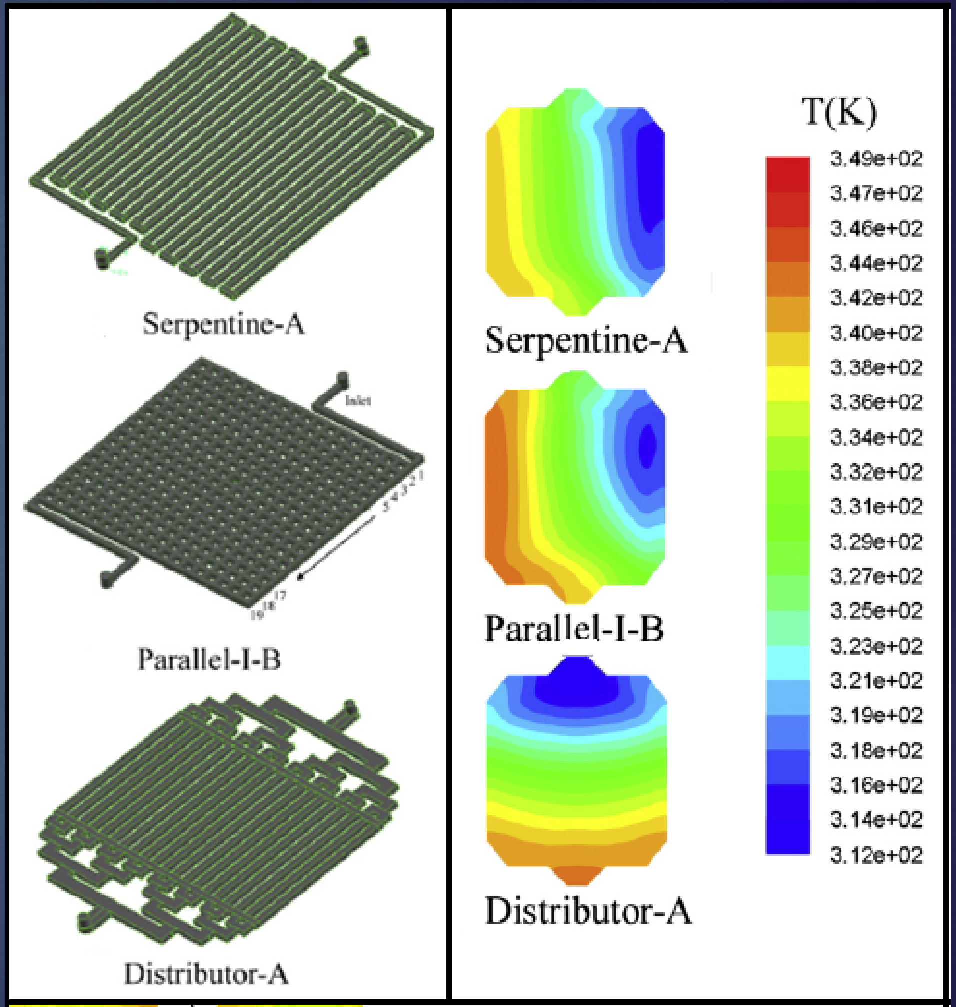
	Air Cooling	Water Cooling
Temperature	-4.7ºC, max -1.5ºC, avg.	-8.0ºC, max -2.7ºC, avg.
Power Output	+8.4W, max +6.3W, avg.	+13.9W, max +9.0W, avg.
Efficiency	+2.6%, max +0.4%, avg.	+3.0%, max +0.5%, avg.



