

Drone-Based Daylight Electroluminescence Imaging of PV Modules using SWIR Cameras

Electroluminescence (EL) imaging of photovoltaic (PV) solar panels provides high accuracy in detecting defects and faults, such as cracks, broken cells, interconnections, shunts, among many others; furthermore, the EL technique is used extensively due to a high level of detail and direct relationship to injected carrier density.

This technique is commonly practiced only indoors - or outdoors from dusk to dawn - because the crystalline silicon luminescence signal is several orders of magnitude lower than sunlight. This limits the potential of such a powerful technique to be used in utility scale inspections, and therefore, the interest in the development of electrical biasing tools to make outdoor EL imaging truly fast and efficient.



Figure 1: Drone with Raptor 640 SWIR camera

A team at Technical University of Denmark (DTU) lead by Gisele Alves dos Reis Benatto and Peter Behrendorff Poulsen have used a drone-based system capable of acquiring EL images using an Owl 640 SWIR camera, running at a frame rate of 120 frames per second and imaging in the 1125-1175nm range. In a single second during high irradiance conditions, this system

can capture enough EL and background image pairs to create an EL PV module image that has sufficient diagnostic information to identify faults associated with power loss. See Figure 1. Figure 2 highlights the Signal and sensor involved in daylight EL imaging.

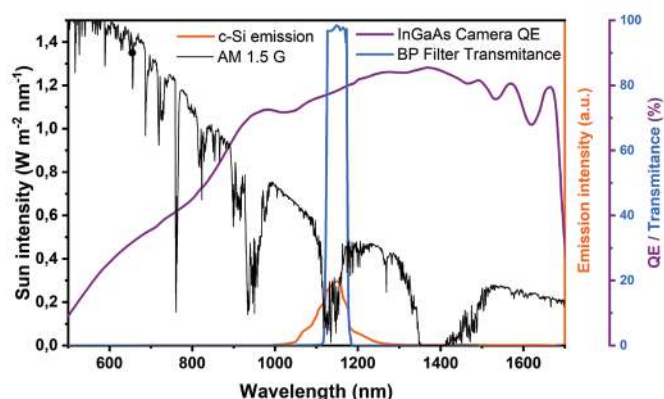
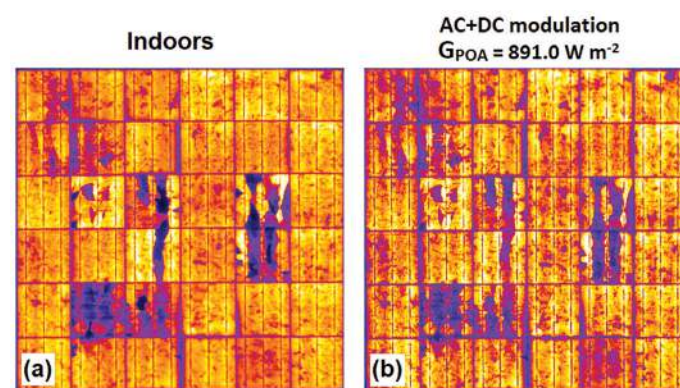


Figure 2: Signal and sensor involved in daylight EL imaging.

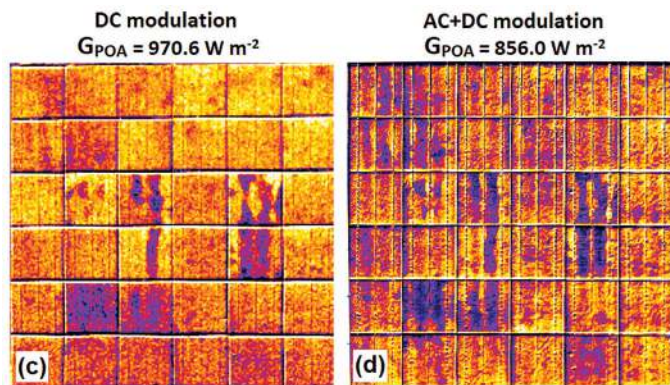
Figure 3i highlights drone based EL images, acquired with global horizontal solar irradiance close to one sun in the plane of the array, where one sun equals 1000 W m^{-2} .



a) stationary and indoors under low light
b) stationary and outdoors in daylight with AC+DC modulation;

Figure 3i: Mechanically stressed PV panel EL images - stationary

It shows images acquired indoors (a) and outdoors from a stationary position (b).



c) in motion and outdoors in daylight with DC modulation

d) in motion and outdoors in daylight with AC+DC modulation

Figure 3ii: Mechanically stressed PV panel EL images - in motion.

When the drone starts to fly overhead, you can see further EL images shown in figure 3ii. It shows images with DC modulation (c) and AC & DC modulation (d). It presents lower quality compared to those obtained indoors and stationary in daylight in figure 3i, but still having sufficient quality to identify the main features related to the module power loss.

With further work on the algorithms, this technique shows much promise. It is an obvious advantage to use a drone to inspect PV modules on a solar farm during daylight hours.

Images and data courtesy of DTU FOTONIK, Department of Photonics Engineering.



Figure 4: Owl 640 S InGaAS camera

- **SWIR technology.** Enables high sensitivity imaging from $0.9\mu\text{m}$ to $1.7\mu\text{m}$
- **High quality sensors.** 99.5% operability, 640×512 $15\mu\text{m}$
- **High Speed Imaging.** Owl 640 S achieves up to 300Hz
- **On-board Automated Gain Control (AGC).** Enables clear video in all light conditions
- **On-board intelligent 3-point NUC.** Enables highest quality images
- **Easy control of camera parameters.** Control of Exposure, Gamma and intelligent AGC
- **Compact and lightweight:** $50 \times 50 \times 74.2\text{mm}$ / 260g
- **Rugged, fanless.** Operation tested up to 2.3 teslas.

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