DuraMAT
Durable Module Materials Consortium

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Measurement of PV cell crack characteristics in PV modules using digital image correlation

Fall 2020 DuraMAT Workshop – Virtual

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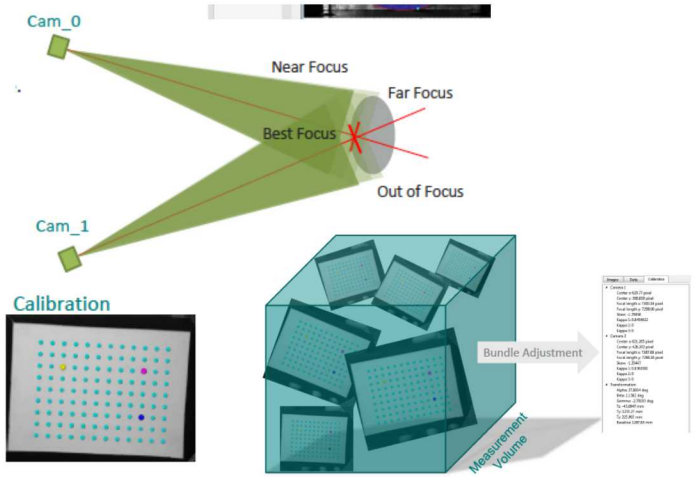
Measurement of PV cell crack characteristics in PV modules using digital image correlation

PI: Joshua S. Stein– Sandia National Laboratories

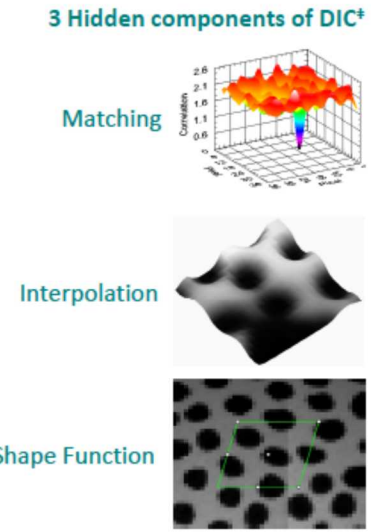
Demonstration Project Areas

- Advanced characterization and method development
- Validation of new materials to solve PV cell crack problems
- Tool for understanding how PV cell cracks evolve over time

Steps of Stereo DIC



3 Hidden components of DIC‡



Core Objectives & Teaming

Core Objective(s): Multi-scale, multi-physics model, Materials solutions

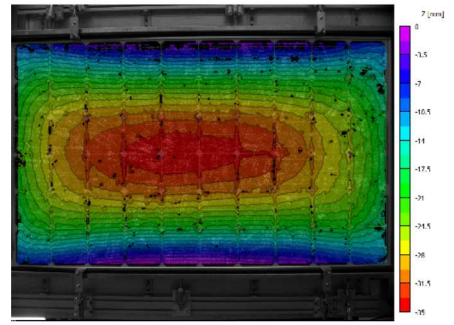
Team: Joshua Stein, Charles Robinson, Jennifer Braid, Bruce King

Technology Summary & Impact

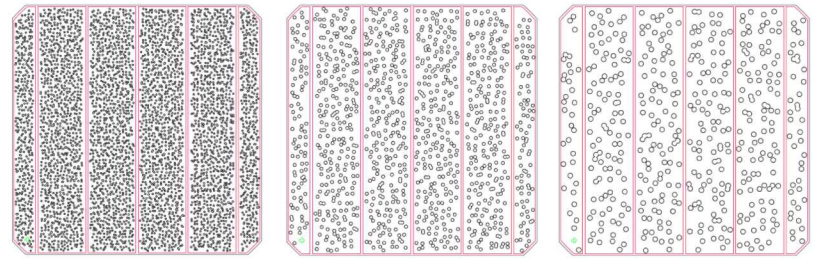
Goal is to measure PV cell crack widths (gaps) within encapsulated PV modules using stereo digital image correlation (DIC).