Comparison of water-cooled vs. air-cooled heat pipe system

Method 3: Heat Sink

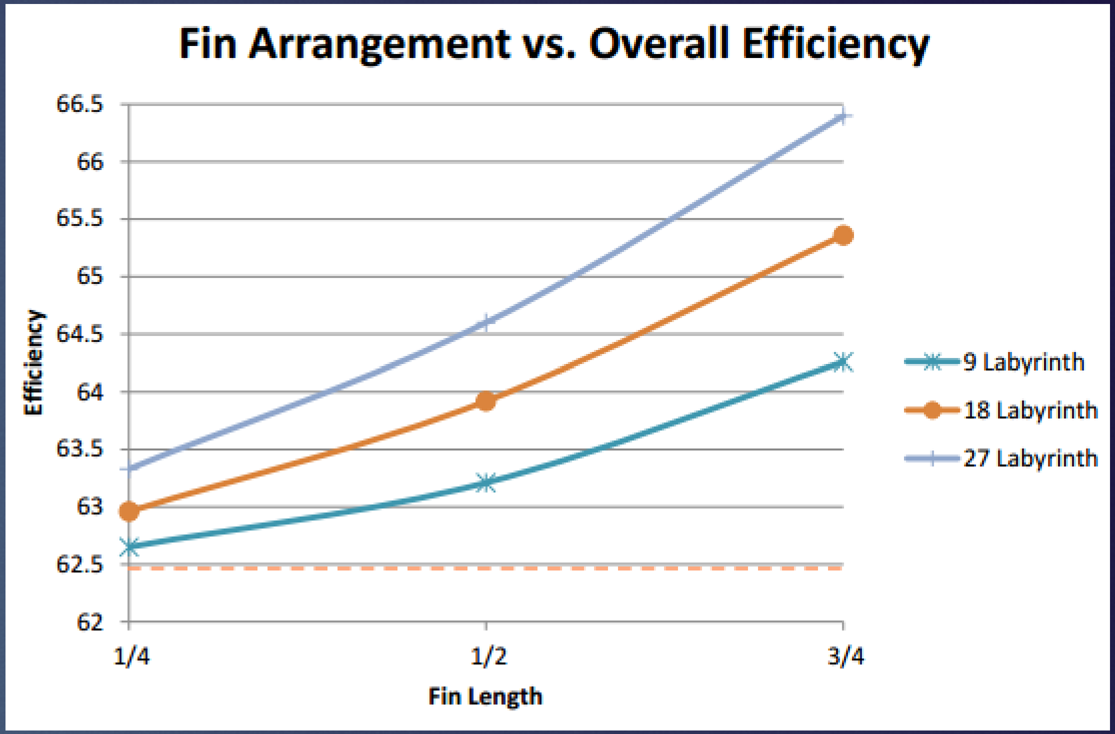
- Medium flows through micro-channel heat exchangers
  - (100-1000μm diameter)
- Liquids have higher heat capacity
  - Lowers max temperature



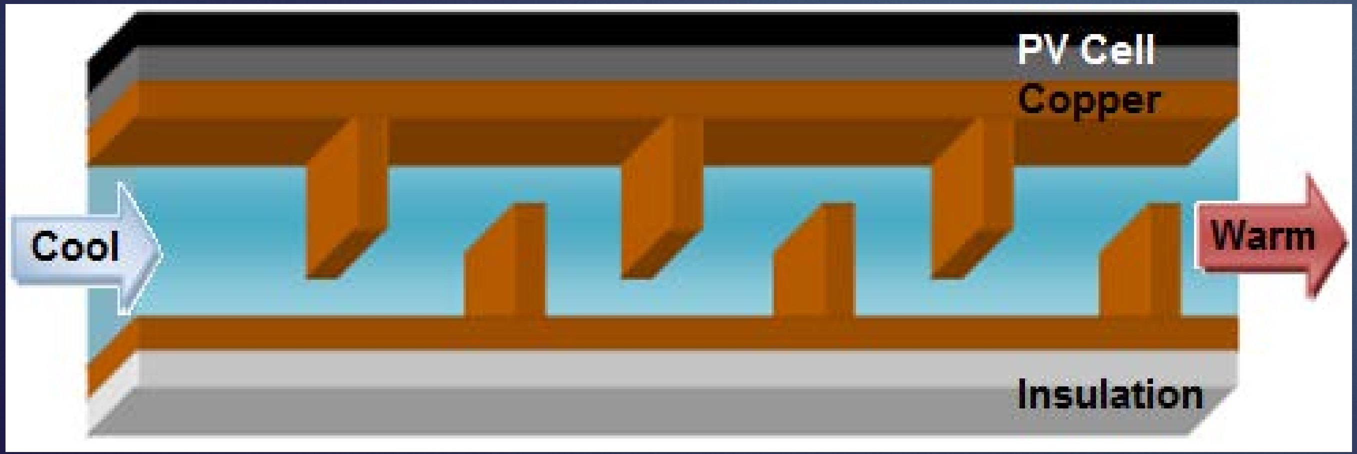
Sample heat sink patterns with temperature distribution

