# Questions About IEC 62108 Implementation

**NREL PV Module Reliability Workshop**

Mike Ludowise,  Feb. 18-19, 2010

This presentation does not contain any proprietary or confidential information

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Innovation Inspired by Nature

# Outline

- Introduction
  - Intent of 62108 – “Concentrator Photovoltaic (CPV) Modules and Assemblies - Design Qualification And Type Approval”
  - Brief History
- Experience in Implementing 62108 from an HCPV manufacturer’s viewpoint
  - Design variations
  - Inappropriate cell tests
  - Vague directions, desired additions
  - Other Issues
- Conclusions & Questions

From the viewpoint of a newcomer in CPV interested in applying the standard in a balanced way within an industrial setting, but without the benefit of silicon PV experience.




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# Introduction

- Intent of 62108
  - To specify the minimum requirements for the design qualification and type approval of concentrator photovoltaic (CPV) modules and assemblies and receivers
- History
  - IEEE 1513 issued in 2001 as first CPV standard
    - Started in 1997, NREL led effort
    - Expired in 2006
    - Served as first draft of IEC 62108
  - IEC 62108 issued in 2007 as comprehensive CPV standard
    - Started in 2000, NREL led effort
    - Influenced by IEC 61215, “Design Qualification and Type Approval” aimed at flat plate terrestrial crystalline silicon PV modules
- Few HCPV system fabricators in 2002
  - HCPV is still a nascent branch of the PV industry
  - 2007 marked the entry of many companies into the HCPV space
  - Experience is “testing” 62108 against real world realities:
    - Widely varied HCPV system designs
    - Application to contemporary HCPV III-V cells
    - Tight funding, budget, and time-to-market constraints




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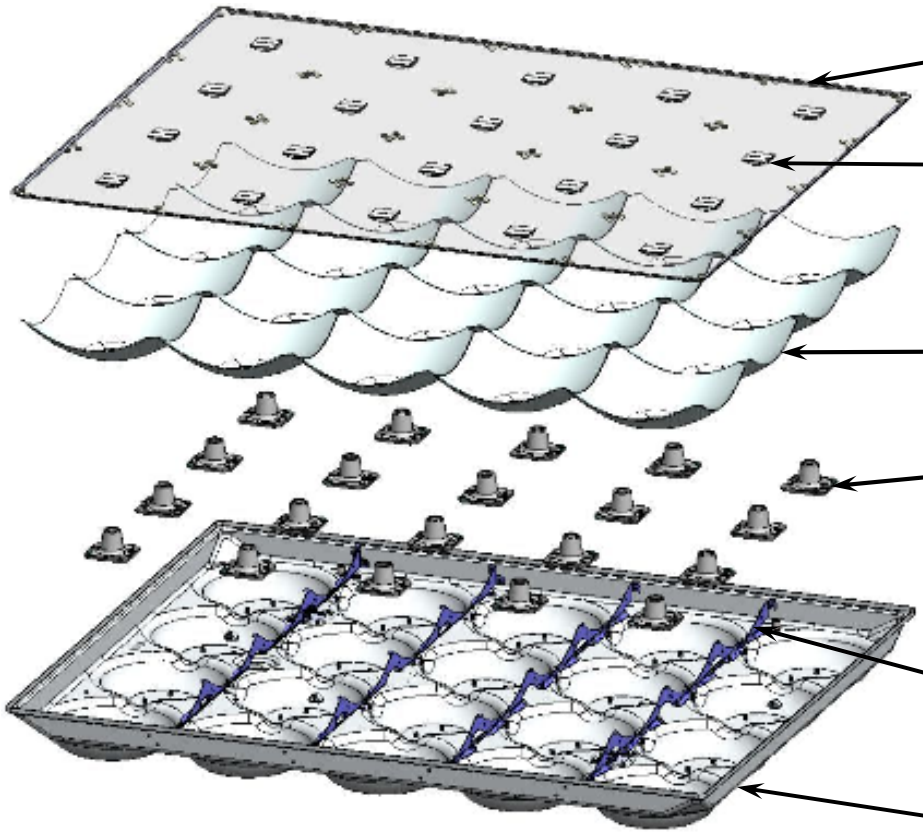
# Parts Identification - Module Assembly



