Specifications for **integrated IPCE (Incident photon to current efficiency)**

The system should consist of the following:

1. Solar Simulator
2. IV Measurement system
3. QE measurement system

General specification:

1. The system should be fully integrated and enclosed for dust proof, safe operation and dark measurement.
2. The system should have continuous irradiance monitoring via a fiber coupled and temperature compensated photoreceiver.
3. The system should have collimated (parallel - sun like) light output ($\leq \pm 1°$) to avoid shadowing from the top contacts.
4. The system should have corrections for irradiance fluctuations according to IEC 60891.
5. The system should have reduced dependency of uniformity & intensity from working distance.
6. Solar cell current, solar cell voltage, solar simulator irradiance and sample temperature should be measured simultaneously with a max. channel-to-channel delay of 25 ns.
7. The system should have simple lamp replacement (exchanging integrated lamp, reflector & heat sink modules) with no need for realignment.
8. The system should have Non-reflective black finish of sample holder for reducing stray light.
9. The electronic loads should also be used for voltage biasing of solar cell during QE measurement.
10. The system should have various interlocks & sensors ensure operator safety.
11. The contact mechanism should be usable for both QE and Solar simulator IV measurement system
12. The system should have modular sample holder & contacting adapter design.
13. The system should have safety compliance should be according to ISO.
14. The system should be fully software controlled
15. The system should be field upgradeable to the following option variable intensity (0 to 100%), flash measurement capabilities, internal QE.
16. The system should come with integrated PC (with operating system and software).
17. All pre installation requirements (table size, power supply etc.) should be clearly mentioned in the quotation.
18. Soft and hard copy of the manual should be provided with the instrument.
19. Minimum one year warranty of the instrument including all the parts should be provided from the date of installation.
20. Test report of the instrument should be provided.
21. Service should be available in India after sales.

22. Free installation training session to be done at IIT Madras.

Solar Simulator:

1. Light source: continuous steady 500 W xenon light source (ozone-free).
2. Life time of light source should be at least 1000 hours.
3. Maximum illuminated area should be 100 mm x 100 mm (vertical illumination).
4. Instability: temporal long-term instability and short-term instability should be < ±2% and < ±0.5% respectively.
5. Simulator should be a class AAA (according to IEC & ASTM E 927).
6. Collimation angle must be ≤ ± 1°.
7. Lamp shutter can be operated by both manually and automatically.
8. Lamp current measurement meter should be provided for monitoring and controlling lamp current.
9. Data like current, voltage, solar simulator irradiance and sample temperature should be taken simultaneously (< 25 ns).
10. The system should have continuous irradiance monitoring and corrections for irradiance fluctuations according to IEC 60891.
11. Light isolation box for sample loading and unloading.

I-V measurement:

1. Voltage range: 0.4 milivolt to 40 V (resolution < 400 µV)
2. Current range: 0.2 microampere to 4A (resolution ≤ 200 nA)
3. I-V measurement should be fully automated.
4. The electronic loads should also be used for voltage biasing of solar cell during QE measurement.
5. I-V measurement & control software.

Sample holder:

1. Solid brass sample holder should compatible with different sample sizes of 20 x 20 mm^2, 30 x 30 mm^2, 40 x 40 mm^2, 50 x 50 mm^2, and 100 x 100 mm^2 solar Cells.
2. One probe tip for voltage sensing in center (needle type).
3. One spring loaded temperature sensor (PT100).
4. Current can be drawn via entire sample holder surface or one single probe tip.
5. Separate vacuum channels for each cell size
6. Sample holder should have temperature variation in the range of 10 – 50 ^oC.
7. Temperature instability: < ± 0.1°C

8. The same holder should be usable for both solar simulator and QE measurement.
9. The temperature measurement should be fully software controlled.
10. The temperature control should be used for both QE and solar simulator I-V.

Contact mechanism:

1. 2 x Micropositioner with magnetic base and adjustable extension.
2. Adjustable probe tip height / contact pressure.
3. Equipped with Accuprobe Kelvin probes tips enabling 4 - point contacting
4. Black powder-coated steel cover plate serving as magnetizable base plate
5. 2 x replacement probe tips
6. Allows for contacting of samples in substrate configuration with contacts on illuminated side

Vacuum sample holding:

1. Integrated Vacuum pump for vacuum fixation of samples.
2. All necessary hoses & quick-connects for vacuum.

Quantum efficiency inbuilt in the system:

1. System should be able to determine external quantum efficiencies.
2. Additional lamp and optics for spectral illumination.
3. Dual source illumination unit with automated switching (halogen & xenon lamp).
4. Grating monochromator with at least 3 gratings.
5. Source wavelength: 300 – 1800 nm with resolution: 0.5 nm and step size: 0.1 nm.
6. Focal length: 180 to 200 mm.
7. Two Dual-Phase Lock-Ins for simultaneous measurement of sample and monitor detector
    a. 0.7 µV/°C DC-Drift.
    b. Frequency Range: 1 mHz – 250 kHz.
    c. Synchronized with output signal of chopper.
    d. Fully software-programmable.
8. Sample measurement data corrected by monitor detector data
9. Si & InGaAs based reference detector (300-1800 nm).
10. Rotating wheel-based optical chopper with frequency Range 1-1000 Hz.
11. Current Pre-Amplifier
    - Variable gain: 10^3 – 10 V/A
    - Switchable AC/DC mode
    - Bandwith DC – 100kHz 11
    - Equivalent input current noise: 2 pA/vHz.
    - Fully software-programmable

- Current range and voltage bias range same as I-V measurement system.

Multi-crystalline silicon WPVS reference cell:

1. 2 x 2 cm² polycrystalline Si solar cell encapsulated in black anodized housing with protective quartz window and two LEMO connectors (I-V & temperature) according to WPVS standard.
2. Calibrated for the following characteristics (including calibration certificate):
    a. Illuminated I-V Curve (Isc, Impp, Voc, Vmpp, Pmpp, FF, Efficiency)
    b. External Quantum Efficiency
    c. Spectral mismatch factor
3. The reference cell should be used for calibrating both QE and Solar simulator I-V measurement.

Software:

1. Software for illuminated I-V curve, dark I-V curve and reverse breakdown characteristic should be available.
2. Analysis and correction capabilities for following parameters: Voc, Isc, FF, Efficiency, Vmpp, Impp, Pmax, Rs, Rsh.
3. Corrections for temperature & irradiance fluctuations according to IEC 60891.
4. Fitting of data to one diode model.
5. Data points per measurement: 1 - 10000
6. Reference cell database
7. Following user inputs should be available:
   Device name, cell area, scan speed & direction, voltage range, number of data points, comment.
8. Ability to perform hysteresis sweeps and start or stop at Voc
9. Corrections for irradiance fluctuations according to IEC 60891
10. Software-programmable readjustment of solar simulator irradiance either continuously or before each IV measurement to ensure long-term stability.
11. Continuous irradiance stabilization by real-time closed-loop feedback control
12. Temperature dependent I-V measurements.
13. Automated and software controlled temperature scans with programmable temperature set-points.
14. Automated determination of temperature coefficients
    α (Isc), ß (Voc), γ (Pmax).
15. Temperature dependent determination of all solar cell parameters
16. Relative and quasi-absolute EQE.
17. Mutual calibration of I-V and EQE measurements via spectral mismatch calculation (absolute EQE required).