



# Technical Specification and Performance Data

## Perovskite Solar Simulator XES-50S3-PSC

### 1. Product Overview

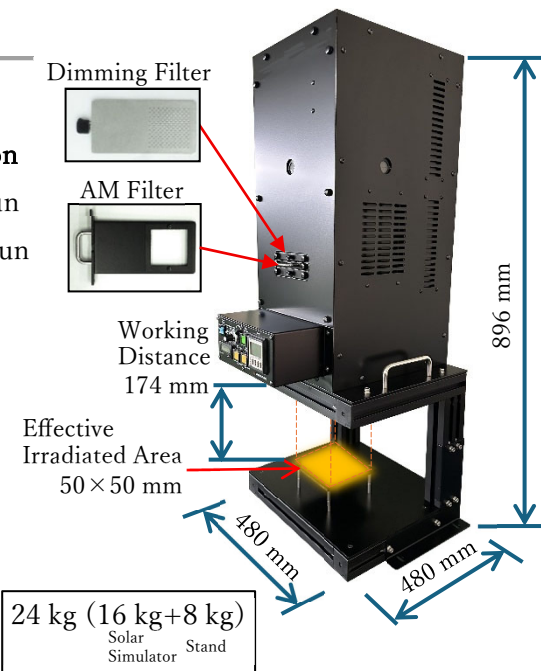
This system is a solar simulator designed for the research and evaluation of perovskite solar cells. Perovskite materials are highly sensitive to irradiance intensity, spectral distribution, and thermal load.

This system is designed to control these factors appropriately and provide a highly reproducible measurement environment.

### 2. Key Features

#### 2.1 Optimized Light Control for Perovskite Evaluation

- Wide irradiance adjustment range: 0.1–1.2 sun
- Maximum initial irradiance capability:  $\geq 1.4$  sun
- Estimated duration for maintaining 1 sun irradiance:  $\geq 3000$  hours
- Continuous and reproducible control from high to low irradiance
- Rapid stabilization to the target irradiance after adjustment



#### 2.2 High Stability in the Low Irradiance Region

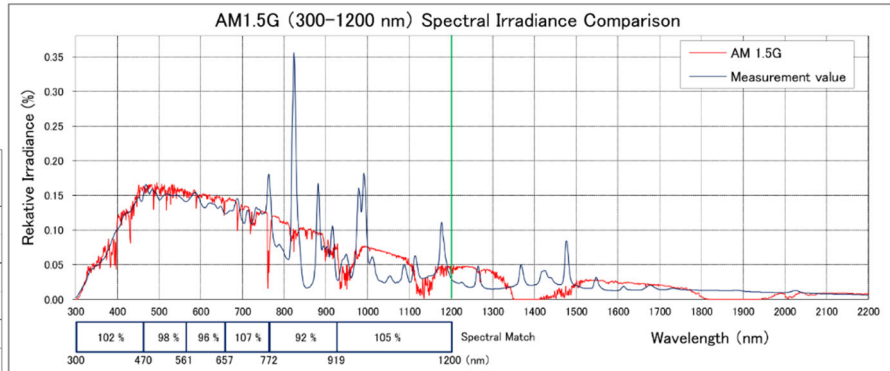
- Verified by measurement at 0.06 sun (approx.  $59 \text{ W/m}^2$ ) (see Section 12)
- Stability confirmed by 24-hour continuous and 6-hour intermittent measurements
- Short-Term Instability (STI):  $\leq 0.25\%$  (IEC Class A+ equivalent)
- Long-Term Instability (LTI): within  $\pm 1\%$  (1-hour evaluation, IEC Class A+ equivalent)
- Measured values are below the specified limits (e.g., STI: 0.10%, LTI: 0.35%)
- In the stable region (after approx. 14 hours), drift is negligible (within measurement resolution)
- The main/sub pyranometer ratio remains constant, indicating that observed variations are due to pyranometer temperature characteristics

## 2.3 Selectable Spectral Characteristics According to Application

### Standard Type

- 300–1200 nm: within  $\pm 12.5\%$  (IEC Class A+)  
→ Suitable for general photovoltaic evaluation

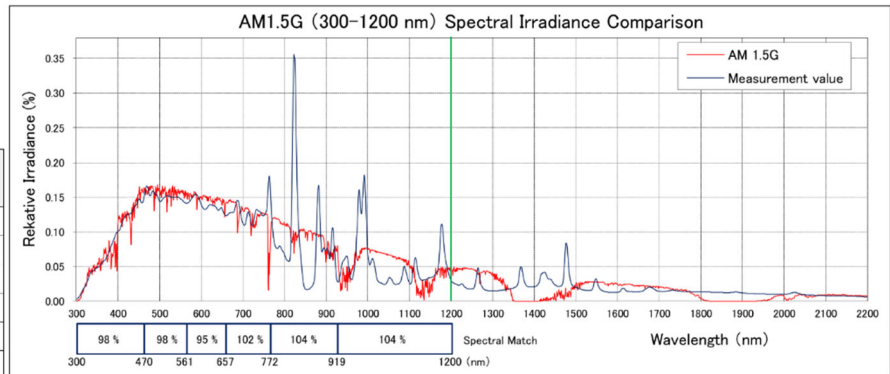
WaveLength (nm)	Spectral Match (%)	Class
300-470	101.8%	A++
470-561	98.1%	A++
561-657	96.4%	A++
657-772	106.6%	A++
772-919	92.4%	A+
919-1200	104.7%	A++



