

## Solar Cells Reporting Summary

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### ► Experimental design

#### Please check: are the following details reported in the manuscript?

##### 1. Dimensions

|                                          |                                                                        |         |
|------------------------------------------|------------------------------------------------------------------------|---------|
| Area of the tested solar cells           | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Methods |
| Method used to determine the device area | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Methods |

##### 2. Current-voltage characterization

|                                                                                                                                                                                |                                                                        |                                                                                                                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Current density-voltage (J-V) plots in both forward and backward direction                                                                                                     | <input type="checkbox"/> Yes<br><input checked="" type="checkbox"/> No | A more accurate method (quasi-steady-state (QSS) I-V sweep) was used. 10 voltage points were collected in the QSS measurement, with each bias voltage applied and held until the measured current stabilized (Supplementary Fig. 10). |
| Voltage scan conditions<br><i>For instance: scan direction, speed, dwell times</i>                                                                                             | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Methods                                                                                                                                                                                                                               |
| Test environment<br><i>For instance: characterization temperature, in air or in glove box</i>                                                                                  | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Methods                                                                                                                                                                                                                               |
| Protocol for preconditioning of the device before its characterization                                                                                                         | <input type="checkbox"/> Yes<br><input checked="" type="checkbox"/> No | Methods                                                                                                                                                                                                                               |
| Stability of the J-V characteristic<br><i>Verified with time evolution of the maximum power point or with the photocurrent at maximum power point; see ref. 7 for details.</i> | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | A more accurate method (quasi-steady-state (QSS) I-V sweep) was used. 10 voltage points were collected in the QSS measurement, with each bias voltage applied and held until the measured current stabilized (Supplementary Fig. 10). |

##### 3. Hysteresis or any other unusual behaviour

|                                                                           |                                                                        |                                                       |
|---------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------------------------------------|
| Description of the unusual behaviour observed during the characterization | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Negligible hysteresis was found.                      |
| Related experimental data                                                 | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Newport certification report in Supplementary Fig. 10 |

##### 4. Efficiency

|                                                                                                                                 |                                                                        |                                                                                                                                              |
|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| External quantum efficiency (EQE) or incident photons to current efficiency (IPCE)                                              | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Supplementary Fig. 10                                                                                                                        |
| A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | The integrated JSC from EQE spectra is consistent with the JSC from J-V measurements as certified by Newport PV Lab (Supplementary Fig. 10). |
| For tandem solar cells, the bias illumination and bias voltage used for each subcell                                            | <input type="checkbox"/> Yes<br><input checked="" type="checkbox"/> No | Not relevant                                                                                                                                 |

##### 5. Calibration

|                                                                         |                                                                        |         |
|-------------------------------------------------------------------------|------------------------------------------------------------------------|---------|
| Light source and reference cell or sensor used for the characterization | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Methods |
| Confirmation that the reference cell was calibrated and certified       | <input checked="" type="checkbox"/> Yes<br><input type="checkbox"/> No | Methods |

Calculation of spectral mismatch between the reference cell and the devices under test

☒ Yes  
☐ No

It has been calibrated.

## 6. Mask/aperture

Size of the mask/aperture used during testing

☒ Yes  
☐ No

Methods

Variation of the measured short-circuit current density with the mask/aperture area

☐ Yes  
☒ No

Newport certification report in Supplementary Fig. 9 and Supplementary Fig. 10

## 7. Performance certification

Identity of the independent certification laboratory that confirmed the photovoltaic performance

☒ Yes  
☐ No

Certified by Newport PV Lab

A copy of any certificate(s)

*Provide in Supplementary Information*

☒ Yes  
☐ No

Newport certification report in Supplementary Fig. 9

## 8. Statistics

Number of solar cells tested

☒ Yes  
☐ No

At least 100 devices were tested (Fig. 2).

Statistical analysis of the device performance

☒ Yes  
☐ No

Figure 2

## 9. Long-term stability analysis

Type of analysis, bias conditions and environmental conditions

*For instance: illumination type, temperature, atmosphere humidity, encapsulation method, preconditioning temperature*

☒ Yes  
☐ No

Figure 6