

Metrology Underpins China's Photovoltaic Industry

Authors: Haifeng Meng*, Junchao Zhang, Wende Liu, Nan Xu, Meng Wang, Bifeng Zhang, Chuan Cai, Shuai Man, Zhiwei Liu, Peilin Yan, Limin Xiong*, and Haiyong Gan*

Institutes: Optics Division, National Institute of Metrology, China
Contact: menghf@nim.ac.cn; xlmn@nim.ac.cn; ganhaiyong@nim.ac.cn



Introduction

Renewable and clean energy has become the focus of global attention because of climate change, and ever-increasing photovoltaic (PV) energy alone accounts for three-quarters of renewable capacity additions worldwide in 2023. And China is forecast to accounting for 60% of the expansion in global capacity to 2030. Huge PV industry has a huge demand for metrology, knowing that measurement deviations may cause problems in the whole chain from research to application. Along with the development of PV industry and related international standards, NIM has been committed to establishing a complete quantity value chain traceable to the International System of Units (SI) for China's PV metrology, that is from the source cryogenic radiometer to terminal PV products.

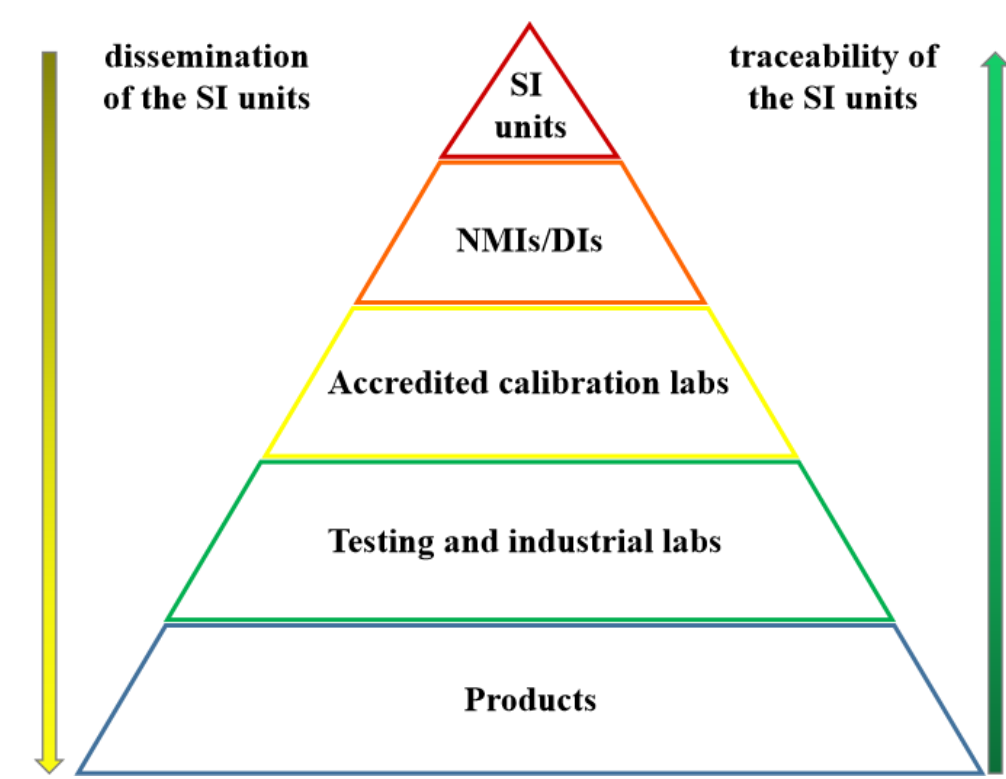


Fig.1 Legislation on metrological traceability.

- SI units transfer their quantities to products through NMIs/DIs, accredited calibration labs, testing and industrial labs.
- From top to bottom is the dissemination of the SI units, and from bottom to top is the traceability of the SI units.
- In PV industry, the value of the PV products' key parameters should be tied to SI units in an unbroken and documented chain of quantity dissemination, including stated uncertainties if necessary. References and standards are the bridges to SI units for PV products.