### High Spectral Match Type (Option A)

- 300–1200 nm: within  $\pm 7.5\%$  (SAN-EI Class A++)  
→ Higher spectral fidelity beyond IEC standards

WaveLength (nm)	Spectral Match (%)	Class
300-470	98.1%	A++
470-561	97.6%	A++
561-657	94.5%	A++
657-772	101.7%	A++
772-919	103.6%	A++
919-1200	104.4%	A++



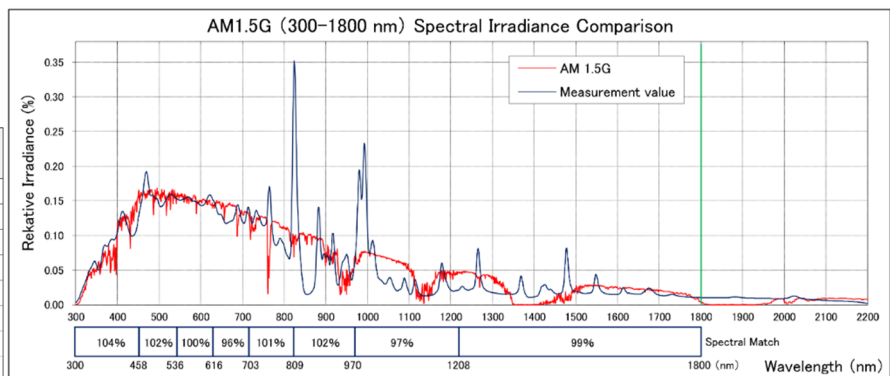
### Extended Wavelength Type (Option B)

- 300–1800 nm: within  $\pm 12.5\%$  (SAN-EI Class S+)  
→ Suitable for broadband material and device evaluation

### \* Extended + High Fidelity (Option C)

- 300–1800 nm: within  $\pm 7.5\%$  (SAN-EI Class S++)

WaveLength (nm)	Spectral Match (%)	Class
300-458	104.3%	S++
458-536	102.0%	S++
536-616	99.9%	S++
616-703	96.4%	S++
703-809	100.5%	S++
809-970	101.7%	S++
970-1208	96.5%	S++
1208-1800	98.8%	S++



### Low Thermal Load Type (Option D)

- Status: under development
- 300–700 nm: target within  $\pm 12.5\%$
- Above 700 nm: intended spectral attenuation
- Purpose: intended to reduce infrared components and sample heating  
Final specifications will be determined based on measured spectral performance, irradiance transmission, thermal behavior, and practical evaluation results.

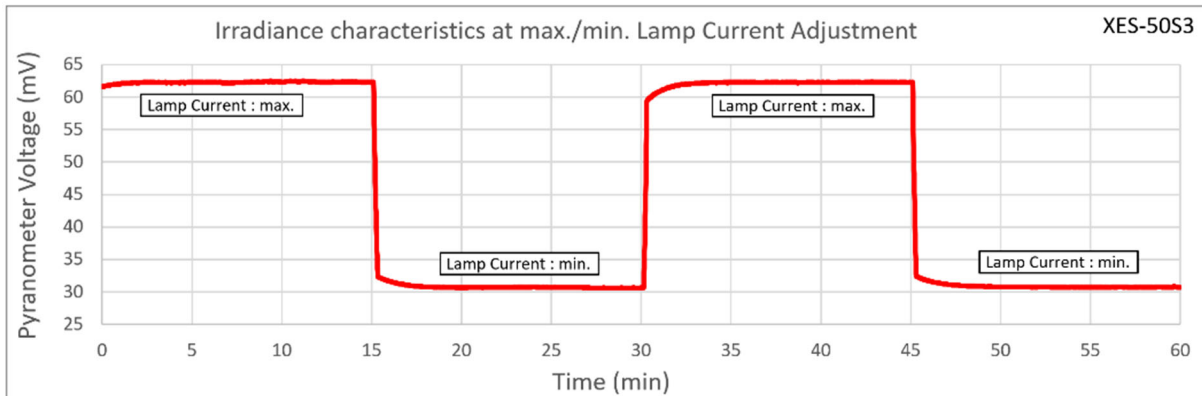
## 2.4 High Reproducibility (Practical Operation)

