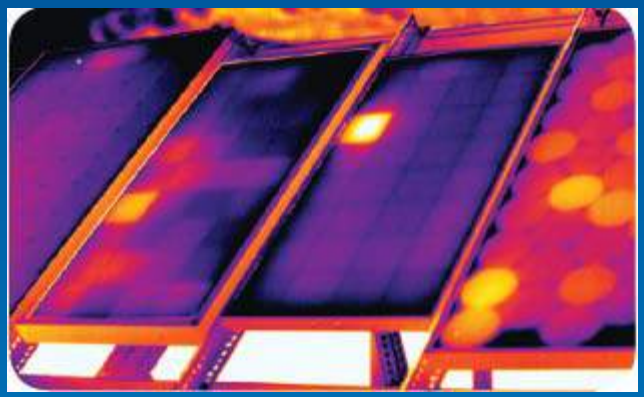
SOLAR CELL PRODUCTION REQUIRES EFFECTIVE METROLOGY

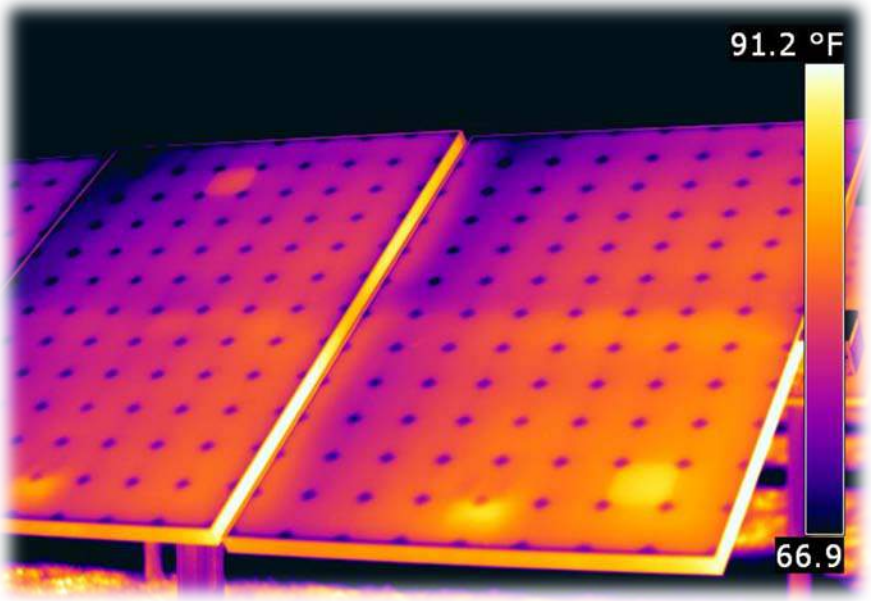


Recent IR Thermography Developments Can Help

6/12/2010

Agenda:

- **Infrared Cameras for Solar Cell Inspection**
- Survey of current solar cell test methods
- New solutions for solar cell installation and maintenance



Solar Cell Inspection:

Solar Farm

Solar Panel

Solar Cell

Solar Cell Product Cycle

R&D

Production

Installation

Maintenance

Advantages of IR:

- Early stages of development or production
  - Electrical: I-V, C-V, Carrier Characteristics
  - Typically requires wafer probing
  - May also require thickness gauging and special sample prep, depending on measurements
- Conventional IR thermography alternative
  - Can reveal shunt and series resistance, cracks, breaks in screen-printed parts, etc.
  - No special prep work required
  - Detection through glass is poor
  - Has relatively low spatial resolution due to thermal diffusion

