SOLAR CELL INSPECTION WITH RAPTOR PHOTONICS' OWL (SWIR) AND FALCON (EMCCD)

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Solar cell inspection relies on imaging the photoluminescence or electroluminescence signals from a wafer to characterize it. The peak emission for Silicon occurs at about 1150nm while it is around 1330nm for Copper Indium Gallium di-Selenide (CIGS) and Copper Indium di-Selenide (CIS).

This value is out of the range of sensitivity for Silicon based detectors, such as CCDs, and traditionally their quantum efficiency is only measured up to 1000nm. However, the emission peak is actually broad enough to allow deep cooled CCD to capture meaningful images using very long integration times (typically minutes). Although interesting, this is insufficient and unpractical for industrial applications.

Alternatively, shortwave infrared (SWIR) InGaAs technology is ideal to directly detect the electroluminescence emitted at 1.3µm by solar cells and ensure their quick characterization (within milliseconds) either during manufacturing or for pre-emptive maintenance operation of a photovoltaic plan.

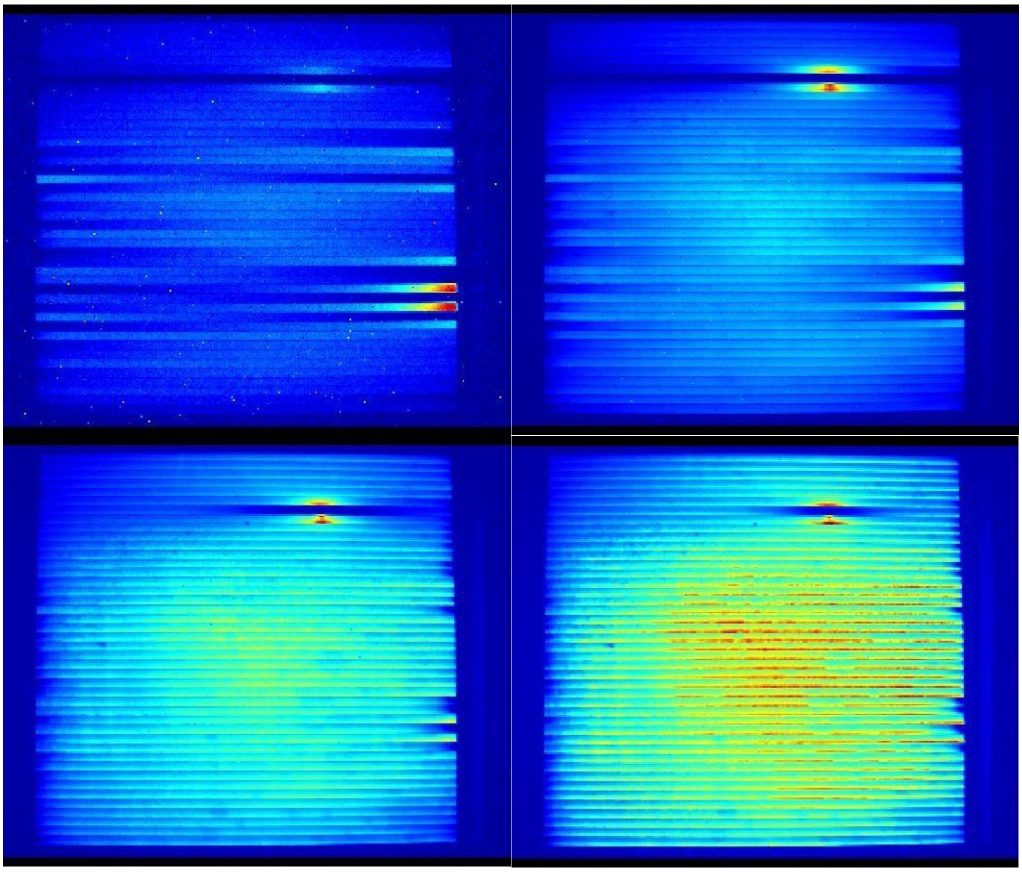

Figure 1: Owl, SWIR imaging of CIGS from 30mA to 620mA and 50ms to 4ms exposure times.