- Irradiance variation after shutter operation: within  $\pm 1\%$
- Effect of shutter closed duration (1 minute to 1 hour): negligible for practical operation
- Stable irradiance reproducibility in repeated measurements

*After each switching event, irradiance quickly reaches the target value and remains stable.  
The irradiance levels are consistent across repeated cycles, confirming high reproducibility.*

*The gradual change observed immediately after switching is mainly due to the temperature characteristics of the pyranometer and does not indicate fluctuation of the intrinsic light source output.*

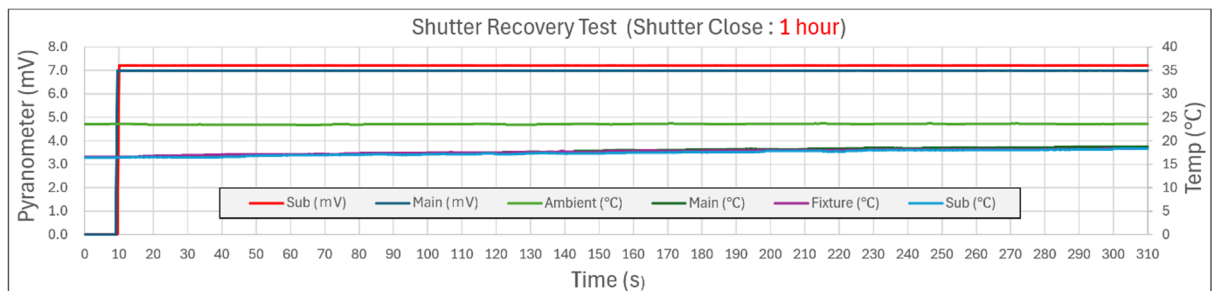
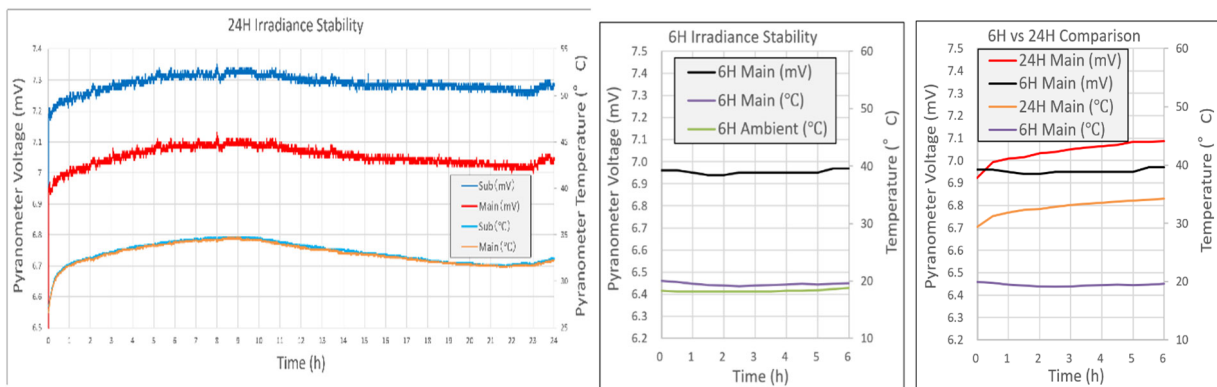
*These results confirm that the system provides high responsiveness, stability, and reproducibility for evaluation applications.*



## 2.5 Performance Verification Based on Measurement

The following evaluations were conducted:

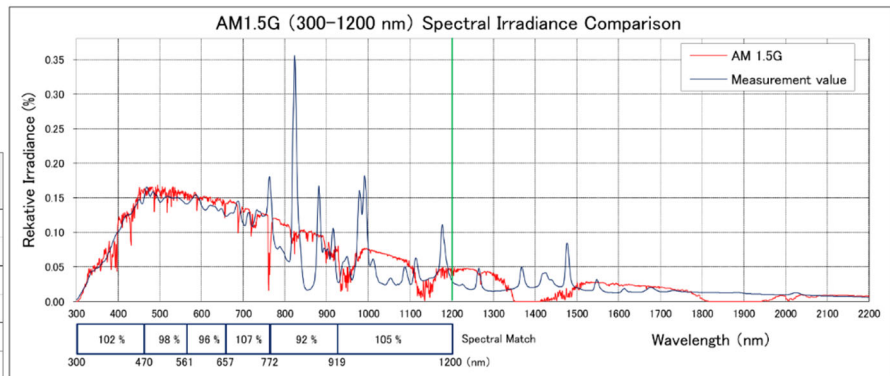
- 24-hour continuous measurement (long-term behavior)
- 6-hour intermittent measurement (isolation of pyranometer temperature effects)
- Shutter recovery test (practical reproducibility)