- As a preliminary test we successfully measured full module displacement using stereo DIC. These results will be used to validate models.
- Contract is placed with D2Solar to build four test modules with screen-printed random dot patterns applied to the cells.
- 1 Prototype module and several minimodules haven been completed.
- Once rest of modules are received, we will apply dynamic loading, EL, and DIC sequentially to track cell movement and crack opening.

Full module displacement from DIC



Three random dot screen patterns for different spatial resolutions



Resources ($)

Period of Performance: May 2020 to Jan 2021 **Total Budget (per year): $50k**

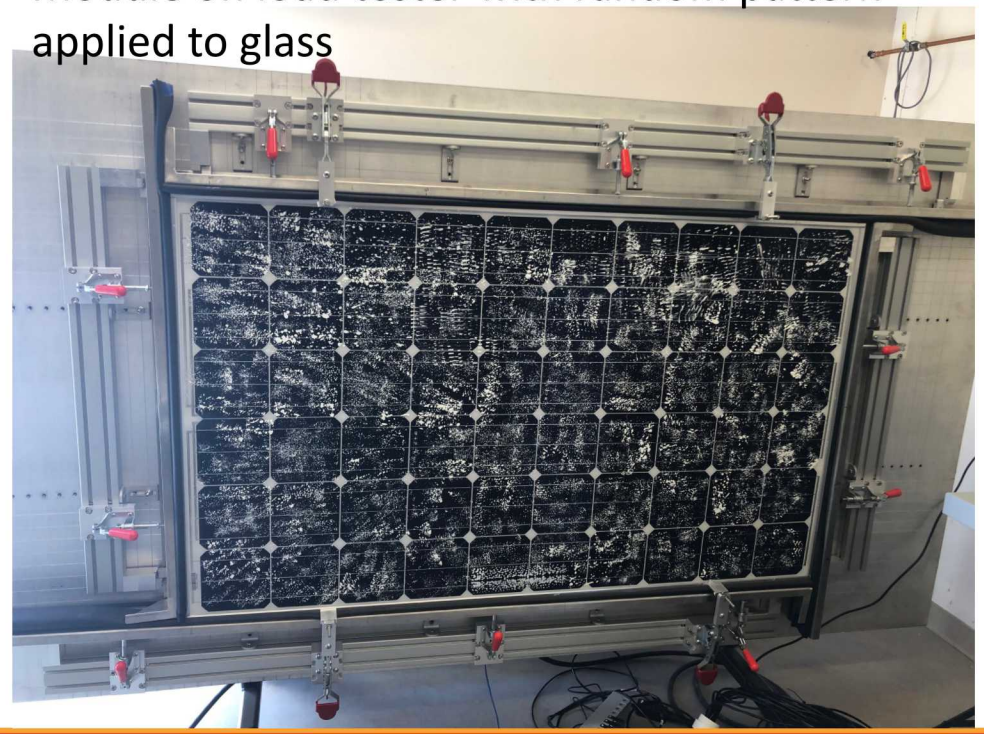
Schedule likely to be affected by COVID-19

Measurement of PV cell crack characteristics in PV modules using digital image correlation

July 2020

Research Highlight: Sandia has made what is thought to be the first full field displacement measurement on a PV module using stereo digital image correlation. Next we will apply a random pattern to PV cells inside a module and use DIC to measure PV crack displacements on a full PV module.

Module on load tester with random pattern applied to glass



Full module displacement from DIC measured at Sandia (-3500 Pa)