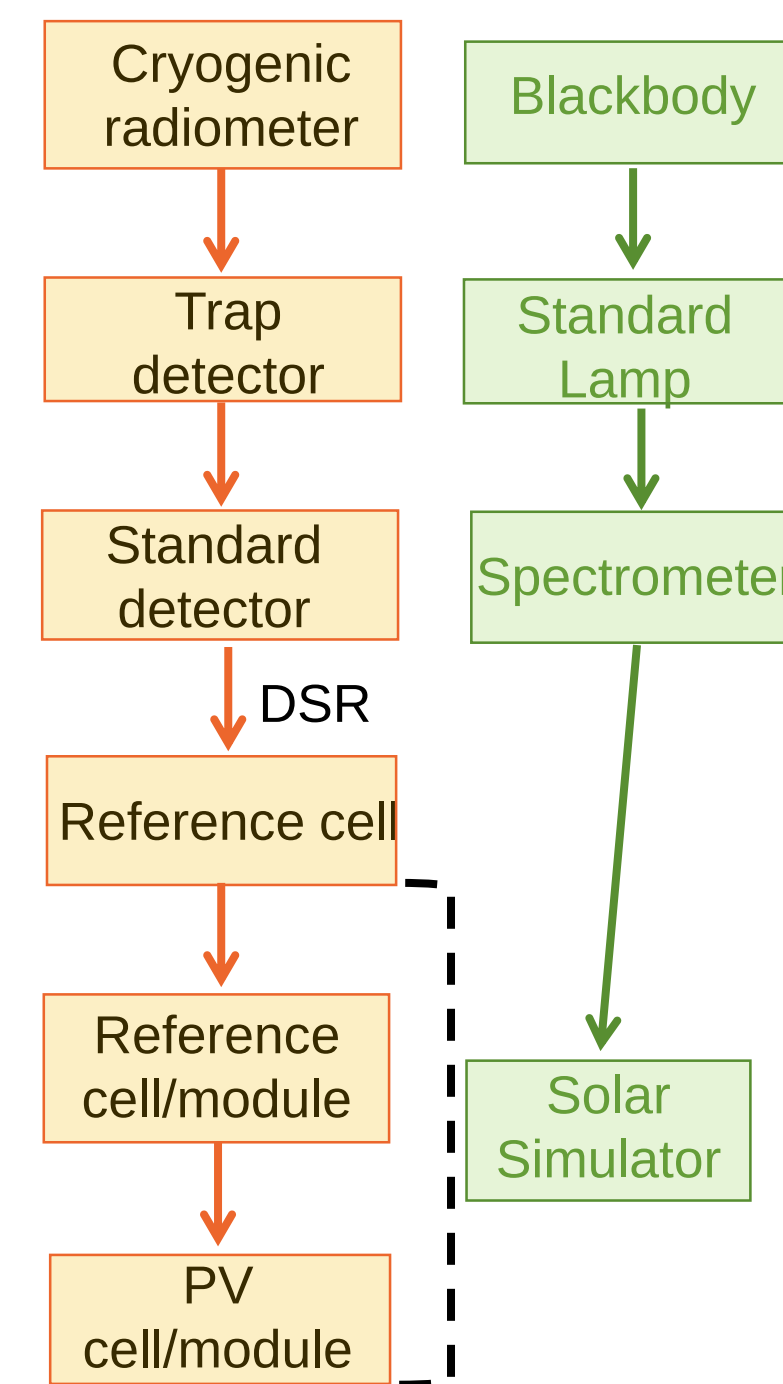


Fig.2 The main routes for PV metrology

Traceable to the optical Watt primary standard

The optical Watt primary standard based on absolute cryogenic radiometer serves as the source of PV metrology, transferring values to standard photodetectors which are bridges for PV value's traceability to the SI units.