### 3. Optical Specifications

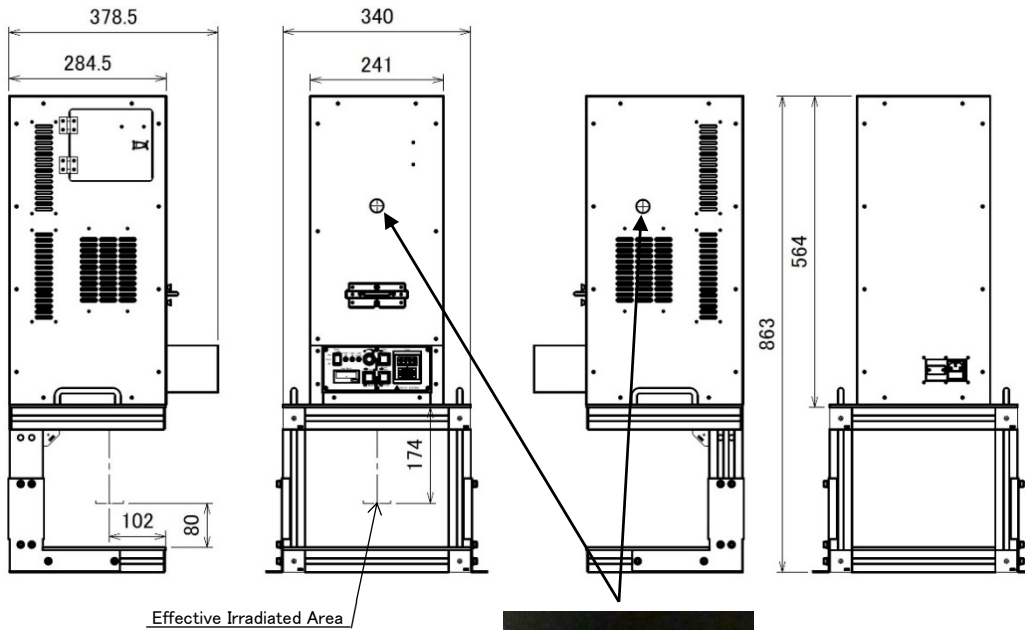
Item	Specification
Spectrum	AM1.5G
Reference standard	IEC / ASTM
Wavelength range	300–1200 nm standard
Spectral match	IEC Class A+
Effective irradiated area	50 × 50 mm
Working distance	174 mm
Irradiance range	0.1–1.2 sun
Maximum irradiance	≥1.4 sun
Minimum adjustable irradiance	≤0.1 sun
Spatial non-uniformity	See measured data

WaveLength (nm)	Spectral Match (%)	Class
300-470	101.8%	A++
470-561	98.1%	A++
561-657	96.4%	A++
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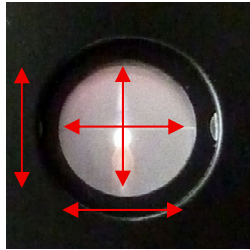


Light transmittance of the mesh filter	Range of irradiance by adjusting mesh filter and lamp current (SUN)														Spatial non-uniformity				
	min.	max.	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2			1.3	1.4	
100 %	0.70	1.40																1.50%	A
60 %	0.42	0.84																1.28%	A
40 %	0.28	0.56																1.54%	A
30 %	0.21	0.42																1.76%	A
20 %	0.14	0.28																1.88%	A
15 %	0.11	0.21																2.13%	B
10 %	0.07	0.14																2.52%	B

#### 4. Dimensions and Control Panel



Arc Monitor  
Vertical adjustment



Arc Monitor  
Horizontal adjustment

*Using a 3-axis precision table,  
the lamp arc is set to its predetermined position.  
This reproduces the optical performance described above.*

There are three shutter operation types:

- ST type: controlled by panel and external contact
- RY type: controlled by panel and external voltage input (0–5 VDC)
- TT type: manual or timer operation on the panel

ST type  
RY type



TT type



## 5. Safety Specifications

- Cooling fan automatically stops approx. 20 minutes after lamp shutdown
- Lamp cannot be turned on if the lamp access cover is not fully closed
- Lamp automatically turns off if the cover is opened during operation
- Lamp shuts down if abnormal overheating is detected
- Lamp operating time is displayed for maintenance reference