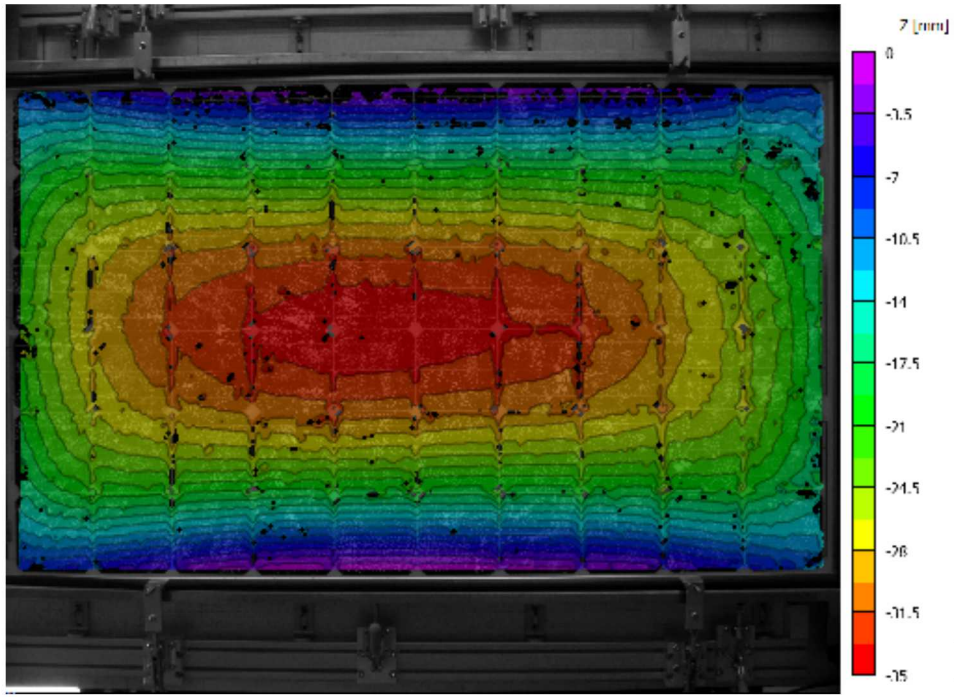
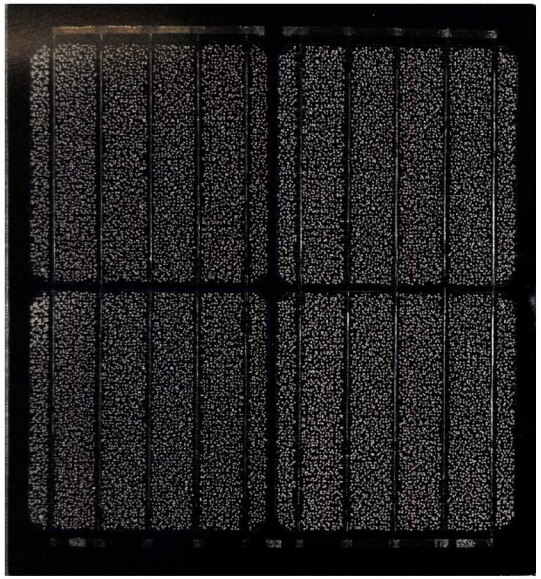