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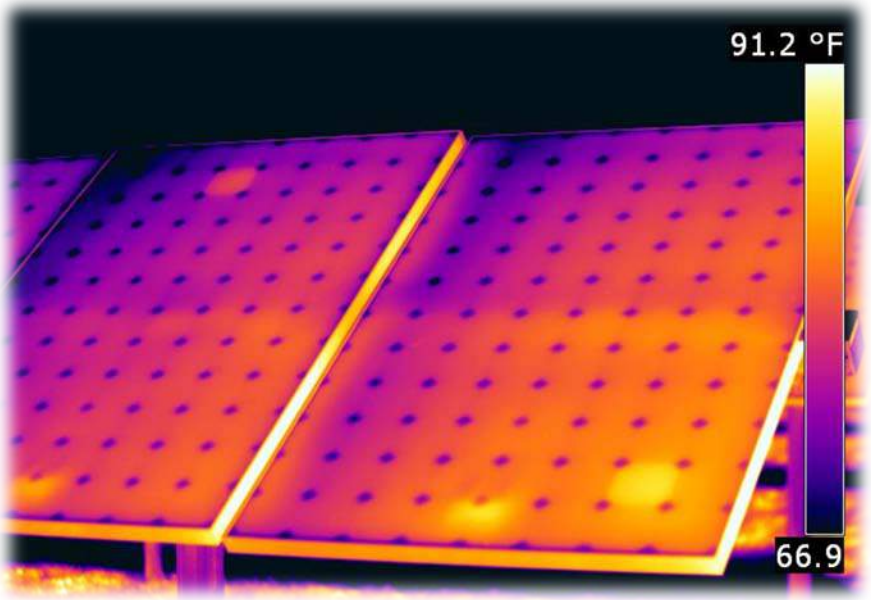


Shunt Detection

- Shunt Detection or Reverse Bias testing
  - Simply wire it backwards
  - Diode / check valve discussion
- Sensitivity & Optical FoV are key
- Easiest of the “R&D” grade thermal test methods
- Careful - may damage the cell.
- Thermal diffusion is the downfall

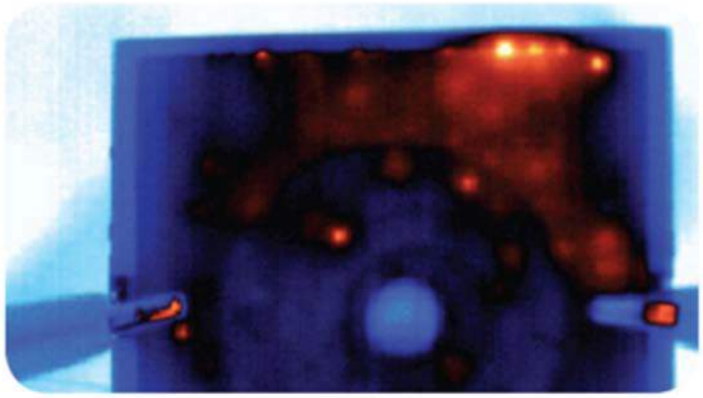
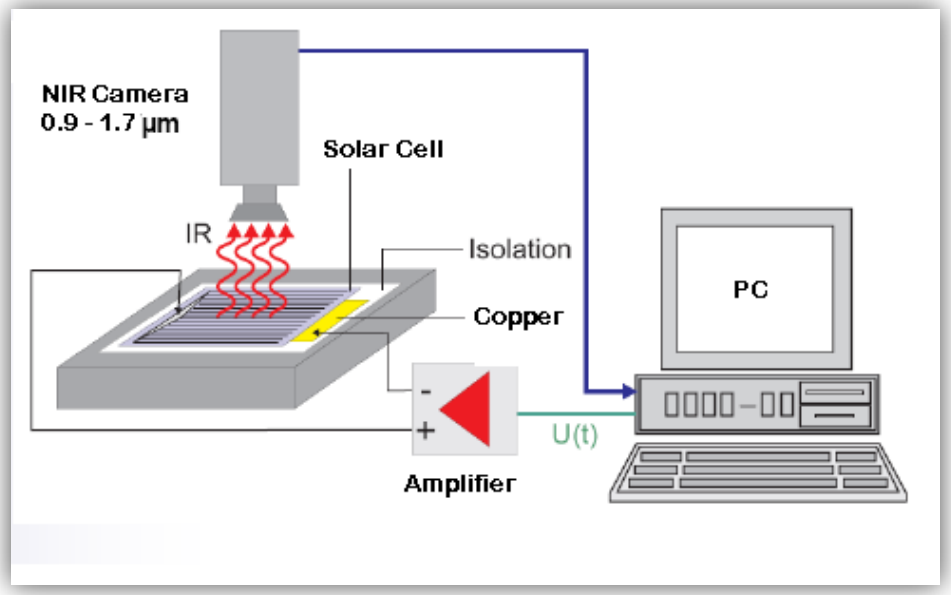