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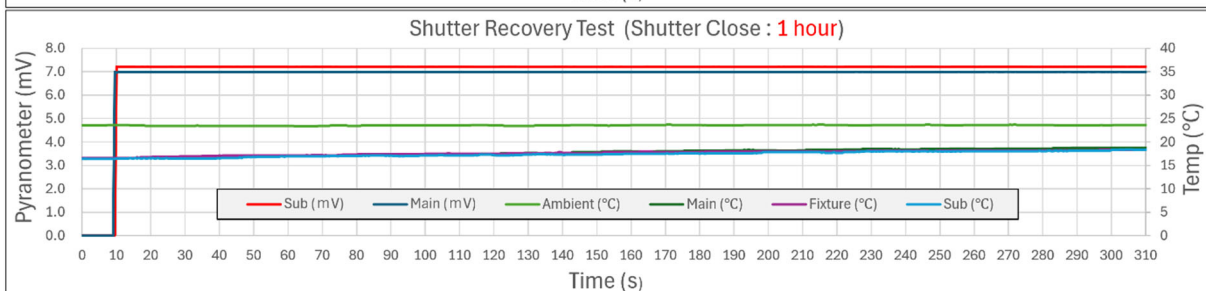
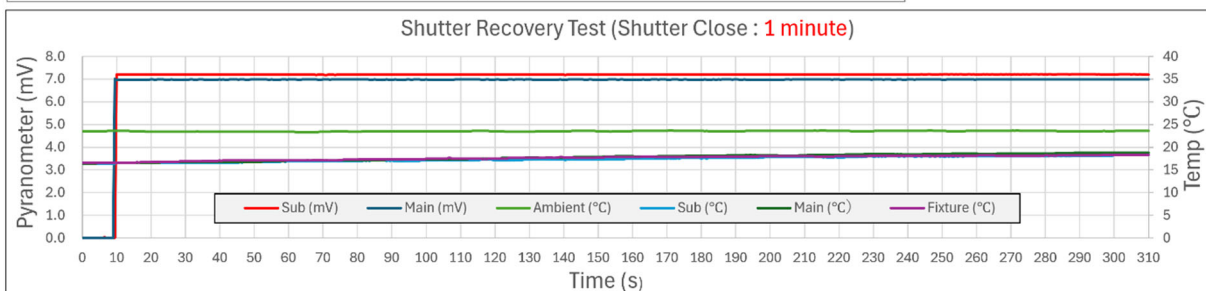
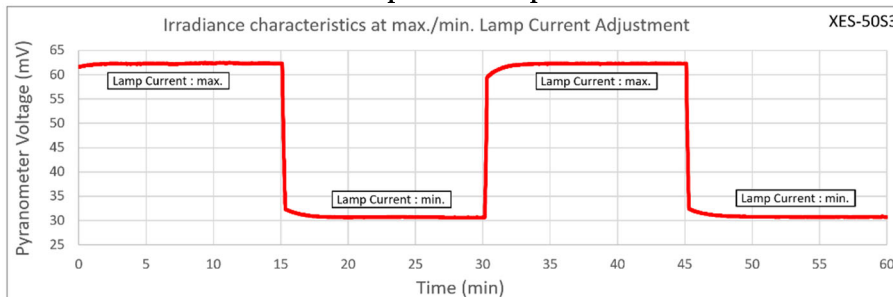
## 6. Electrical Specifications

- Input voltage: 100–120 VAC or 200–240 VAC (specified at order)
- Frequency: 50/60 Hz
- Power consumption: 240 W (max.)
- Dielectric withstand voltage: Input–Output/Ground: 1000 VAC (1 min)  
Output–Ground: 500 VAC (1 min)
- Insulation resistance: Input–Output/Ground: 500 VDC,  $\geq 20 \text{ M}\Omega$   
Output–Ground: 500 VDC,  $\geq 20 \text{ M}\Omega$

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## 7. Operating Specifications

- Warm-up time: approx. 30 minutes
- Irradiance switching: stable in both directions (high→low, low→high)
- Stabilization after shutter operation: rapid

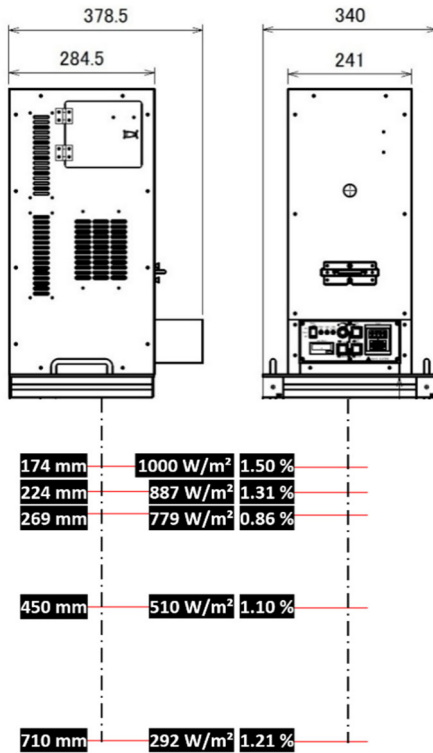
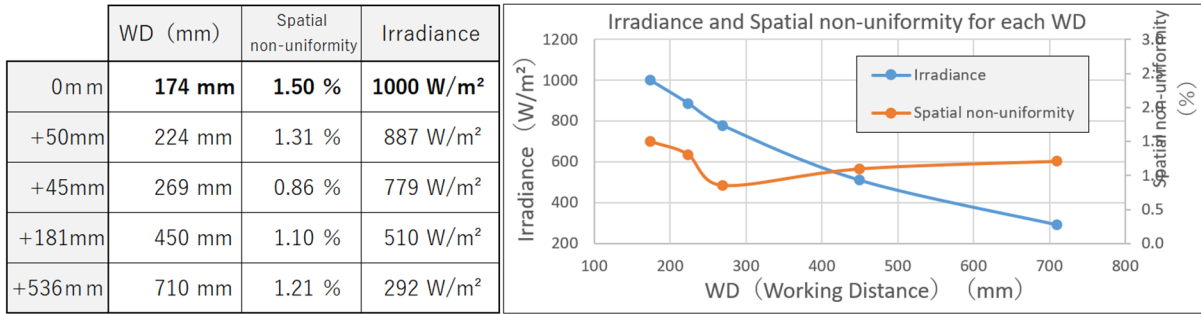