Front glass panel, adhesively attached to backpan rim

Secondary mirror, adhesively attached to front glass

Primary mirror

Receiver - Contains:
- Cell
- Bypass diode
- Tertiary optic
- Thermal path
- Electrical connects

Spacer

Single piece drawn backpan

SolFocus SF1100 Panel

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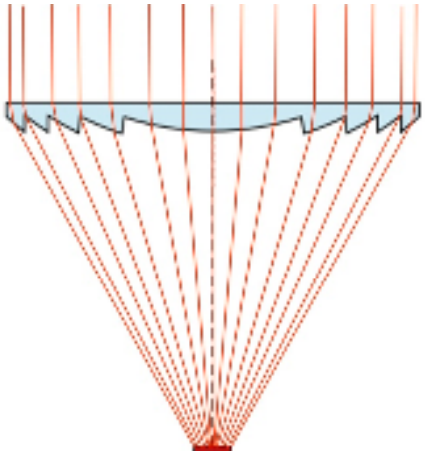
# Two of Many Designs

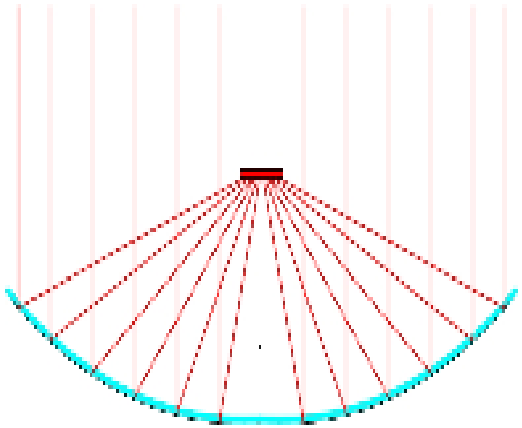
## Two Fundamental Approaches

- Refractive: with lenses



Amonix, California

- Reflective: with mirrors



Solar Systems, Australia

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# Thermal Cycle Test

- Section 10: current cycling in the hi-T parts of thermal cycle test using one of:
  a) Driving the cell to1.25 x $I_{sc}$ forward current using an external DC source
  b) Illuminating with full intensity light to generate 1.25 x $I_{sc}$
  c) Partial illumination combined with an external drive to generate 1.25 x $I_{sc}$

  - Pass:
    - No major visual defects
    - No interruption of current flow during the test
    - Insulation resistance passes per clause 10.4.

- Notes the above may be detrimental to cells – provides alternate and additional test:
  - Retain option a) above with no applied current
  - Drive additional "dead" cells to 1.25 x $I_{sc}$ such that $\Delta T_{test} \geq \Delta T_{operation}$
    - Simulates operational thermal mismatch, fatigue, other stresses
    - Additional receivers pass $\Delta R_{receiver}$ < 2% (excluding the cell).

- Attempts to simulate on-sun stresses; tests the die attach bond line integrity, solder, and electrical connection reliability




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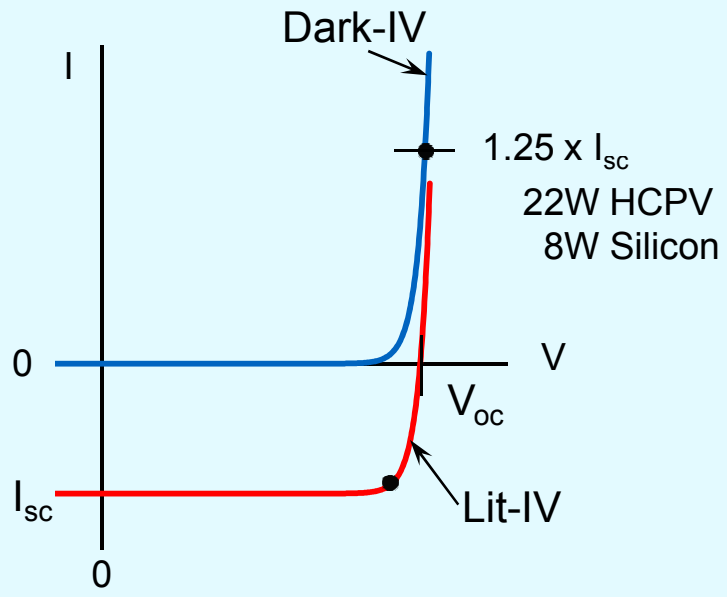
# Dark IV and Light IV Comparison