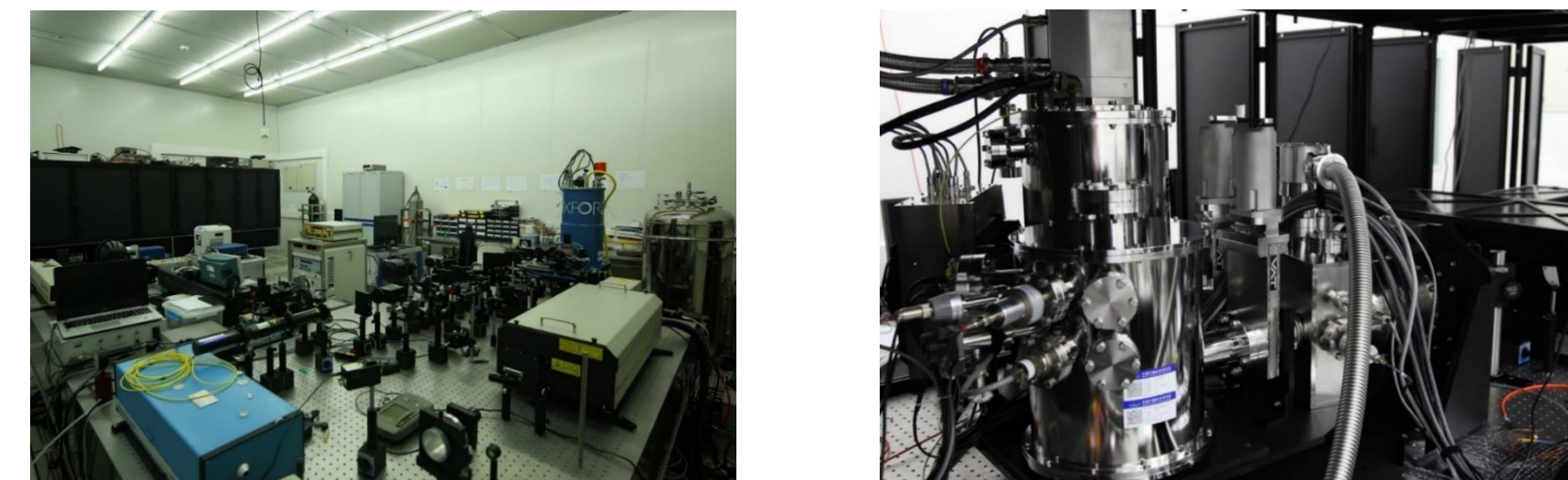


Fig.3 Cryogenic radiometer based on lasers (top) and a monochromator (bottom).

- The left: laser wavelength points. The right: (350~2400) nm.
- The measurement uncertainty of radiation power can reach 2.0×10^{-4} ($k=2$).
- Participated in international comparisons between NIMs.

NIM has also built the measurement standard for photo-detector's relative spectral responsivity, with the help of absolute value from above, it acts as a working standard and achieve convenient value transfer over a wide wavelength range with a low cost but high efficiency.

