On the reliability of the spectral response of photovoltaic modules using bias and modulated light

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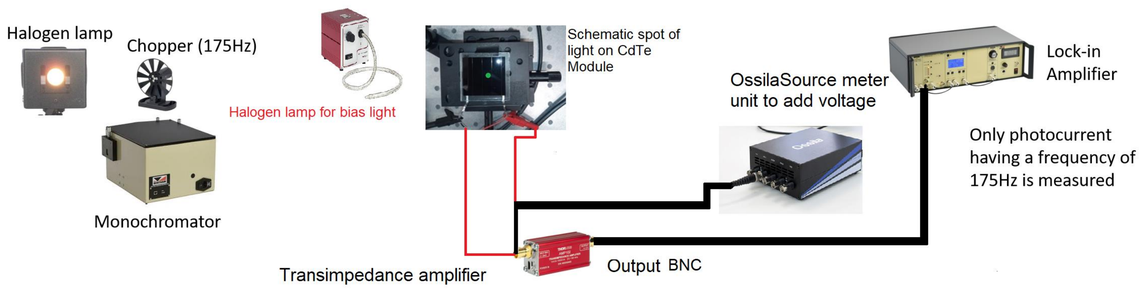
Introduction

External quantum efficiency (EQE) is the ratio between the number of electrical charges contributing to photocurrent to the number of photons of a given wavelength send to the photovoltaic cell. Tiny single cells using different promising materials measure EQE in a laboratory using monochromator and the methodology is very well stablished[1]. In large-area photovoltaic module the procedure to determine the EQE is not straightforward because first, there is no steady-state high intensity monochromatic light source available for full-area module illumination, and secondly, the adjacent cells could affect the photocurrent[1-3].

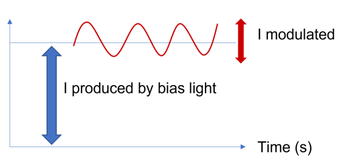
Our objective is exploring new methodologies to determine the spectral response of minimodules of few centimeters as a whole, cheap and easy to implement.

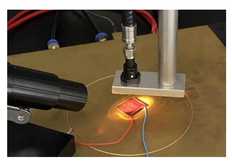
Methodology I

➢ Methodology implementing bias light and DC applied voltage.



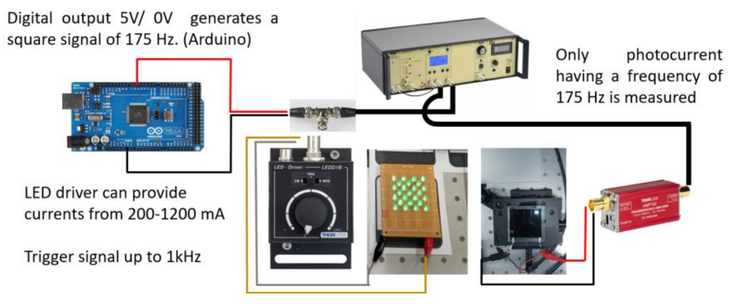
➢ A DC voltage it is necessary to compensate the DC current.



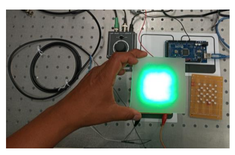


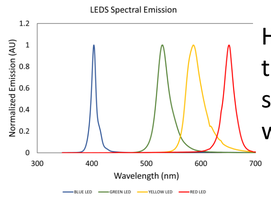
Methodology II

➢ Halogen lamp and Monochromator is replaced by LED array connected in parallel. 25 single LEDS.



➢ Digital square signal (Arduino) offers more stability than mechanical signal (Chopper).





High stability of the LEDs after several minutes working

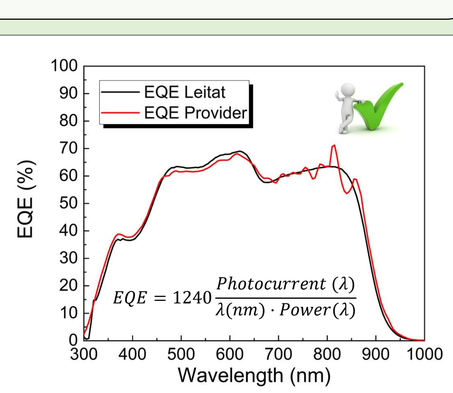
➢ Diffuser is placed 1 cm from the surface of the module in order to homogenize the light arriving to the device.

$$EQE^{*}=1240/\lambda\ (I_{mod}/A_{mod})/(Power/A_{sc})*100\%$$

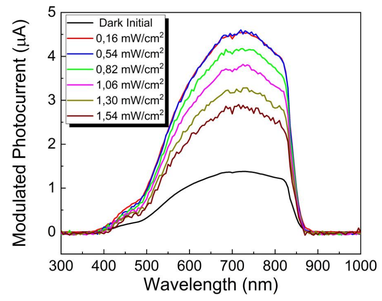
A_{mod}: area of PV minimodule. A_{sc}: area of a calibrated silicon cell.