## 8. Environmental Conditions

- Temperature: 20–30° C (ambient), variation within 5° C
- Humidity: 20–85% RH (no condensation)

## 9. Working Distance Characteristics

- Irradiance decreases as working distance increases
- Spatial non-uniformity is maintained within 2% (without dimming filter)



## 10. Irradiance Stability

This specification is based on measured performance including the low irradiance region.

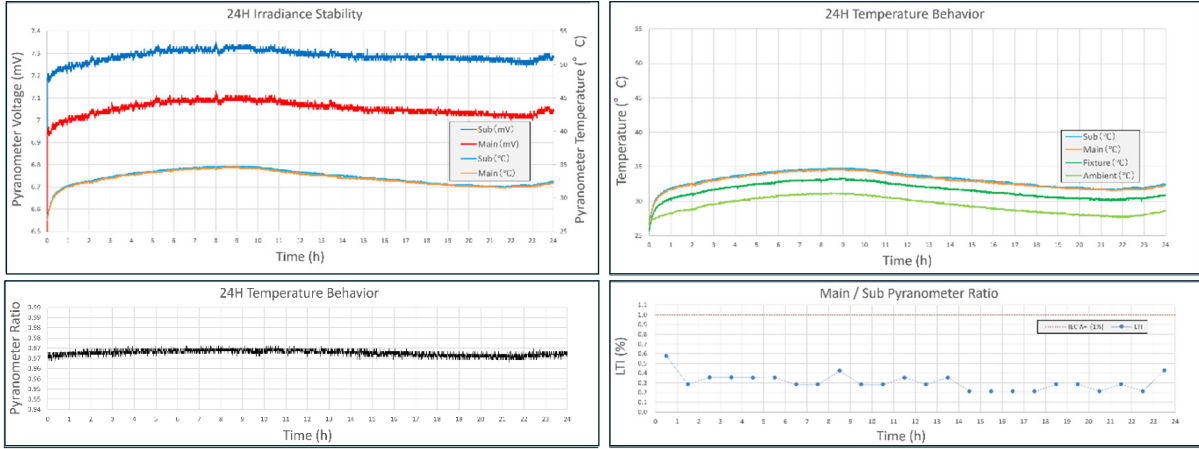
- STI:  $\leq 0.25\%$  in the low irradiance region
- LTI: within  $\pm 1\%$  (1-hour evaluation, IEC Class A+ equivalent)
- Drift during long-term operation: within  $\pm 1\%$

*Variations observed in 24-hour measurements are mainly due to pyranometer temperature characteristics and do not represent intrinsic light source instability.*

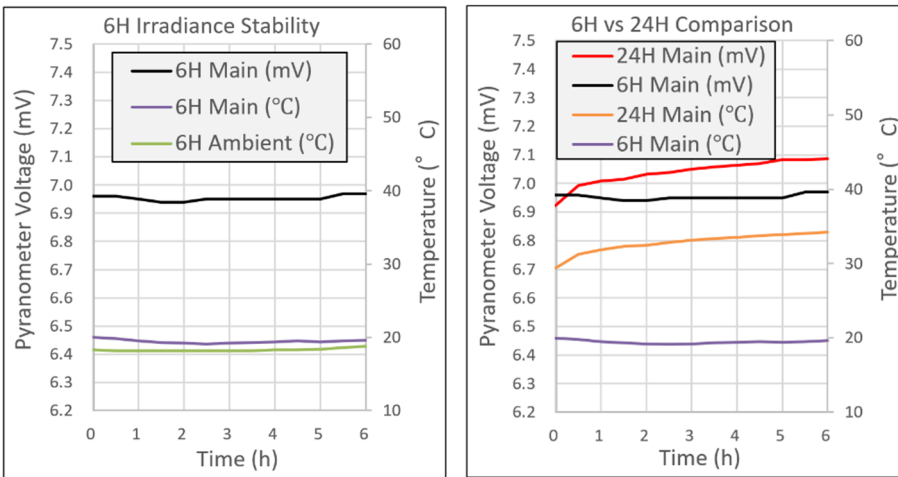
## 11. Basic Performance Evaluation (1 sun)

This section presents the fundamental performance under 1 sun conditions.