However, SWIR camera offer low field of view and low resolution, 320x256 pixels of 30µm and can be an expensive proposition.
EMCCDs offer an interesting solution by combining larger field of view and resolution, 1004x1002 pixels of 8µm, for a better cost than SWIR.
Making use of its high sensitivity in the near infrared (NIR) an EMCCD is capable of detecting the edge of the electroluminescence signal with exposure times short enough to achieve over 10fps.

Figure 1 and Figure 2 show the same solar cells under similar bias current imaged by a SWIR or an EMCCD camera. The defects are clearly visible using both cameras.

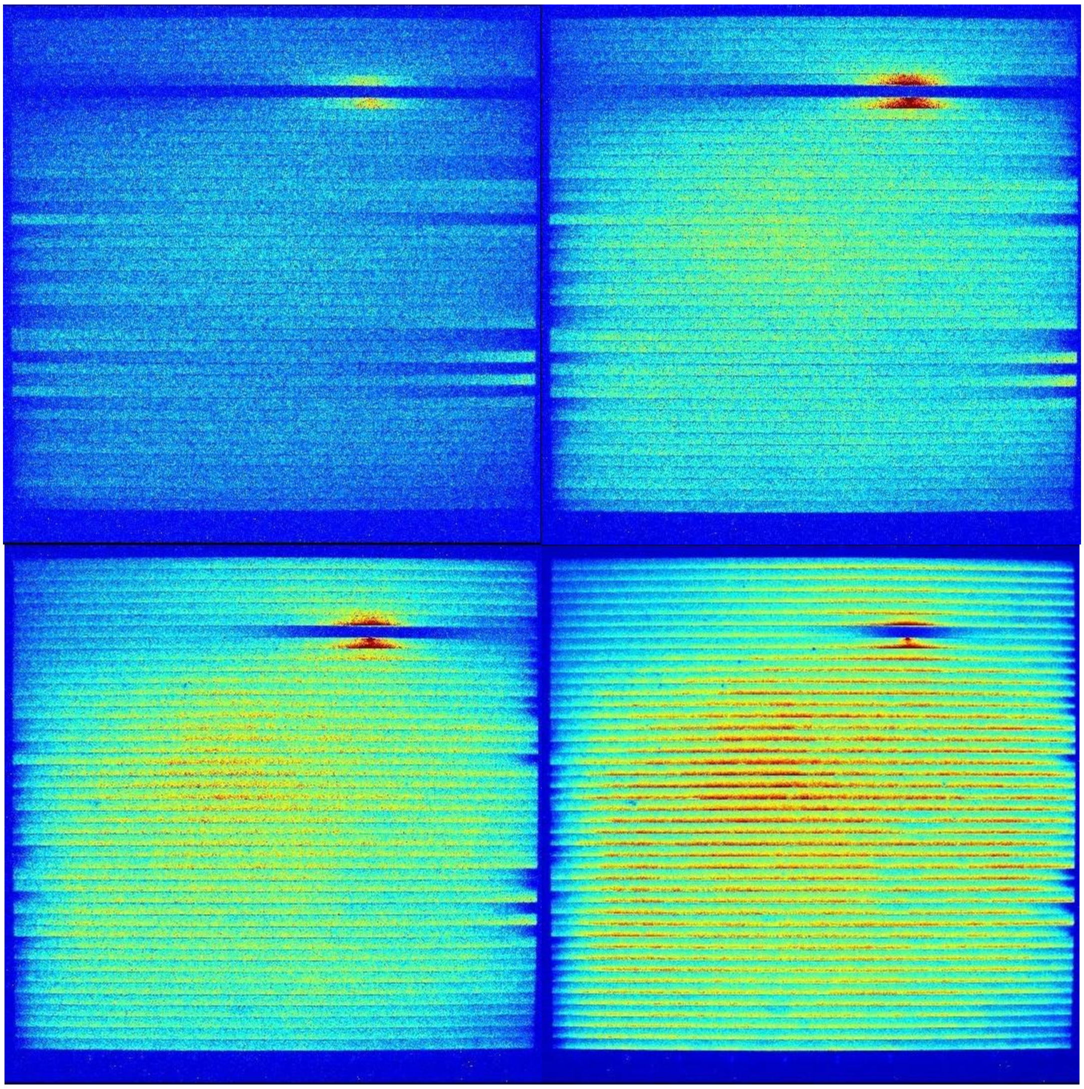

Figure 2: Falcon, EMCCD imaging of CIGS from 80mA to 600mA and 500ms to 300ms exposure times.