Method 4: Fins

- Heat conducted through PV cells to copper fins
- Heat dissipated through fluid flow



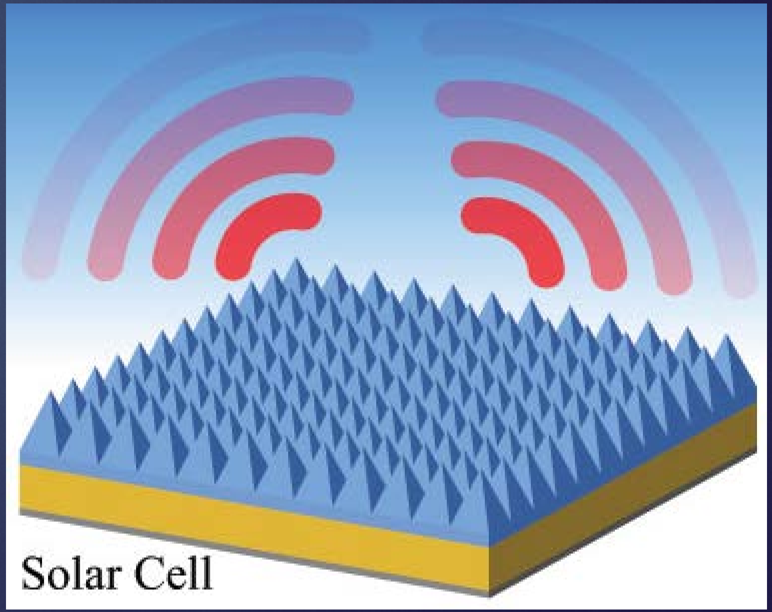
More fins with greater area increases efficiency



Labyrinth (top and bottom) fin arrangement enhanced better flow

Method 5: Thermal Radiation

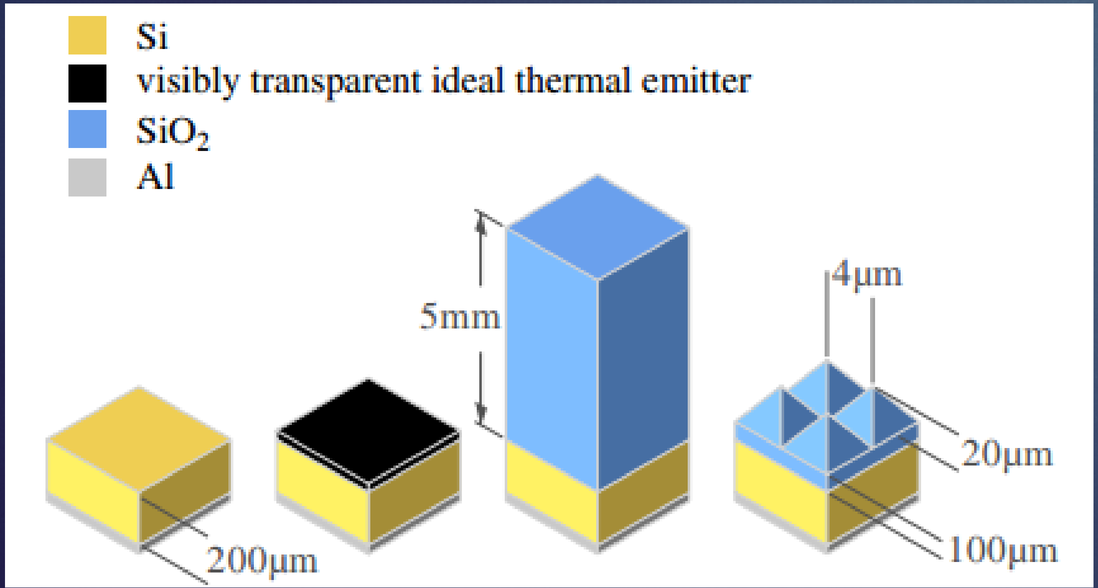
- Pyramidal/cone-shaped structures in thin silica glass layer
  - Silica glass transparent to visible light
    - Visible light λ spectrum: ~700nm to 400 nm
    - Infrared λ spectrum: ~ 1mm to 750nm
  - Redirects heat as infrared radiation to atmosphere