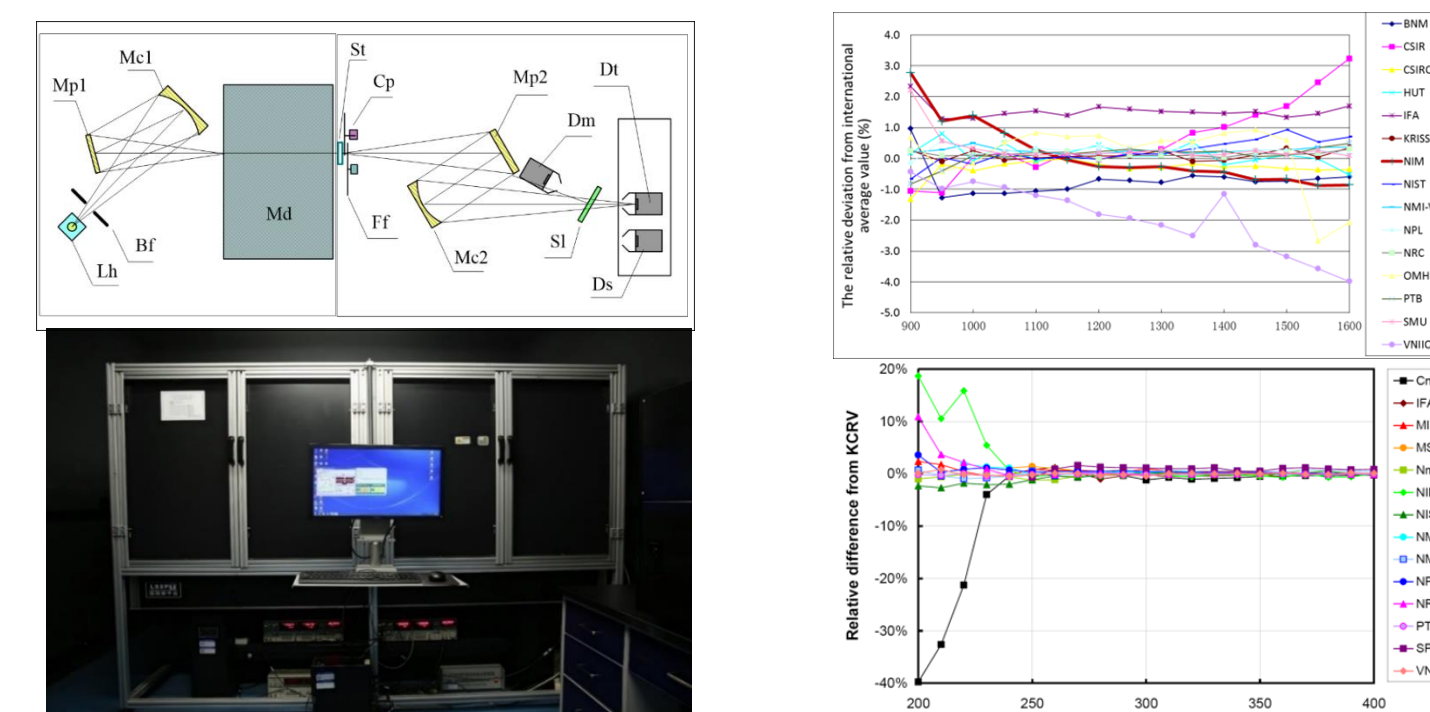
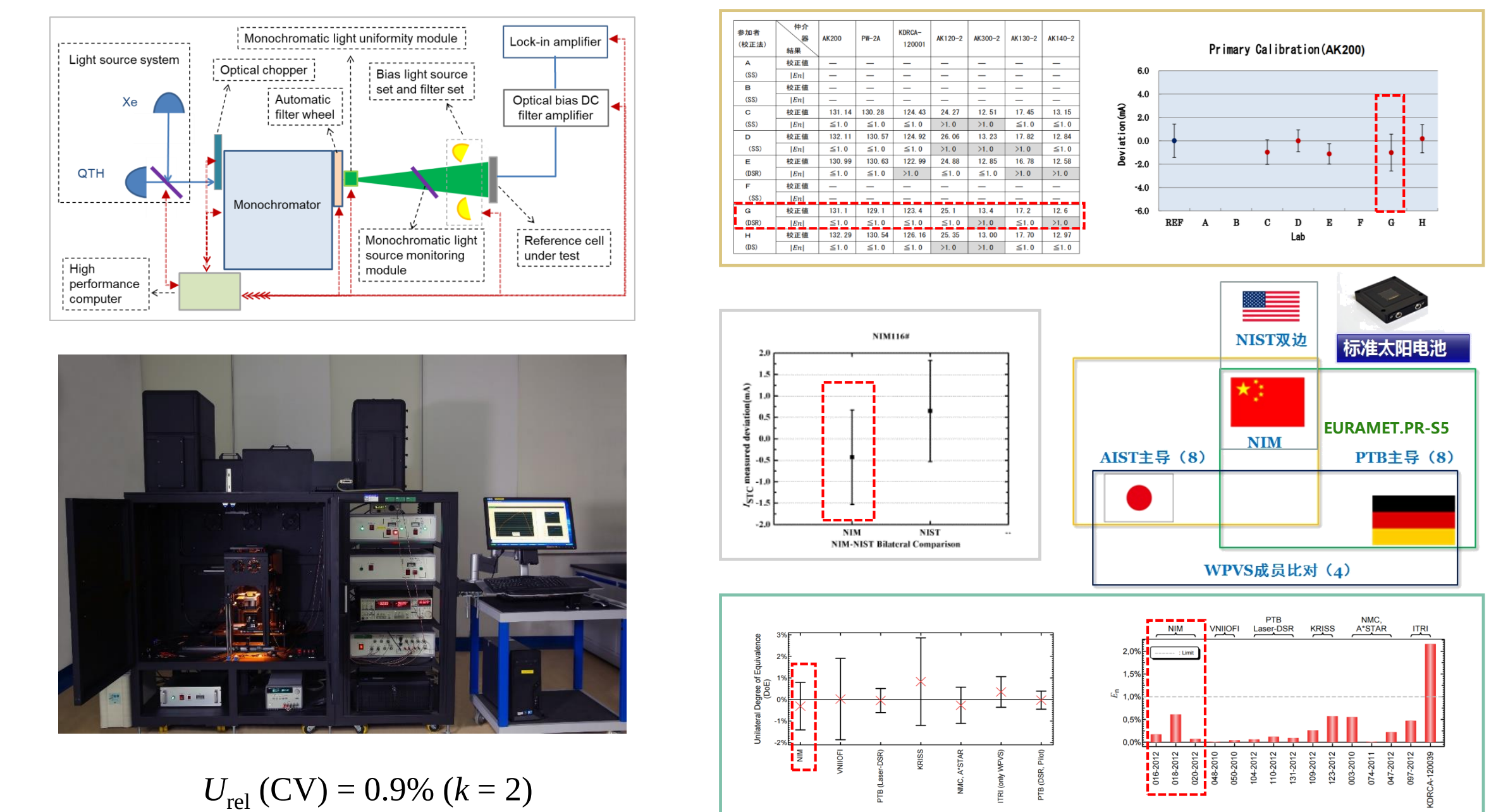