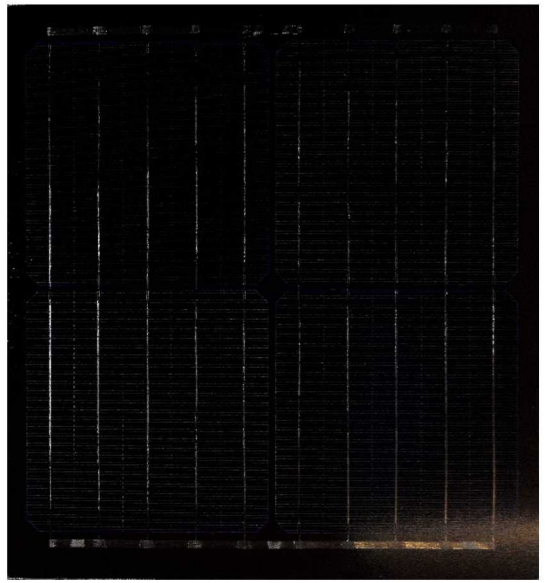
Photo or text credits here

2x2 mini-module test vehicles

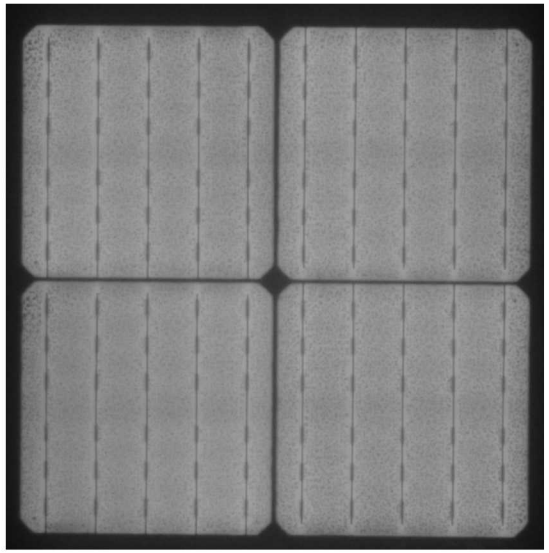
Visible scanned image of 2x2 module (DIC pattern print)



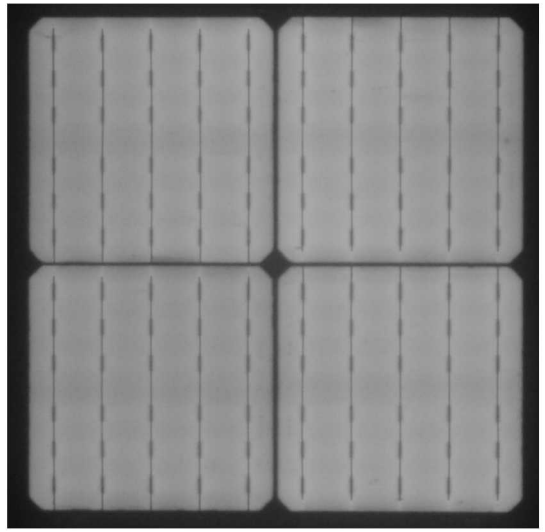
Visible scanned image of 2x2 module (control – no DIC pattern)



EL image of 2x2 module (DIC pattern print)



EL image of 2x2 module (control – no DIC pattern)



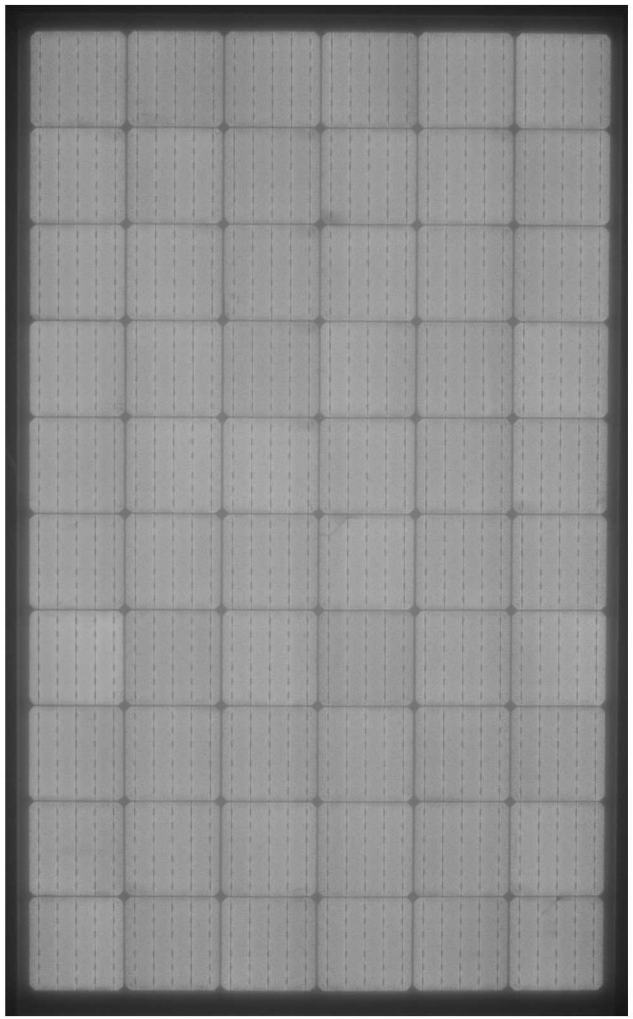
2x2 mini-module was used to test lamination process with screen-printed cells.