Driven 1.25 · $I_{sc}$ pushes the cell to a different operating point beyond the intended design range

Flat silicon conditions do not translate directly to III-V HCPV cells




| Silicon @ 1-sun | III-V HCPV Cell |
|---|---|
| $V_{oc}$ = ~1V | $V_{oc}$ = ~3V |
| $I_{sc}$ = 6A (150cm² cell) | $I_{sc}$ = 6A (1cm² cell) |
| $J_{sc}$ = 40mA/cm² | $J_{sc}$ = 6A/cm² |
| P = 40mW/cm² | P = 17W/cm² |
| P = 6W | P = 17W |
| 1.25·$J_{sc}$ = 50mA/cm² | 1.25·$J_{sc}$ = 7.6A/cm² |
| Monolithic | Epitaxial Construction |

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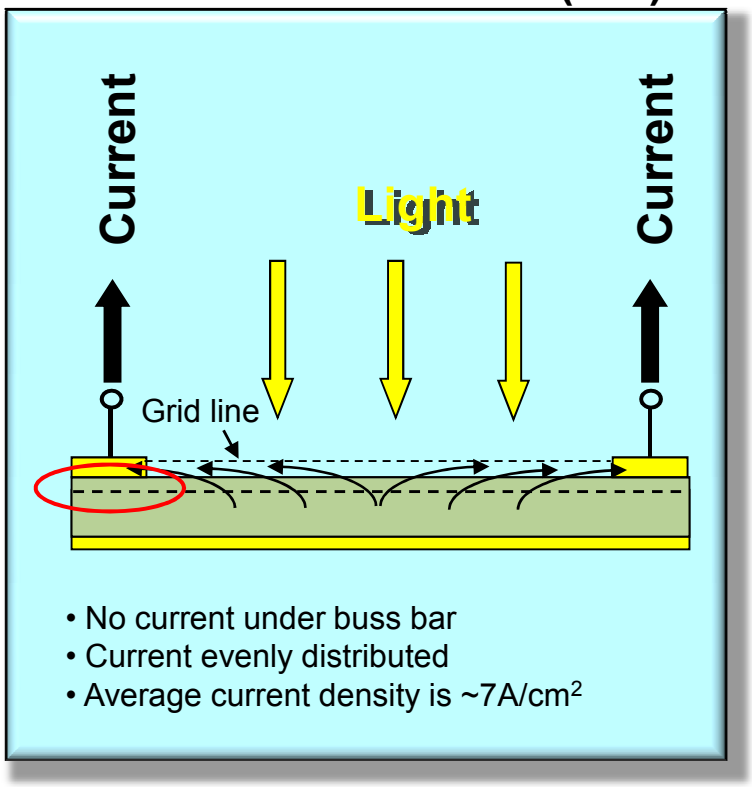
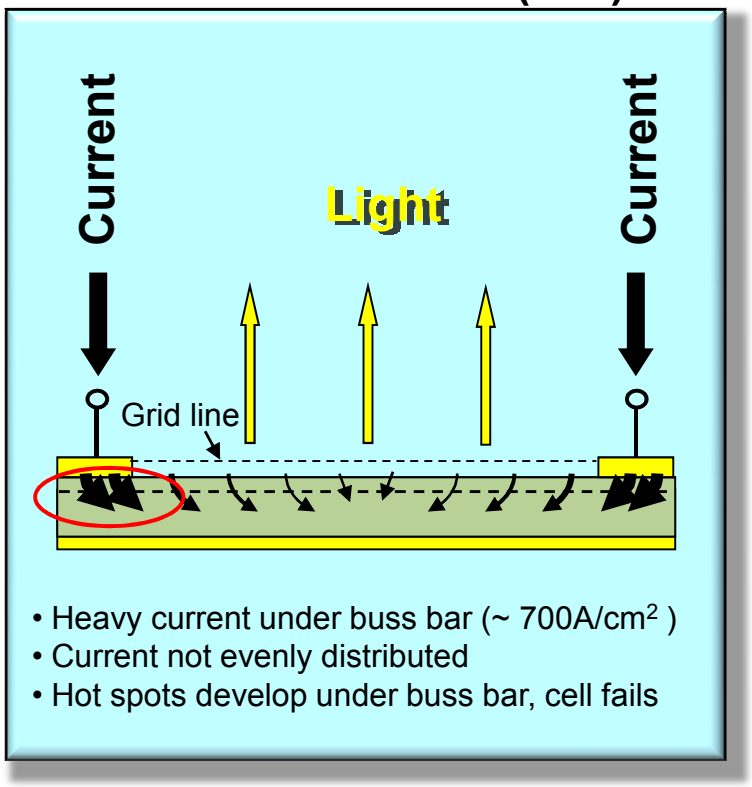
# DIV vs LIV Stress