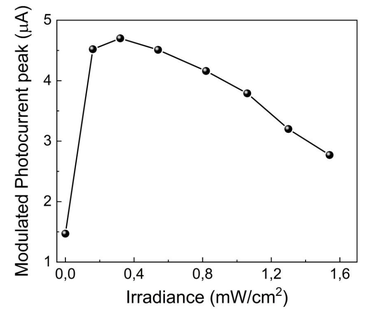
Results

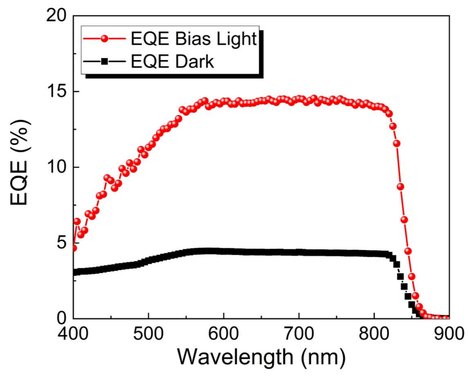
➢ EQE validation: Reference small cell‡ was tested for to validate the setup. Features around 800 nm (red curve) comes from the xenon lamp.



➢ CdTe module: maximum response of the spectrum at low level bias illumination.



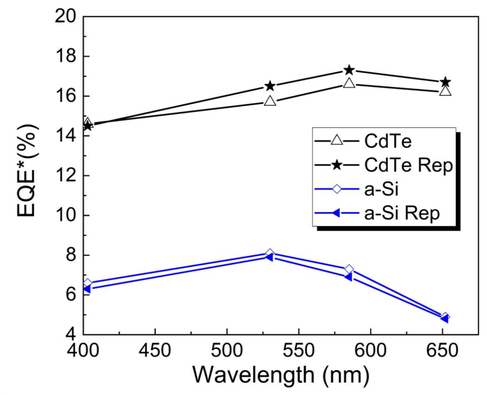


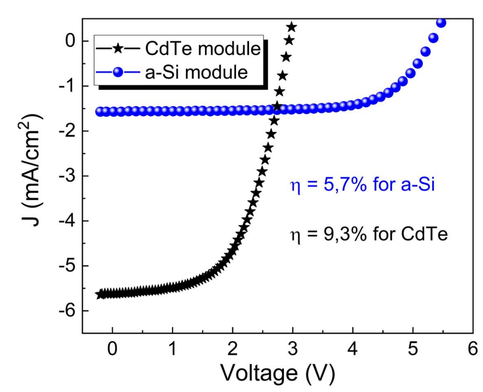


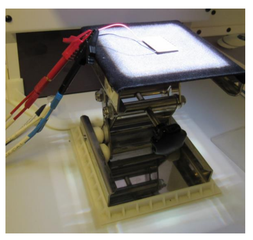
➢ External Quantum efficiency (EQE) of CdTe modules presents higher response when illuminated with bias light (halogen lamp).

➢ EQE by LEDs (EQE*) are reproduceable.

➢ IV curves under 1 sun of simulation do not show big differences in conversion efficiencies of the modules (η) in spite of the difference in PV technologies.







PV module under solar simulator.

Conclusions

When measuring EQE of a few centimeters large PV module using the standard procedure validated for single cells, results vary depending on the position where the spot of monochromatic light hits, and they are bias light and bias voltage dependent. To overcome this, a method to determine spectral response of PV minimodules has been presented. This method is sampling independent and has high reproducibility. Single cell EQE values are not achieved, but it allows for reliable relative characterization of spectral response on cells undergoing improvement processes such as deposition of Luminescent Down Shifting Layers.

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This project is founded by the European Union's Horizon 2020 RIA program, according to the Grant Agreement Nº 815271.
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References

[1] *Non-Intrusive Cell Quantum Efficiency measurements of accelerated Stress Tested Photovoltaic modules*. B. Knisely et al. IEEE Photovoltaic Specialist Conference (2014).
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