Fig.4 Measurement standard for photo-detector calibration and related comparisons.

- 7 CMCs. Measurement Standard for Public Service [1991]国量标计证字第185号.
- Participated in CCPR K2 series comparisons and achieved good consistency.

Measurement standard for reference solar cells

NIM has built the measurement standard for the primary calibration of reference solar cells based on DSR (Differential Spectral Responsivity) method, obtaining short circuit current under standard test conditions by integral calculation of SR with the standard spectrum, which also called calibrated value (CV).



$$U_{rel}(CV) = 0.9\% (k=2)$$

Fig.5 Measurement standard for the primary calibration of reference solar cells and related comparisons.

- 1 CMC. Measurement Standard for Public Service [2015]国量标计证字第283号.
- Proficiency Testing Provider (PTP) of CNAS, CNAS PT0037.
- Traceable to the cryogenic radiometer through standard detectors, and act as the reference for the following I-V measurement..
- Attended international comparisons piloted by AIST (ILC005) and by PTB (EURAMET.PR-S5), and piloted a bilateral comparison with NIST. Results show good consistencies.
- Organized the first national proficiency testing of reference solar cells in China.

Measurement standard for solar simulators and I-V testers

Considering that the I-V characteristic parameters of solar cells and PV modules are commonly measured with solar simulators, to avoid the mismeasurement caused by solar simulator's performance, NIM has built a measurement standard to measure the three key parameters including spectral mismatch, non-uniformity and instability of irradiance intensity. Spectrometer used here is effectively calibrated by standard lamp as shown in Fig.2. NIM also developed in-situ calibration system for I-V testers.