Figure 2. *IR image of 60x60mm silicon solar cell showing shunt defects (orange areas) under steady state reverse bias conditions.*

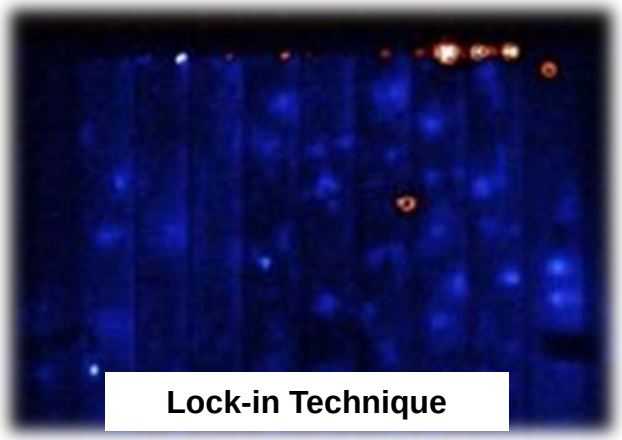
Electroluminescent Testing

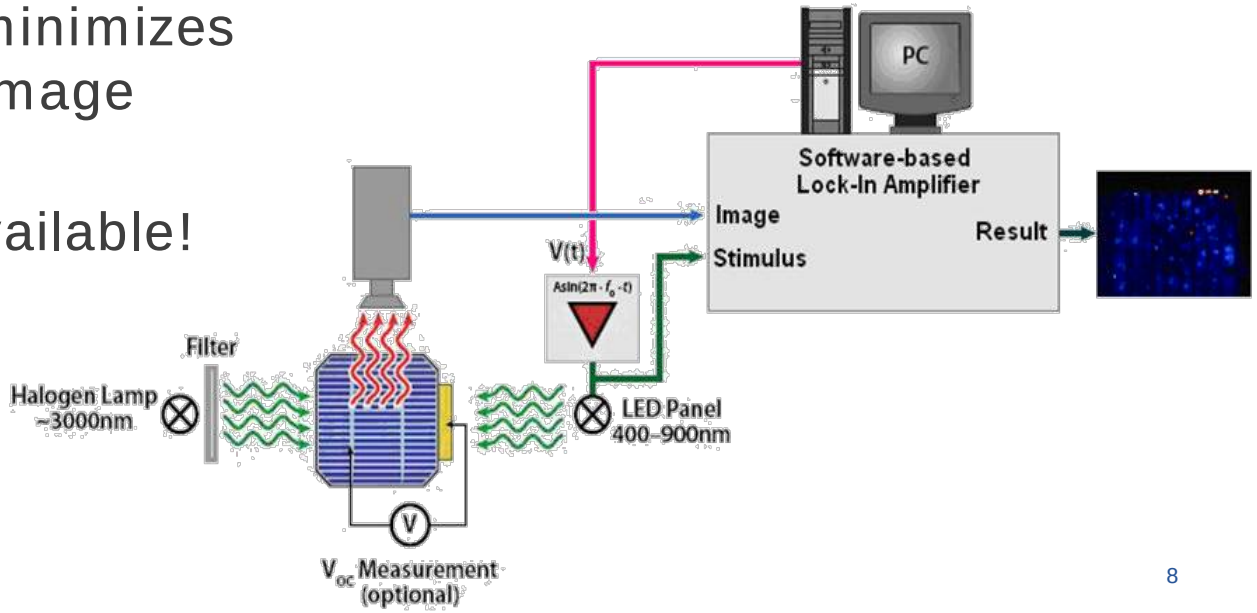
- Apply a forward voltage & current to the PV Cell.
- Electrons in -> Photons Out
- Requires a Near IR camera
- Works in steady state or lock-in.