Another application of solar cell electroluminescence beside cell characterization during manufacturing consists in the pre-emptive maintenance of an existing photovoltaic power plant. This requires being able to quickly identify the solar panels with defective solar cells which are responsible for reducing the overall efficiency.

In this case, a large range of panels are driven under reverse bias and quickly scanned by either camera, SWIR or EMCCD, in video mode. The cells which are either damaged or operating at lower efficiency immediately appear allowing the identification of the panels which should be replaced in order to restore the overall efficiency.

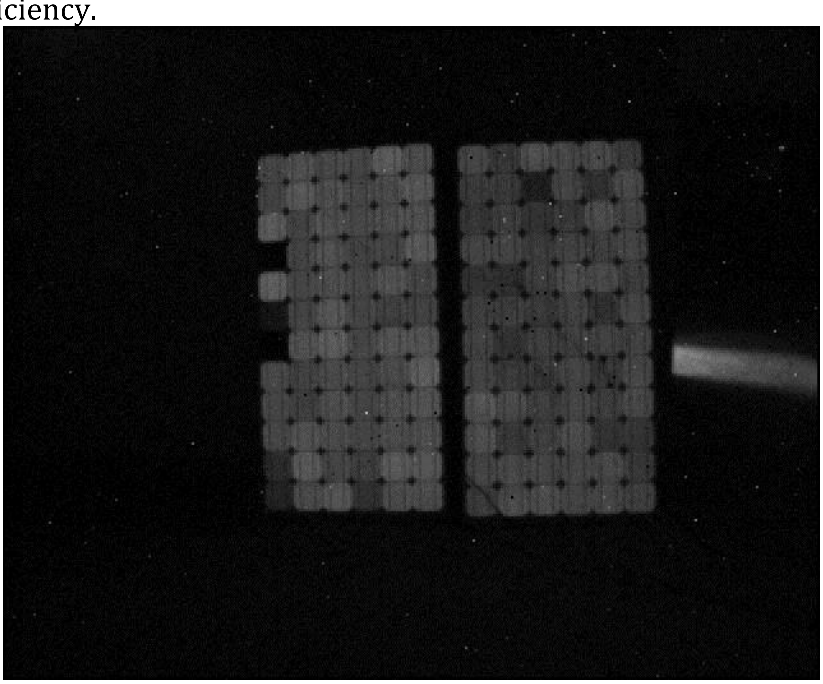

Figure 3: Owl, SWIR video of solar panels with variable current at 30 fps. The defective cells are clearly visible.