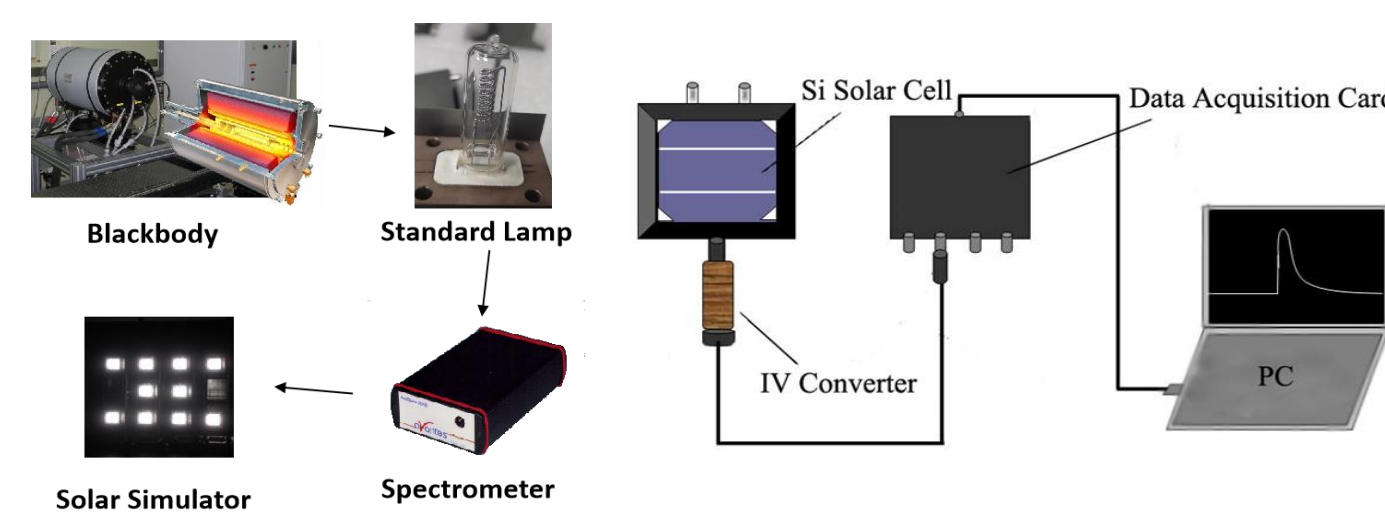


Fig.6 Scheme of optical performance calibration setups for solar simulators.



Fig.8 Service area of NIM's solar simulator on-site calibration.

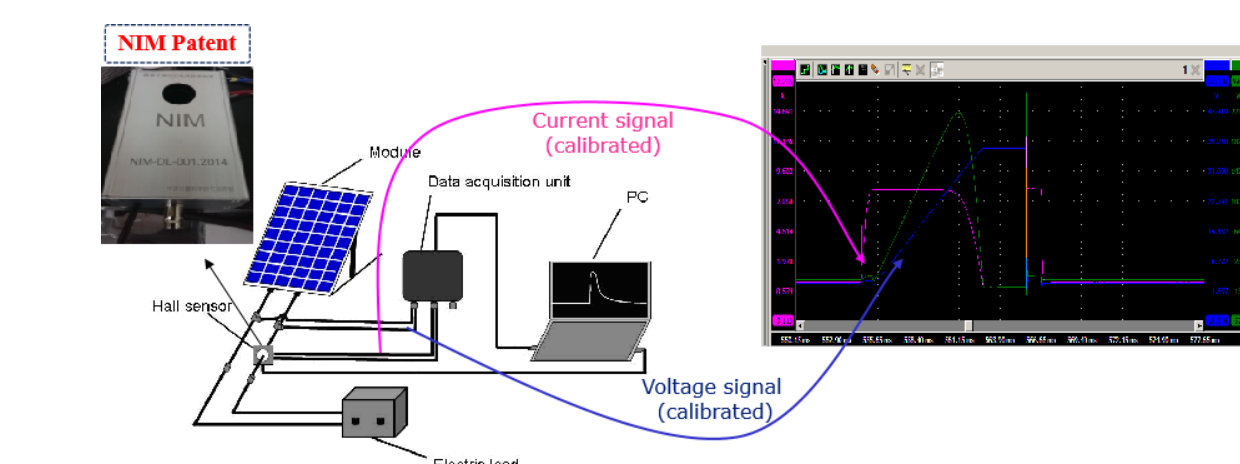


Fig.7 Scheme of in-situ calibration system for I-V testers.

- Measurement Standard for Public Service [2015]国量标计证字第282号.

- Since 2009, NIM has been providing on-site calibration for various types of solar simulators, reaching an average of 1,000 units per year since 2016.
- Our services are not limited to mainland China, Taiwan (China), and Hong Kong (China), but also extend to other countries or regions such as Germany, USA, Australia, Japan, South Korea, Malaysia, Thailand.

Measurement standard for solar cells/modules

The measurement standard for the calibration of solar cells and PV modules, measuring their I-V characteristics based on solar simulators. (Measurement Standard for Public Service [2015]国量标计证字第286号).