Lock In Thermography

- Filter removes almost all noise
- InSb works best
- ε α don't matter, NEdT/100!
- Small current, minimizes possibility of damage
- Best Solution available!





Gross Defect Detection

- Simple inspection with low cost uncooled IR camera, typically a handheld.
- Requires minimal training
- Every installer should be performing this test
- Easy Reporting software available

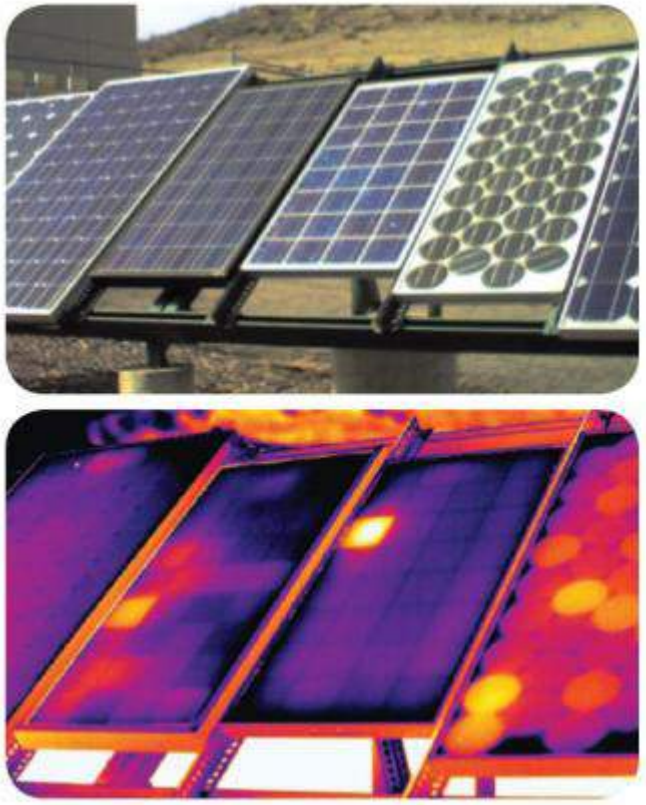


Figure 3. Solar cell testing using an uncooled microbolometer handheld camera.