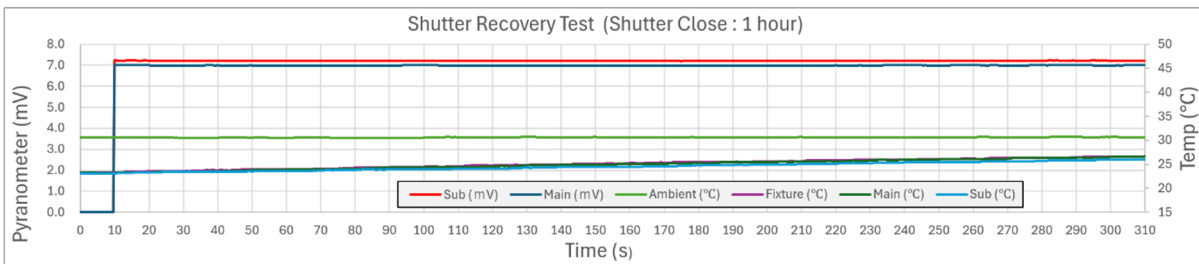
- **24-hour continuous measurement**



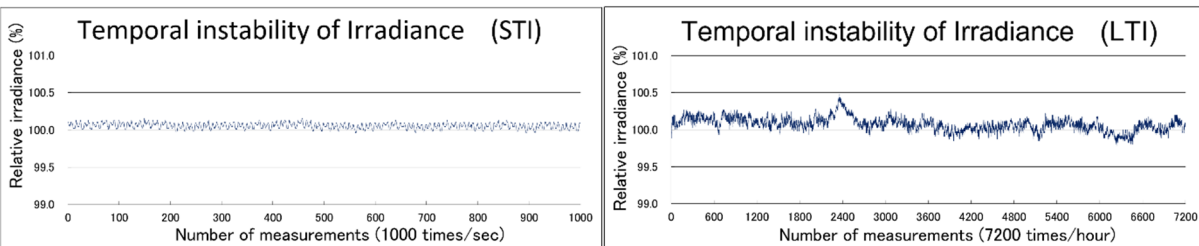
- **6-hour intermittent measurement**



- **Shutter recovery test**



- **STI / LTI evaluation**



Measured STI and LTI are below the specified limits, taking into account temperature effects of the measurement system.

## 12. Stability Evaluation in the Low Irradiance Region

This section presents system performance in the low irradiance region.

The system was evaluated using the lowest transmission filter and minimum lamp current.

### Measurement Conditions:

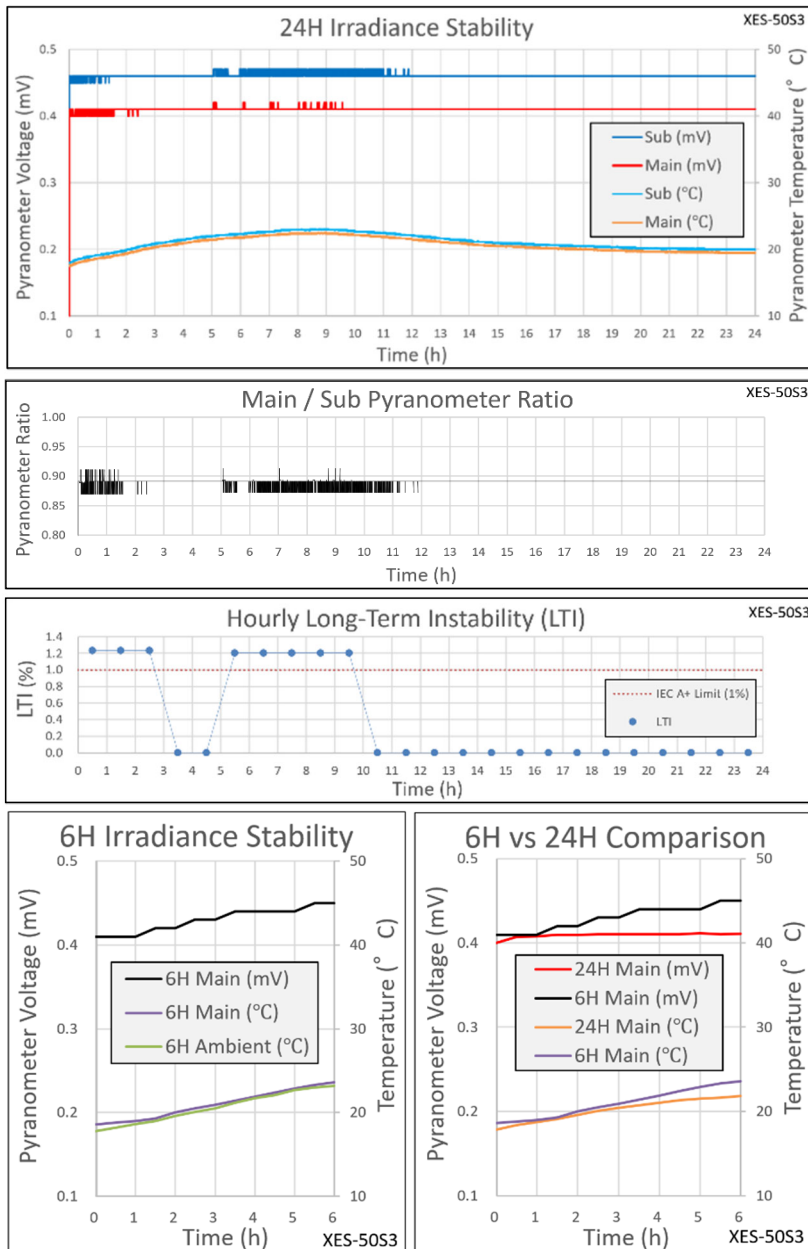
- Irradiance: approx.  $59 \text{ W/m}^2$  (approx. 0.06 sun)
- Measurement duration: 24-hour continuous and 6-hour intermittent

