Non-Intrusive Cell Quantum Efficiency Measurements of Accelerated Stress Tested Photovoltaic Modules

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Figure 2. The Arizona State University Photovoltaic Reliability Laboratory C-M-QE system

Cell-Module Quantum Efficiency (C-M-QE) Technique

- Different from Cell QE and Full Module QE
- Measures QE of specific location on individual cell within module
- Avoids backsheet penetration, enabling multiple measurements during multi-step stress tests
- Beneficial for analysis of failures due to stress testing
- Technique involves voltage and light biasing of module, see Figure 1

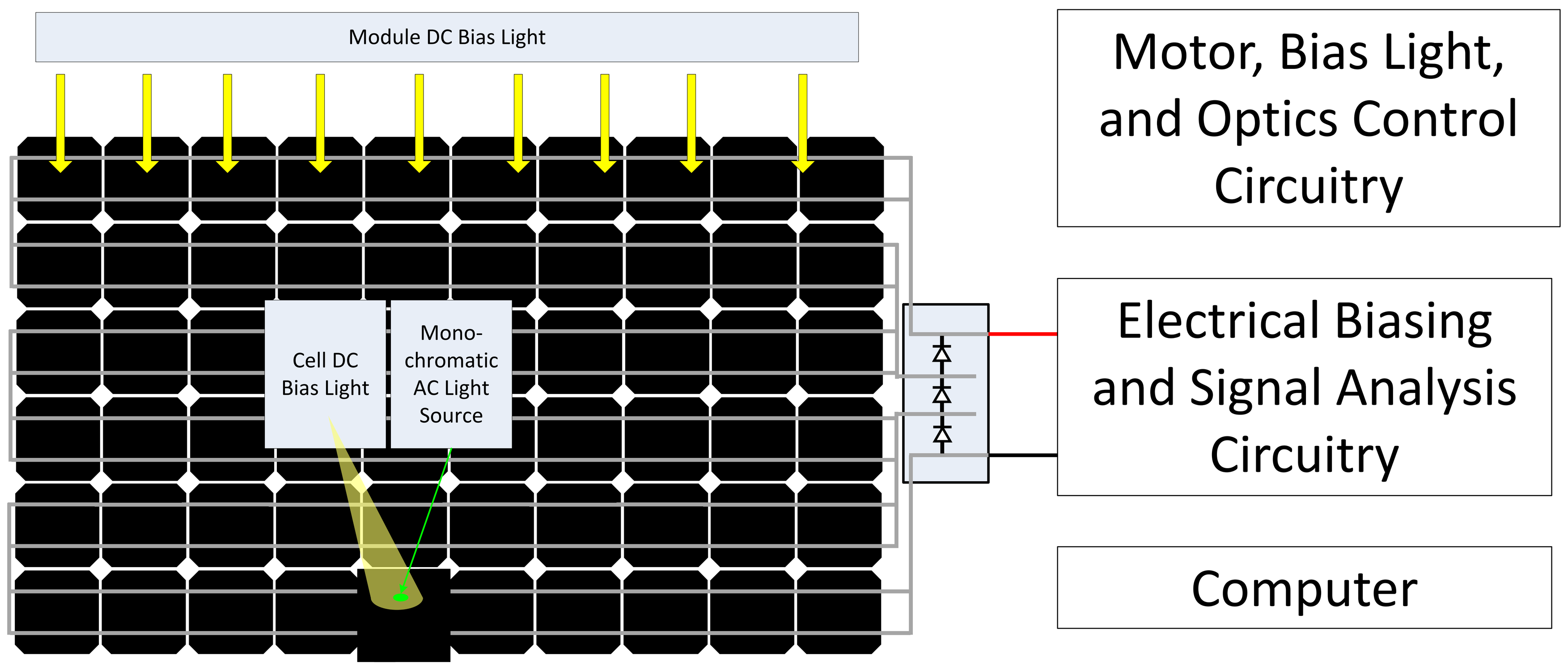

Figure 1. C-M-QE System configuration

Cell QE, Full Module QE, and Cell-Module Quantum Efficiency (C-M-QE) comparison

- **Cell QE** requires electrical connection to the individual cell. In a module, this requires backsheet penetration to access the cell's terminals, preventing subsequent stress tests.
- **Full Module QE** illuminates entire module. Result is current-limiting cell response at each wavelength. Different cells may limit current at different wavelengths. Stress tests may change which cell is limiting.
- **Cell-Module QE** enables one to measure QE at a location of interest, apply stress, and measure the same location again.

Measurement Validation

- QE scaling affected by extent of stress, see Figure 3
- Scaling artifact understood to be due to stress-induced cell shunting
- Authors are interested in exploring use of pulsed voltage and/or pulsed light bias to counteract signal loss due to cell shunting [1]