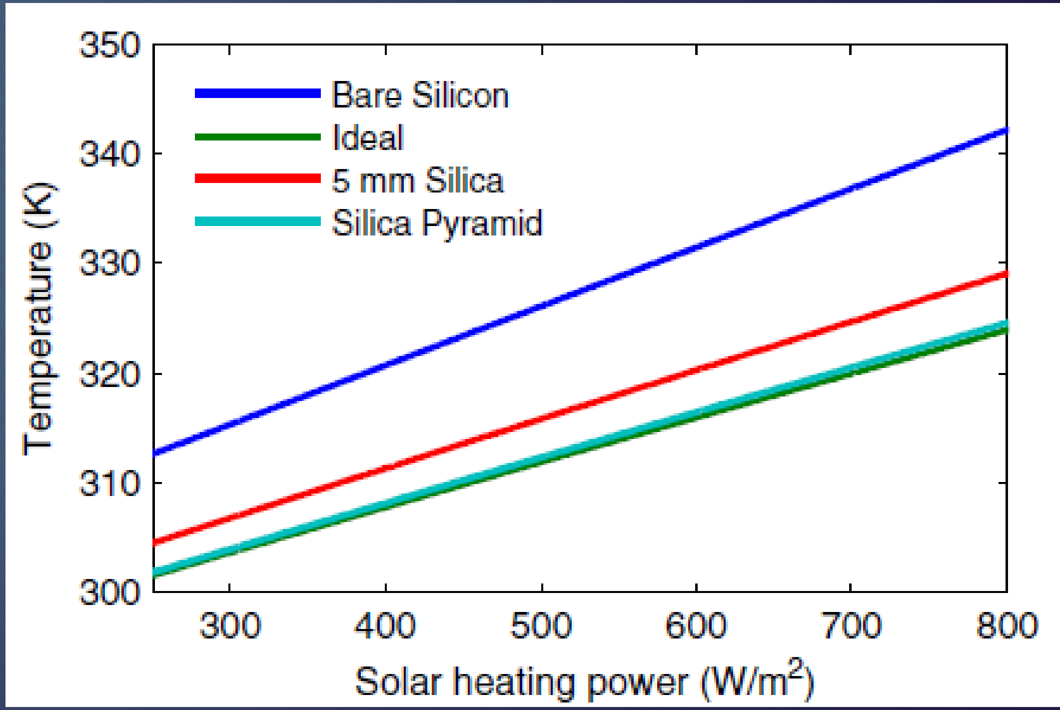
Cone-shaped silica glass surface

Method 5: Thermal Radiation

- Temperature drop of 17.6K results in relative efficiency increase of 7.9% at 800W/m^2



Comparison of solar cell surfaces



Comparison of different surfaces with temperature and radiation

Conclusion

- Lower operating temperatures increase efficiency of solar cells
- Many methods of solar cell cooling
  - Air/Water, Heat Pipe, Heat Sink, Fins, Thermal Radiation
- Consider the cost of these systems
  - Installation, pumps, water (other liquid), maintenance

Questions?

References

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