### Results:

- 24-hour variation correlates with pyranometer temperature
- 6-hour measurement confirms intrinsic light source stability
- LTI in the stable region is negligible

### Conclusion:

The system demonstrates high intrinsic stability.



### 13. Design Concept (Perovskite-Oriented)

This system is designed to address:

- Instability in the low irradiance region
- Thermal effects due to irradiation
- Hysteresis and light-induced behavior
- Separation of measurement system and light source effects

Maintaining stability below 0.1 sun is a design requirement.

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### 14. Notes

The data shown in this document are representative measured examples under defined measurement conditions.

Values may vary depending on configuration, measurement conditions, operating environment, and detector characteristics.

The data are provided for technical reference and do not constitute guaranteed specifications unless explicitly stated.

Specifications are subject to change without notice.

Option D, the low-thermal-load filter concept, is currently under development.

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**SAN-EI Electric Co., Ltd.**

E-mail : [info@san-eielectric.co.jp](mailto:info@san-eielectric.co.jp)

<https://www.san-eielectric.co.jp/am/en/>

## Appendix A

### Comparison Between IEC-Based Solar Simulator and PSC-Dedicated Solar Simulator

Applicable Standards:

IEC 60904 series, ASTM standards (AM1.5G)

→ PSC: No widely established international standard (currently application-driven)

Item	IEC-Based Solar Simulator	PSC-Dedicated Solar Simulator
Primary Purpose	Standardized evaluation of silicon and conventional solar cells	Evaluation of perovskite solar cells under realistic and stress-sensitive conditions
Applicable Standards	IEC 60904 series, ASTM standards (AM1.5G)	No widely established international standard (currently application-driven)
Spectral Range	Typically 300–1200 nm (IEC A/A+/AAA classification range)	Extended range (e.g., 300–1800 nm or beyond) depending on device sensitivity
Spectral Match Accuracy	IEC classification (A, A+, AAA)	Higher or customized accuracy (e.g., $\pm 7.5\%$ or application-specific tuning)
Infrared (IR) Handling	Not specifically optimized; IR included as part of spectrum	IR reduction or control emphasized (low-heat filters, thermal management)
Irradiance Level	Fixed at 1 sun (1000 W/m <sup>2</sup> )	Wide range (e.g., 0.1–1.2 sun or lower) for sensitivity and degradation studies
Stability Requirement	IEC temporal instability classes (A+, A, etc.)	High stability required especially at low irradiance (e.g., STI $\leq 0.25\%$ )
Measurement Focus	Compliance verification (spectral match, uniformity, stability)	Device behavior analysis (low-light performance, transient response, degradation)
Thermal Consideration	Limited (not a primary design factor)	Critical (device degradation strongly affected by heat)
Shutter Operation	Secondary importance	Important (frequent ON/OFF cycles, recovery behavior must be stable)
Low Irradiance Performance	Not specified / not critical	Essential (stable operation at very low irradiance required)
Uniformity Requirement	IEC spatial non-uniformity ( $\leq 2\%$ typical)	May allow relaxed uniformity depending on research priority
Light Source Design	Optimized for standard compliance	Optimized for controllability, stability, and thermal suppression
Filter Design	Standard AM filters (AM1.5G / AM0)	Multiple customized filters (e.g., low-heat, extended IR, PSC-specific tuning)
Evaluation Methodology	Defined by IEC (standard test procedures)	Combination of IEC + additional methods (24H, 6H, shutter recovery tests)
Data Interpretation	Pass/Fail classification (AAA, etc.)	Continuous analysis (drift, thermal effects, operational behavior)
System Philosophy	Standardization and comparability	Application-driven optimization and transparency of real behavior

This appendix is provided for reference to explain design philosophy and application differences. It does not define product specifications.