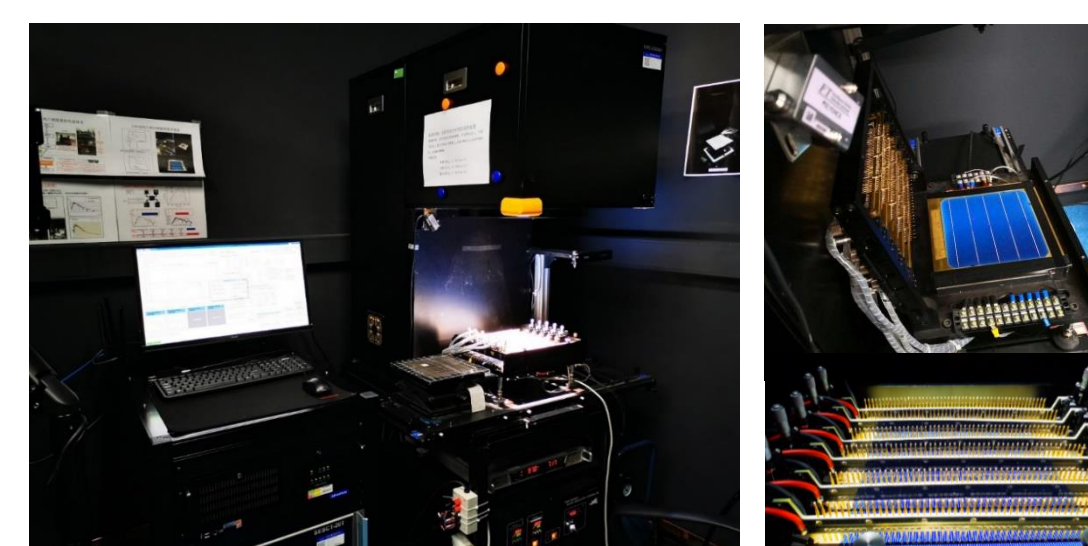


Fig.9 Photos of I-V calibration setup for solar cells and statistics of its services.

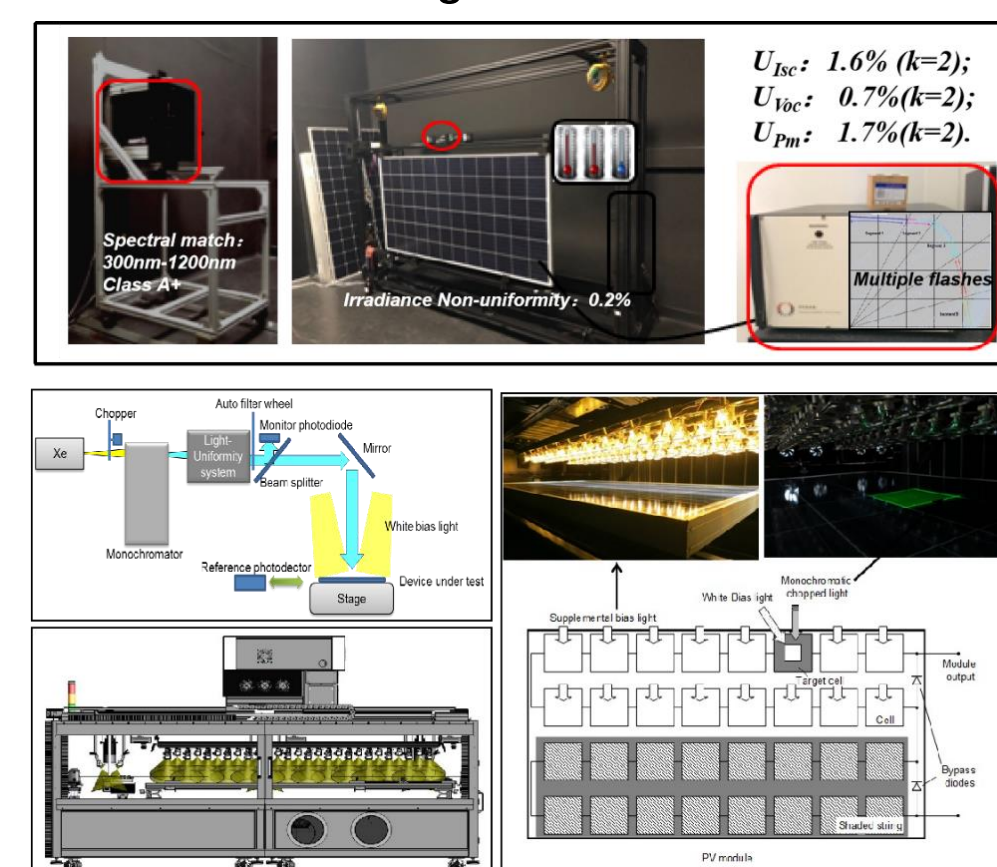


Fig.10 Photos of I-V and SR measurement setups for PV modules.