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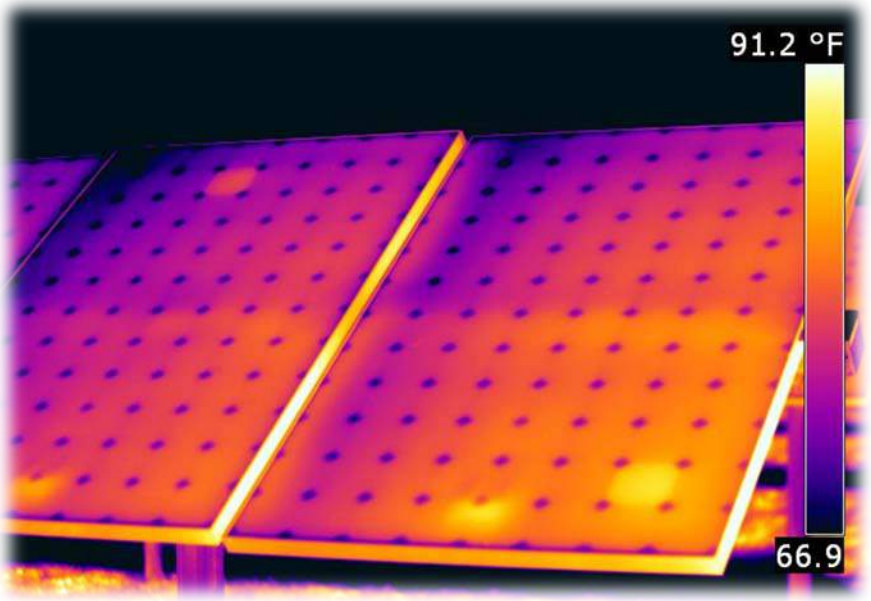
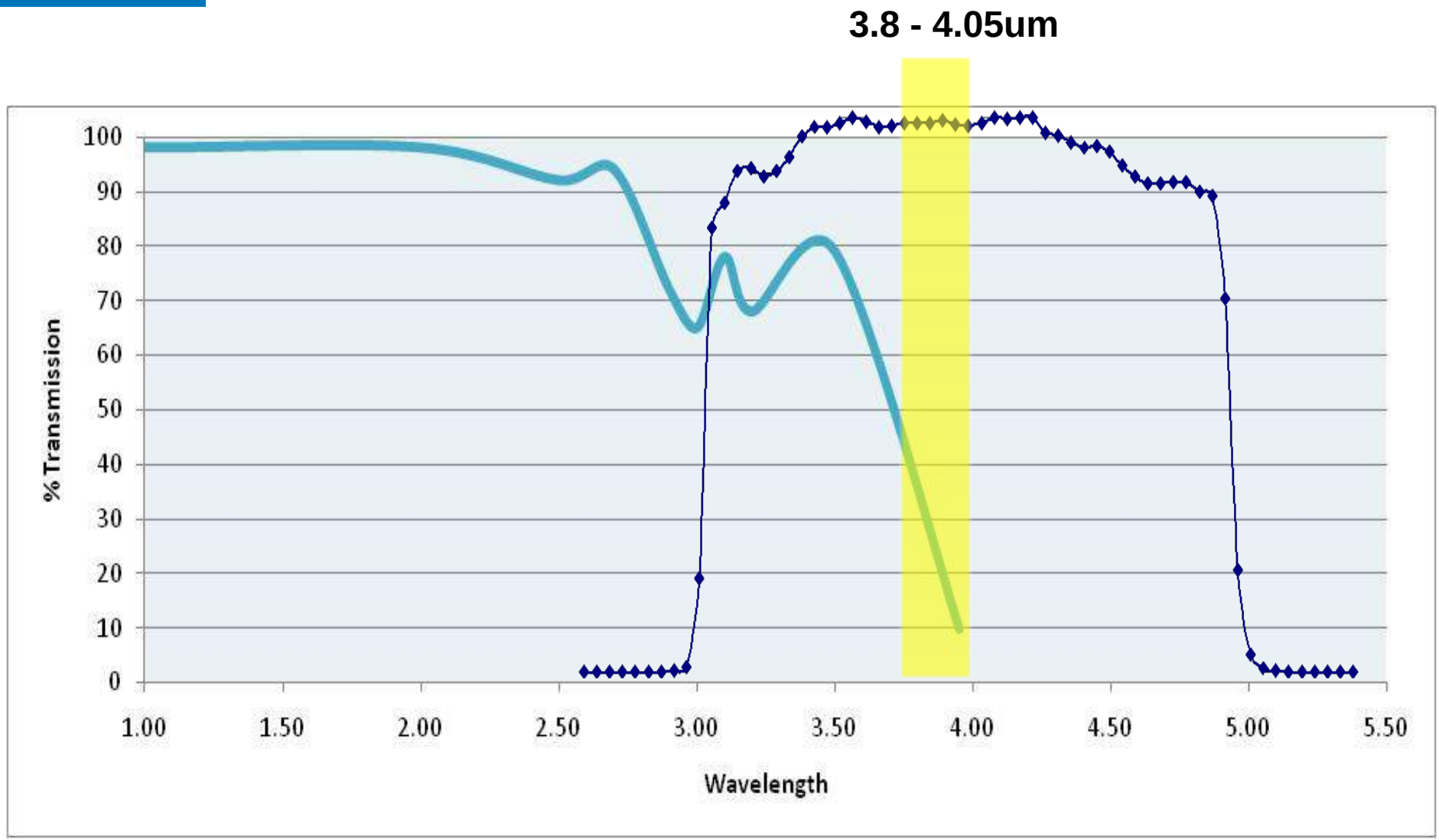


