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Alpha-Prototype Outdoor Photoluminescence Imaging Tool for Solar Module Field Testing

Oliver Kunz[1], Germain Rey[1], Raghavi Bhoopathy[1], Mattias K. Juhl[1], Rhett Evans[1], Ziv Hameiri[1] and Thorsten Trupke[1]

[1]*University of New South Wales Sydney, Kensington, NSW 2052, Australia*

Over the last decade we have seen a dramatic increase in utility scale photovoltaic (PV) deployment [1] that has been driven by an extraordinary solar module cost reduction [2], [3]. Utility scale PV systems are now approaching GW size and can contain millions of individual PV modules [4]. It is important to note that most utility scale systems have been installed in *recent* years and hence, their long-term field performance is, as of yet, unknown [5].
Photoluminescence (PL) imaging [6] has been vital for this breath-taking development, since it provides a direct visual and spatially resolved measure of material and device quality and can be used throughout the entire solar manufacturing chain [7], [8]. The only place where PL imaging has not been widely applied in the PV value chain is imaging of field deployed solar modules; mainly due to the very strong ambient sunlight [9]. Nevertheless, development of outdoor PL imaging is highly desirable and allows closing the quality control loop in the PV value chain.

We have recently developed a technique that allows PL imaging of field-deployed solar modules without needing to interfere with the electrical wiring of the system [9], [10]. The technology allows examination of performance limiting faults in solar modules after installation and throughout the lifetime of solar power plants. It can also be useful in identifying latent faults at a stage where they are not yet performance limiting. This is not easily done with other used technologies, such as thermal infrared imaging thermography [11]. Apart from assessing failures in solar power plants and mitigating the associated risk, our technology is also useful in advising the industry on future technology directions.

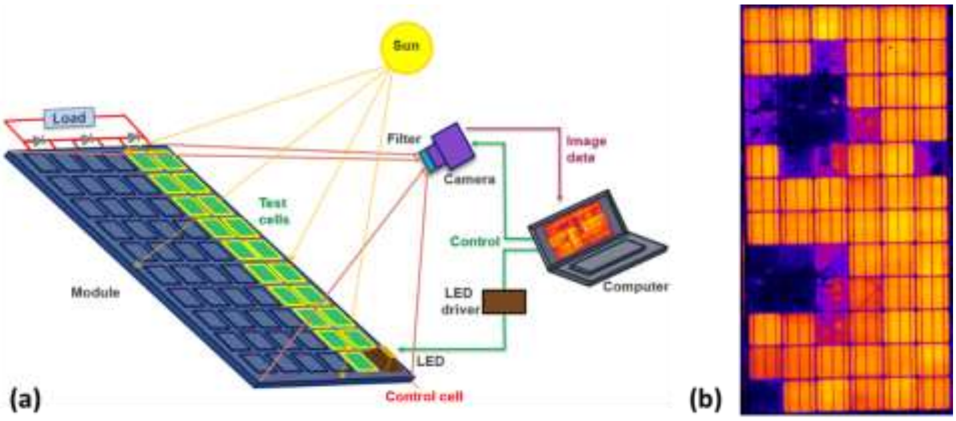

Figure 1. (a) Schematic of outdoor PL system utilising optical modulation via a high-power LED array; (b) outdoor PL image of a 72 cell silicon PV module.

Our technology is schematically depicted in Figure 1(a) and comprises an near-infrared (Indium-Gallium-Arsenide) camera with a suitable optical filtering, an optical modulator [termed "LED" in Figure 1(a)], drive electronics and a computer for image capture and processing. The imaged module can be part of a field installation and the ambient sunlight is used as the sole illumination source to excite the electronic charge carriers that subsequently produce the PL signal. A narrow optical bandpass filter centred around the peak wavelength of silicon PL emission is vital for this approach, since otherwise the very strong ambient sunlight prohibits taking outdoor PL images.