## Illuminated Drive (LIV)




- No current under buss bar
- Current evenly distributed
- Average current density is ~7A/cm$^2$

## External Drive (DIV)




- Heavy current under buss bar (~ 700A/cm$^2$ )
- Current not evenly distributed
- Hot spots develop under buss bar, cell fails

- Any small defects under the buss bar concentrate forward current
- Thermal run-away results

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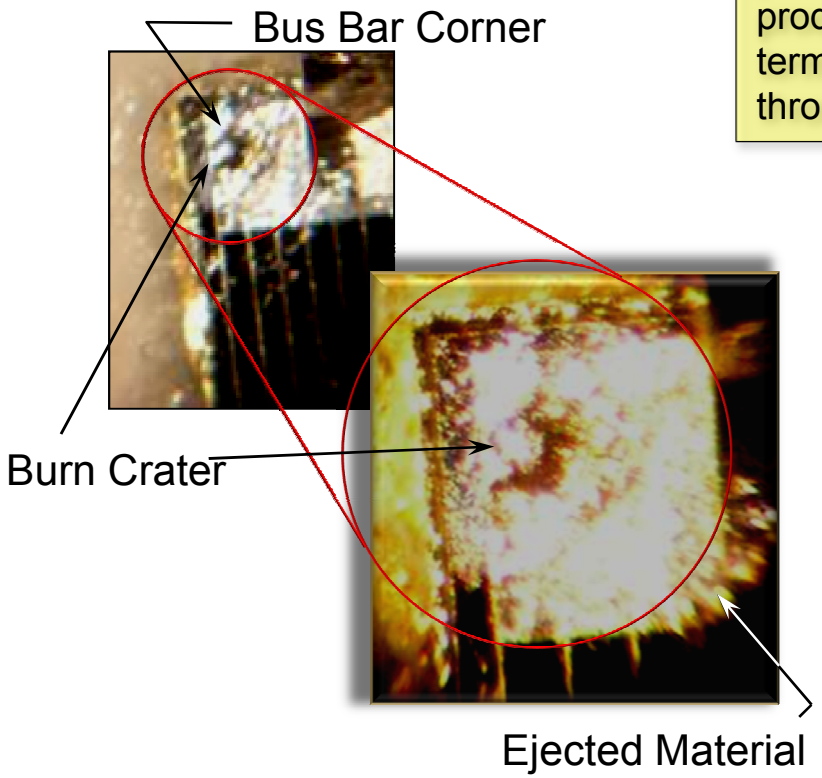
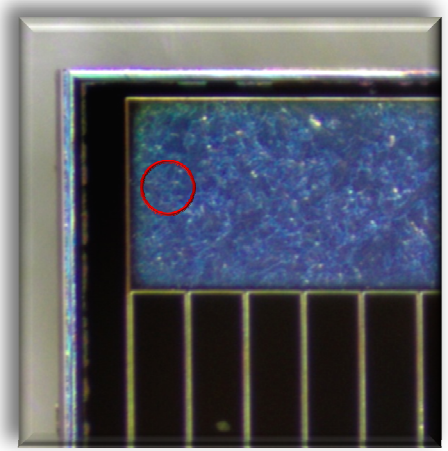
# Cell Failures from Over-current Stress