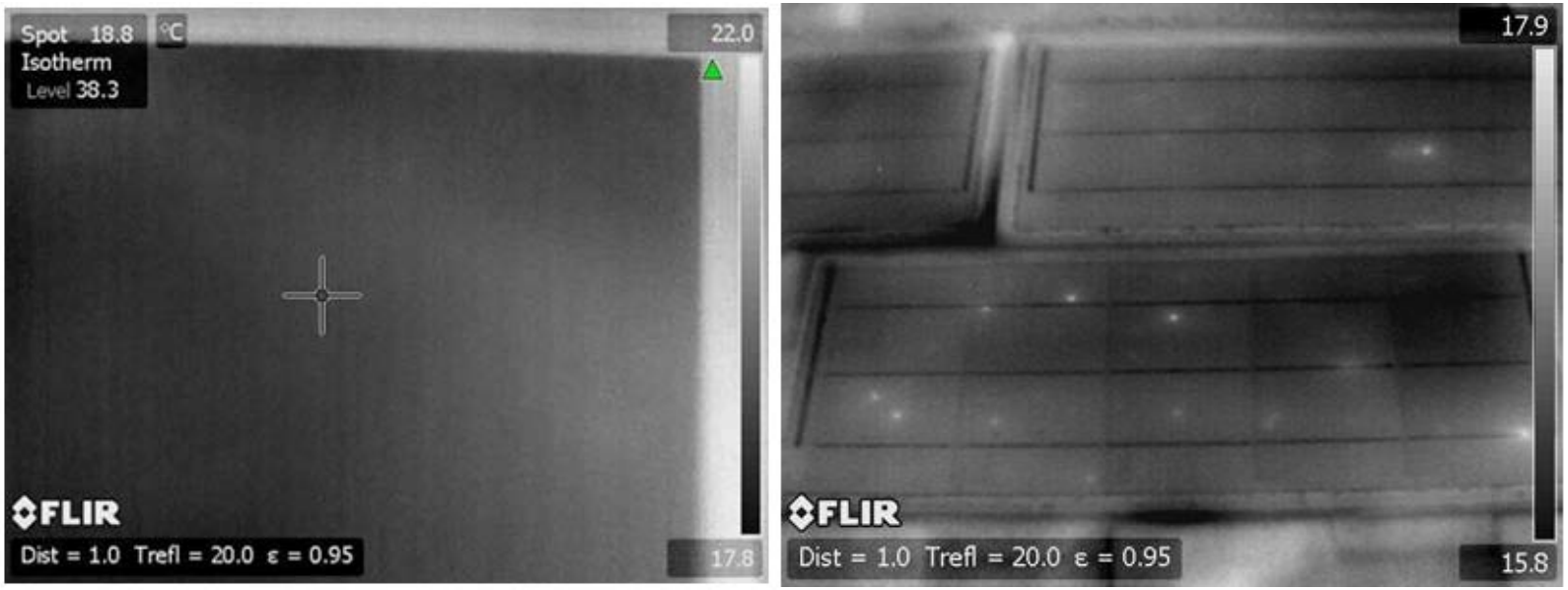
Detailed defect detection

- Need to see detailed IR image for defects in preshipping & installed panels
- The challenge:
  - Glass attenuates energy in the spectral region where IR detectors are most sensitive
  - If you can overcome the glass absorption problem, a sensitive detector (~20mK) may see the defect
  - Glasses selected for solar panels typically have high transmittance in the 0.4 – 1.1µm range
  - However, transmittance remains relatively high up to about 4µm

Seeing IR Radiation Through Glass



Seeing IR Radiation Through Glass



Defect detection in solar panel roof assemblies with protective glass covers. Left: standard InSb IR camera. Right : same camera with 3.80-4.05µm spectral filter. Defects are bright spots.

SUMMARY

- IR thermography can spot shunt and series resistance defects, cracks, and other anomalies
- Filtered InSb cameras allow effective inspections of most types of solar panel assemblies
- This makes them suitable for both R&D and production applications
- A major advantage is the short time required to complete a set of measurements
- Another is no elaborate sample preparation
- In most cases, data can be acquired in seconds, compared to minutes or hours with other methodologies

QUESTIONS AND ANSWERS

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