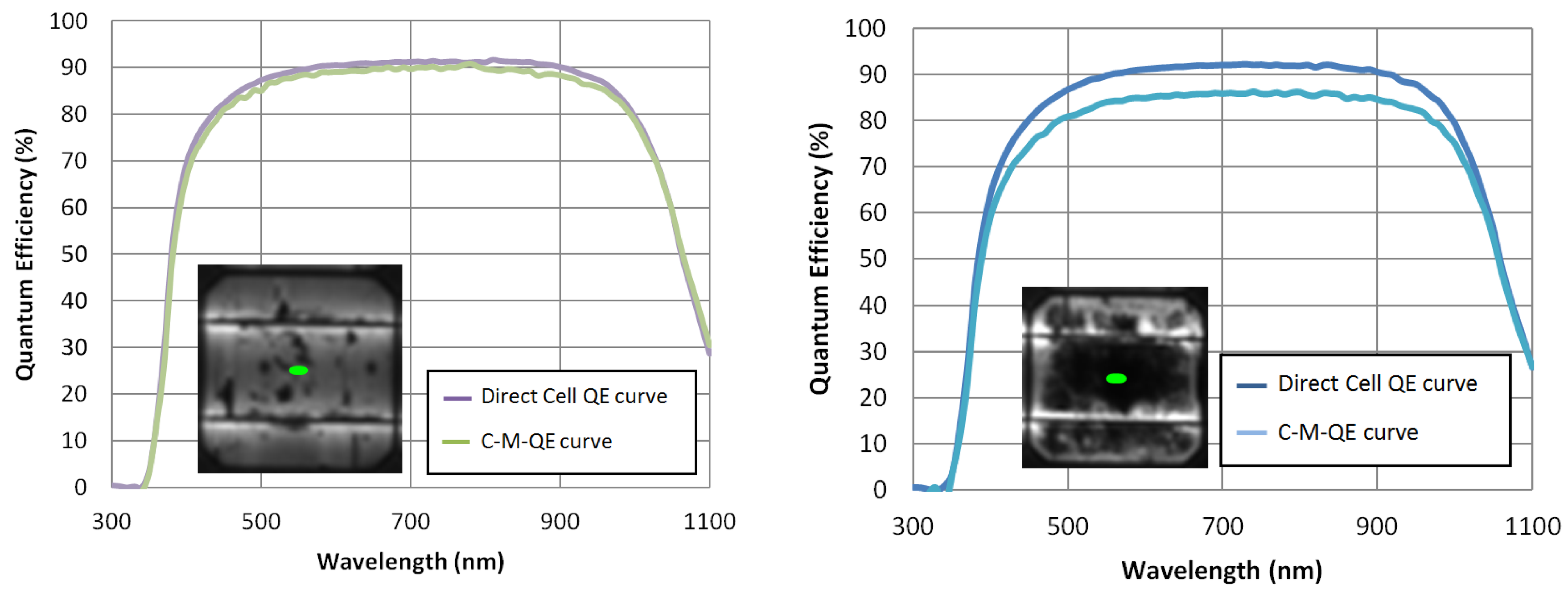

Figure 3. Example QE Measurements showing scaling artifact. Green spot superimposed on EL image indicates tested location

Use case example

- QE of an encapsulated silicon solar cell coupon before and after PID stress, see Figure 4
- Scaling understood to be due to stress-induced cell shunting
- Explanation of permanent loss of blue response explained elsewhere [2]

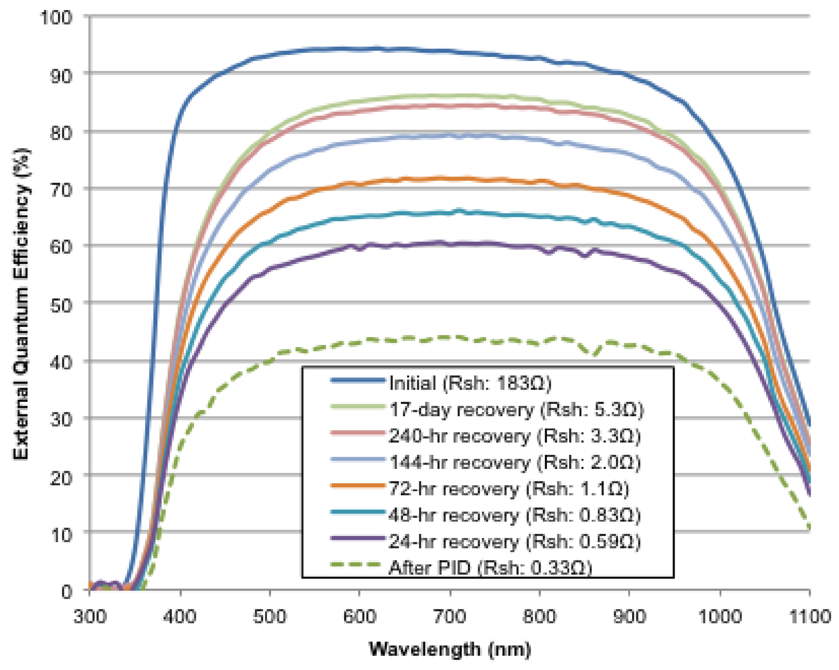

Figure 4. Cell QE Measurements showing wavelength-dependent PID-induced loss [3]

Summary

- Useful Cell-Module QE measurements require module-level light and voltage bias.
- Cell-level light bias not found to have significant influence on QE measurement of crystalline Si module.
- QE of stressed cells reveals information about wavelength-dependent module failure mechanisms.

References and Acknowledgement

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[2] J. Oh, S. Bowden, and G. TamizhMani, "Application of reverse bias recovery technique to address PID issue: Incompleteness of shunt resistance and quantum efficiency recovery," Abstract submitted, IEEE PVSC, 2014
[3] J. Oh, G. TamizhMani, and S. Bowden, "Scaling Error of Quantum Efficiency Measurements for Heavily Shunted Cells in Reliability Research," Abstract submitted, IEEE PVSC, 2014

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