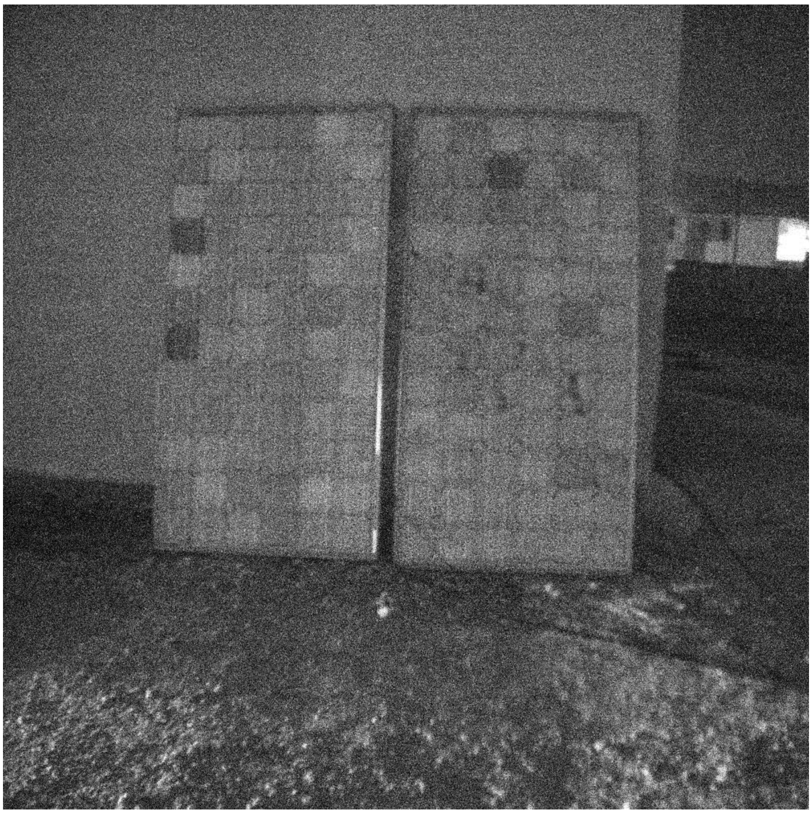

Figure 4: Falcon, NIR video of the same solar panels with variable currents at 20 fps. Again the defective cells are clearly visible. Contrast could be improved using a visible filter.

In conclusion, both technologies, SWIR and EMCCD work well for the characterization of solar cells. They offer a choice of solutions to suit a range of applications and customer's requirements:
SWIR allows for the fastest imaging albeit with a limited resolution and at a higher cost, while EMCCD offers higher resolution and better cost alternative at a more limited frame rate.

Figure 5: Falcon EMCCD camera

- **1004 x 1002 EMCCD sensor.** Enables optimum image resolution in low light imaging applications
- **B/W EMCCD technology.** Enables high sensitivity imaging with up to 1000x on-chip gain
- **16 bit CameraLink output.** Provides wide dynamic range
- **65% QE from Virtual Phase sensor.** Optimum Photon collection
- **No Image intensifier.** Optimum B/W image sharpness in ALL light conditions
- **Full Frame Transfer.** No mechanical shutter required, vibration-less CCD readout
- **Realtime Imaging.** Optimum image sharpness in ALL light conditions
- **XCAP software compatible.** Ready-to-Run powerful Image Analysis Software

Figure 6: Owl InGaAS camera

- **SWIR technology.** Enables high sensitivity imaging from 0.9mm to 1.7mm
- **Optional Visible extention.** Enables high sensitivity imaging from 0.4mm to 1.7mm
- **14 bit CameraLink output.** Enables high speed digital video with inteligent auto AGC
- **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.** Enables control of Exposure, Gamma and intelligent AGC
- **500ns minimum exposure.** Ideal for active imaging applications
- **Ultra compact, Low power (< 5W).** Ideal for hand-held, mobile or airborne systems
- **Rugged, No fan.** Enables integration into UAV, handheld or any Electro-Optic systems

About Raptor Photonics

Raptor Photonics Limited is a global leader and manufacturer of high performance, industrial-grade and extremely rugged ultra-low light digital & analogue cameras. Raptor specializes in complete cameras and core engine solutions using CCD, EMCCD, Scientific CMOS and SWIR sensor technology. The extreme low light capability of Raptor's cameras makes them ideal for day/night surveillance, homeland security and scientific markets. Raptor Photonics Ltd is a registered ISO 9001:2008 company and is headquartered in Larne, Northern Ireland.

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