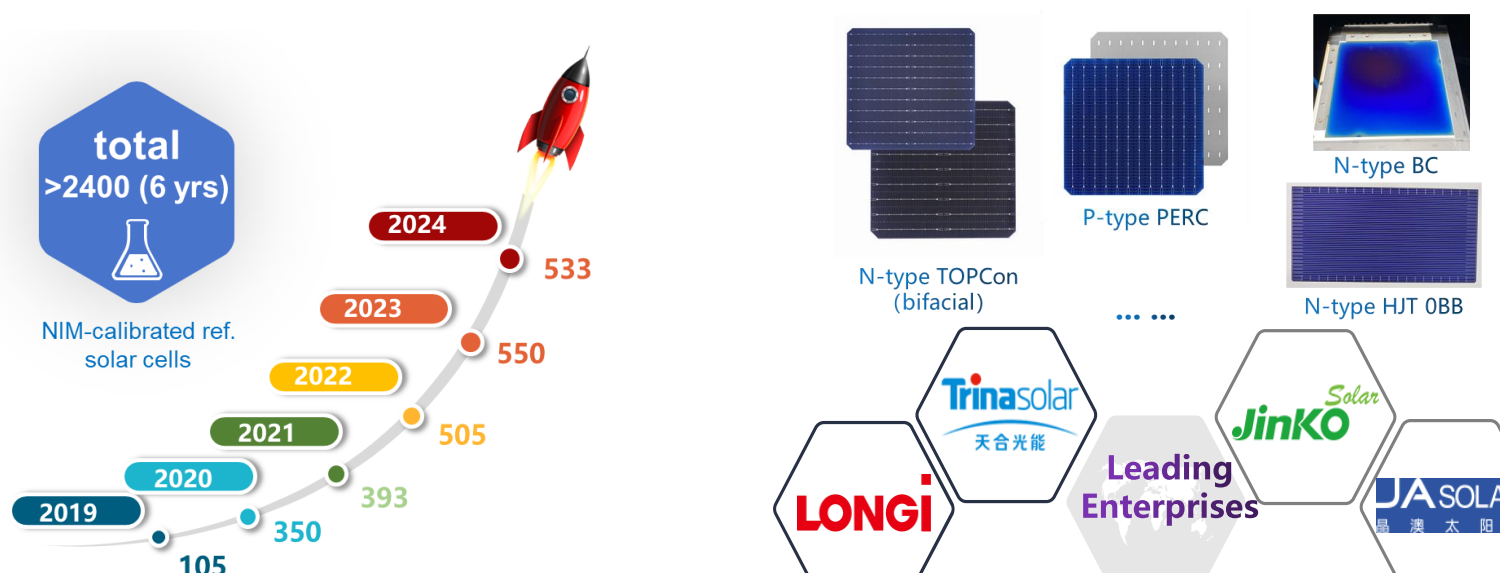


Fig.11 Statistics of new-type photovoltaic devices' efficiency measurement.

- NIM has provided calibration of various types of reference solar cells and modules for the leading PV enterprises, effectively supporting the research and development of PV products.
- The transmission and comparison of reference PV modules have improved the measurement consistency, helping to solve trade frictions caused by inaccurate measurement of PV module's power.

Conclusion

NIM has established a quantity value chain traceable to the International System of Units (SI) for China's PV metrology, providing valuable support to the PV industry in China. In the future, NIM will continue to enhance its efforts to develop PV-related measurement capabilities and build a more comprehensive metrology system for the PV industry. With the advancement of metrology system, key parameters of PV devices will be measured with increasing accuracy and credibility. The role of metrology will be better seen in helping the PV industry to reduce trade frictions and achieve clean energy goal.

References

- [1] Renewables 2023, Analysis and Forecast to 2028, International Energy Agency, 2023.
- [2] Renewables 2024, Analysis and Forecast to 2030, International Energy Agency, 2024.
- [3] Haifeng Meng et. al., Metrology boosts the quality of China's photovoltaic products, OIML BULLETIN, 3, 27-33, 2023.
- [4] IEC 60904-1 Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics.
- [5] IEC 60904-2 Photovoltaic devices - Part 2: Requirements for photovoltaic reference devices.
- [6] IEC 60904-4 Photovoltaic devices - Part 4: Reference solar devices - Procedures for establishing calibration traceability.
- [7] IEC 60904-9 Photovoltaic devices - Part 9: Solar simulator performance requirements