The used filter has a bandwidth of 25 nm with a centre wavelength of 1135 nm. It is noteworthy that this technology only works due to the fortunate fact that a strong dip in the sun spectra exists in the same wavelength region (due to water vapour absorption) which very strongly limits the exposure of the camera to diffusely reflected sunlight from the solar module.

A critical key feature of this technology is the use of optical modulation of the modules, i.e. the solar cells of the module are toggled from a high current extraction state (usually around maximum power point) to a low current extraction state (usually close to open-circuit condition) by either exposing one or more test cells in the module to high power illumination or by shading them, respectively. As such, no access to the solar module terminals is needed and any module in a solar power plant can conveniently and rapidly be imaged without needing to interfere with solar power plant wiring. A PL image taken with this technique of a highly defective module under full sunlight is displayed in Figure 1(b). The image is of sufficient quality to show all significant electronic defects down to individual cell cracks. For this image, to capture the entire module, the optical modulator had to be moved several times which is unacceptable for inspection of higher volumes of solar modules.

To use this technology routinely in solar power plants, it is required that a system is built that is robust, independent and that can move easily through the rows of a large-scale PV installation. Software integration is needed such that images can be taken with the push of a button, just like with a mobile phone camera. Therefore, we are currently building an alpha prototype commercial system that enables fast and convenient capture of outdoor PL images. A snapshot of the current system is shown in Figure 2(a). The picture shows the robust frame to which all necessary electronic components are attached, except for the optical modulator (see red light on module), it is fully battery powered and does not require mains power. Note that the final version of this prototype will have an optical modulator that fully covers one row of six cells such that only two images are required to capture the entire module.

We are currently in the final stages of the tool building phase and expect to have initial field-testing results available by the time of the conference. At the conference we will present the developed technology, the design consideration of the alpha-prototype tool and early results from solar farm field testing. We expect that this technology, once used routinely and at scale, can provide helpful insights into solar power plant field performance. It is also expected that this diagnostic tool can provide fast and reliable information to the PV industry regarding the field performance of newly developed technologies, such as bifacial, half-cell, shingled and novel high efficiency modules [12].

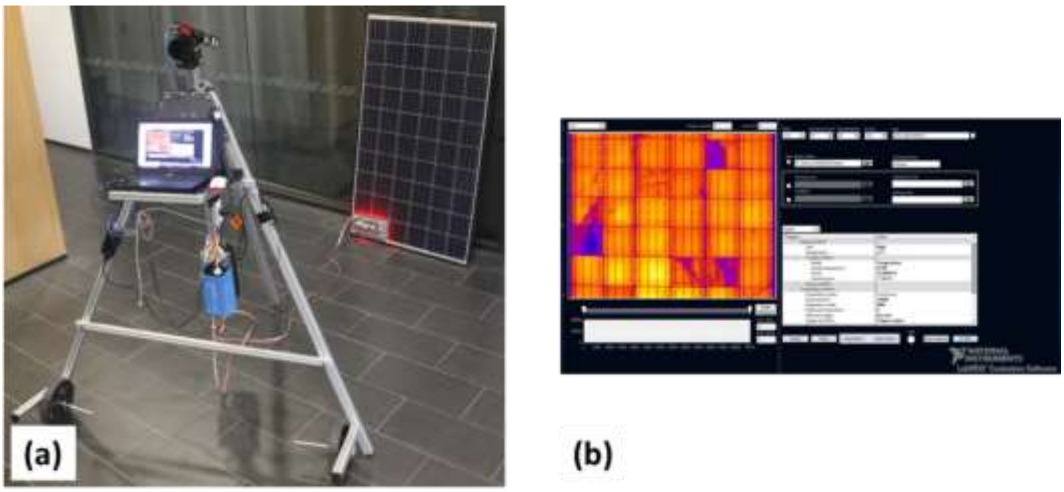

Figure 2. (a) Alpha prototype outdoor PL tool; (b) screenshot of software used to capture and analyse the images and control the optical modulator.

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