We also made sure that EL imaging would work with the painted dot patterns.

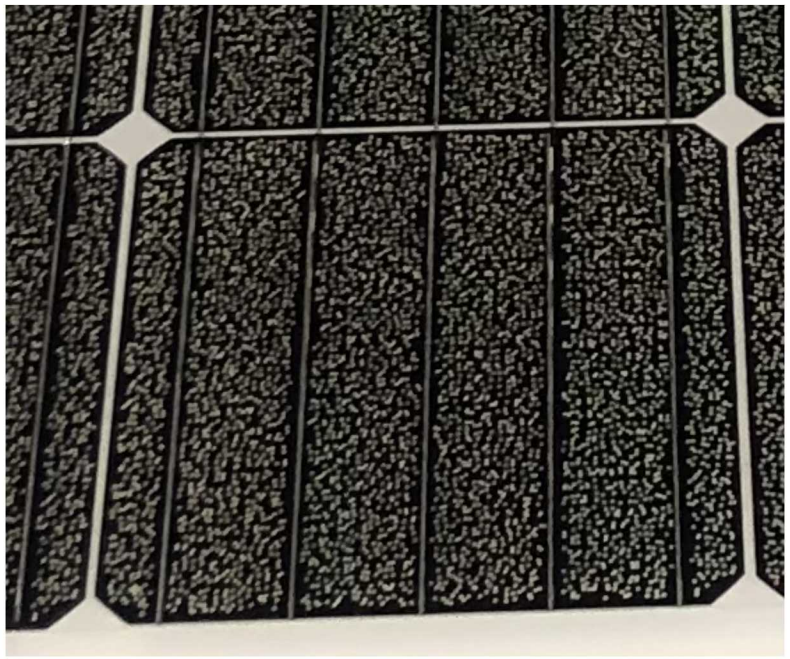
We are also experimenting with black backsheets to improve image contrast.

60 cell module fabrication with 1mm dot print

Visual image of 6x10 module (DIC pattern print)



EL image of 6x10 module (DIC pattern print)



Close-up of dot pattern on full module

Electrical performance comparison

Module ID	Print pattern	Cell Layout	Backsheet color	Isc [A]	Voc [V]	Imp [A]	Vmp [V]	Pmax [W]	FF [%]	pFF [%]	Eff*. [%]
20-0069-001	Control	2x2	Black	9.226	2.705	8.724	2.208	19.26	77.17	83.43	19.7
20-0069-002	1mm DIC	2x2	Black	8.013	2.694	7.619	2.221	16.93	78.37	83.44	17.3
20-0069-003	1mm DIC	6x10	White	8.281	40.38	7.891	33.583	265.00	79.25	83.31	18.1

* Aperture efficiency normalized to cell area

- 1mm DIC print pattern reduces short circuit current by only 13% relative to control module.
- DIC print pattern does not significantly affect EL imagery.
- Full size 6x10 module shows a slightly higher short circuit current (+3%) than the 2x2 modules due to additional light trapping from the white backsheet used.

Quarterly Progress Update

- Q1: Initial proof of concept successfully measured full field module displacements during a dynamic loading test.
- Q1: Contract placed with D2Solar to construct four modules with cells that have been screen printed with random dot patterns.
  - *COVID-19 Impacts: Completion of modules was delayed due to COVID-19 work restrictions in CA.*
- Q2: Minimodule and one full sized module prototype is completed. Three more to be built - We expect delivery in mid October 2020.
- Q3: Once modules are at Sandia, dynamic loading and DIC tests will be performed.
  - *COVID-19 Impacts: Tests currently require several people to be in small room at the same time for extended periods. We are looking into ways to automate the image capture so a single person can run the tests safely.*