US 2004/0261838 A1

**[0012] …** the cause of the current limitation and premature failure of … cells … is the result of the heat produced by tiny local current shunts (sometimes termed “filaments”) that short the metallic busbar layer through the underlying semiconductor material …




Burned Out Cell



New Cell

Currents as low as ~4A have been observed to damage cells -

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# Vague Sections

- **Section 9: Modifications**
  - "Any changes in design, materials, components, or processing of the modules and assemblies may require a repetition of some or all of the qualification tests to maintain type approval. Manufacturers shall report to and discuss with the certifying body and testing agency every change they made."
  - Is the testing agency the best authority to make these decisions?
  - For example, sourcing cells from an alternate supplier:
    - Is there a way to handle identical form, fit and function cells from alternate manufacturers without triggering a re-test?
    - If the cell $V_{oc}$ increases? Internal epi composition change? IMM Cells?
  - Is it more sensible for the IEC standard to be expanded to include major categories of changes that trigger re-testing, and specify the test section affected.




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# Other Issues Worth Addressing

- Cycle time for the full IEC 62801 tests suite is 6 to 9 months
  - Similar flat plate exposure is only about 3 months
  - Long term outdoor & UV exposure pace the tests; 1000kWhrs DNI required
  - Result: ~1yr. to certify against IEC 62108
  - CPV market and technology moves rapidly
  - Difficult for CPV to overcome cycle time handicaps
  - Valuable time to market can be lost owing to small changes
- Hundreds of thousands of dollars may be spent in the process
- Develop field data correlation to accelerated tests of IEC 62108
  - Standards may not identify all degradation modes
  - If CPV cells operate in hot, dry climates, 85°C/85% RH may be overkill
  - UV degradation of index-matching silicones not yet correlated with on-sun exposure
  - Humidity Freeze test does not necessarily mimic stresses found at any location on earth




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# Other Possible Revisions

- Thermal Cycling:
  - Probably cycles too slowly
  - 18 cycles/day => ~5C/min.
  - OK for 1-sun system, but slow for high intensity systems with rapid $\Delta T/\Delta t$
  - May result in under-testing of the receiver assembly

- Carry over test from flat panel
  - Tests carried over from flat panel should be consistent with flat-panel standards
  - E.g., flat panel humidity freeze is 10 cycles; 62108 requires 20 cycles




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# Beyond 62108

- Cell level testing
  - Reliability tests
  - Standards for cell interchangeability
- Enhanced outdoor exposure testing
  - Add a larger population requirement
  - Concentrated sunlight cannot be replicated in a chamber
  - Many degradation mechanisms unique to concentrated sunlight
  - Lends more confidence to customers, investors
- Pooled experience
  - CPV companies have collectively learned much about accelerated testing
  - Try to quantify tests in terms of years of field life
    - Differences in concentrator designs
    - Approximate accelerations for different component or material types would help
  - Quixotic hope of pooling knowledge base to enhance standards
- Vibration or mechanical shock testing
  - Shipping and installation damage
  - Well known correlations for adhesives to static system lifetimes




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# Questions

- What is the best method for simulating on-sun stresses during thermal cycle?
- How should new solar cells be introduced into the product under IEC 62108?
  - When is a re-test triggered, and when is it not?
  - Will solar cell qualification and reliability standards help?
- How to set uniform change thresholds for re-testing :
  - By sub-system, i.e. optics, cell, structural, electrical?
  - When substituted parts are “identical” without cross reference standards?

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