# The future of solar testing: advancing perovskite and tandem modules

As solar module prices continue to decline, the European industry faces challenges, but emerging technologies like perovskite solar cells offer new opportunities. MBJ Solutions' latest LED solar simulator, the MBJ Sunlike Lab, provides an advanced testing solution for next generation tandem modules, ensuring precise measurements and long-term stability in solar research.

Between 2010 and 2020, prices for solar modules fell by around 80% to 90%. In 2010, the price of solar modules was around USD 3-4 per watt peak, while the price fell to around USD 0.18-0.25 per watt peak in 2020. Current daily prices are sometimes below USD 0.10 per watt peak, often below the manufacturing costs.

In Germany, many factories have ceased production for this reason. Only recently, Aleo Solar announced that its production facility in Prenzlau will be closed after 22 years. The prospects in Europe are no better, although the market for renewable energy continues to grow worldwide.

It is, therefore, not surprising that perovskite solar cells are so popular. These cells have the potential to achieve higher efficiency than the currently dominant silicon solar cells and at lower production costs. Perovskite solar cells are easier and cheaper to manufacture than silicon solar cells as they can be produced at lower temperatures and with less energy intensive processes. This cost reduction could enable the European solar industry to become more competitive and significantly reduce production costs for solar installations.

Perovskite solar cells also offer the potential for developing tandem solar cells, combining perovskite layers with existing silicon solar cells.

The manufacturing costs per Wp for tandem solar cells will be cheaper than silicon solar cells and they can achieve a higher efficiency, as solar cells with two active layers utilize light better than conventional single layer cells. As a result, such tandem modules deliver more electricity per surface area.

Despite these advantages, there are also challenges, such as long-term stability and production scalability, that still need to be addressed. Nevertheless, perovskite cells are expected to play a significant role in the future solar industry, especially if these challenges are overcome.

The new technology is an opportunity for Europe. It offers the potential to make European industry more competitive on a global level.

In addition to the aforementioned long-term stability, the power measurement of perovskite solar cells and solar modules is another challenge. The spectrum of the light source has a considerable influence on the overall IV characteristic curve, as the ratio of

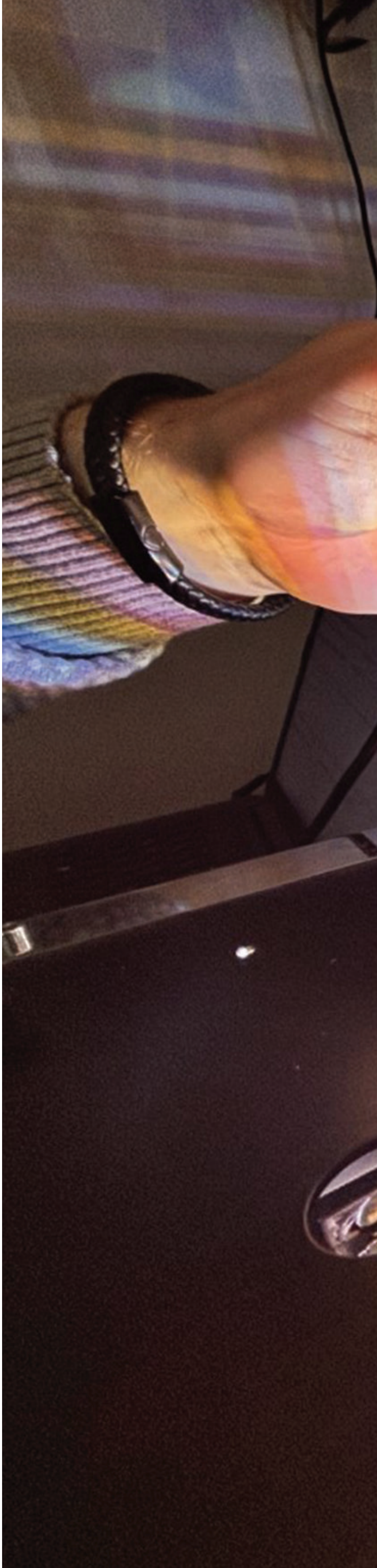


Figure 1: Test setup for the new LED board


Figure 2: Sun simulator for the lab

the generated current per sub-cell depends on it, but must be the same due to the series connection of the sub-cells.

In addition, the electrical power of a perovskite module is not only dependent on the irradiated power, but also on the time course of the irradiation. For a reproducible power measurement, the cells must therefore be preconditioned with light at a constant temperature until the measured power of the cell is stable.

Xenon-based solar simulators are not suitable for this purpose, as they can only be used for a short flash duration of up to 100 ms. LED technology is the solution here. With good thermal management and careful selection of the LEDs, continuous light is technically no problem. Ultimately, one must only consider whether the technical effort is necessary for the task, but this is out of the question for measuring perovskite cells.

MBJ Solutions has a lot of experience in the field of solar simulators for measuring solar modules, with more than 100 systems sold. (Fig. 2). Together with its subsidiary MBJ Imaging, which builds LED lighting for industrial applications, it has extensive know-how in the development and manufacture of industrial LED lighting systems.

At Intersolar in Munich, the company is presenting the MBJ Sunlike Lab, a new LED solar simulator for the laboratory for developing new module technologies such as tandem solar modules. The spectrum is almost perfect or 'SunLike' and is very close to AM1.5G. The pulse duration is long at 500 m and there is the option of continuous irradiation for stabilization processes.

The almost perfect spectrum is achieved with 32 individually adjustable LED channels or light colors per LED board. Together with a design that is suitable for continuous operation and good heat management, this is the ideal basis for the laboratory. The requirements for heat management are high. The LEDs and the associated electronics generate approximately 20 kW of heat. The heat output must be dissipated by a cooling unit. The LED temperature must be kept as constant as possible to ensure that the spectrum remains stable over time.

IEC 60904-1-1:2017 describes aspects of the measurement of multiple PV devices, such as perovskite silicon tandem modules[1]. Each deviation of the test spectrum from the reference spectrum significantly influences the IV characteristic of tandem modules. In addition, the known correction of spectral mismatch as with single PV devices is also not possible with multiple PV devices.

The standard introduces a method for evaluating the described deviations in a single parameter for each connection, the so-called Z-factor or matching factor. To calculate the individual Z-factor, it is necessary to derive the generated current of each cell from its spectral responsivity (SR) and the spectral reference and test irradiance. Therefore, the SR of the individual sub-cells must be measured before the calculation, which makes the measurement procedure more complex.

If a Z-factor exceeds the limit value of 1.00 ± 0.03, the test spectrum must be adjusted until the criteria are met. This further increases the complexity of the measurement. A comparison parameter for estimating the necessary adjustments to the test spectrum is the spectral deviation (SPD) from the reference spectrum, according to IEC 60904-9:2020[2].

MBJ's new LED light source has an almost sunlike spectrum with a spectral deviation (SPD) of 11.9%, a spectral coverage (SPC) of 100% between 300 nm and 1200 nm and a classification of A+A+A+ according to IEC 60904-9:2020[3].

The MBJ Sunlike Lab light source has an excellent long-term instability of less than ± 0.5% and spectral non-uniformities of only ± 0.5%. Measurements of the pulse-to-pulse repeatability of the irradiance in the test plane on the prototype resulted in a standard deviation of ± 0.1% with a coverage factor of k = 2. The new light source has already been successfully tested for its long-term stability in the laboratory (Fig. 1).

Based on the spectrum (Fig. 3) and the spectral response of tandem cells described in the literature, initial Z-factor calculations show that the Z-factors of all sub-cells for various tandem modules with different

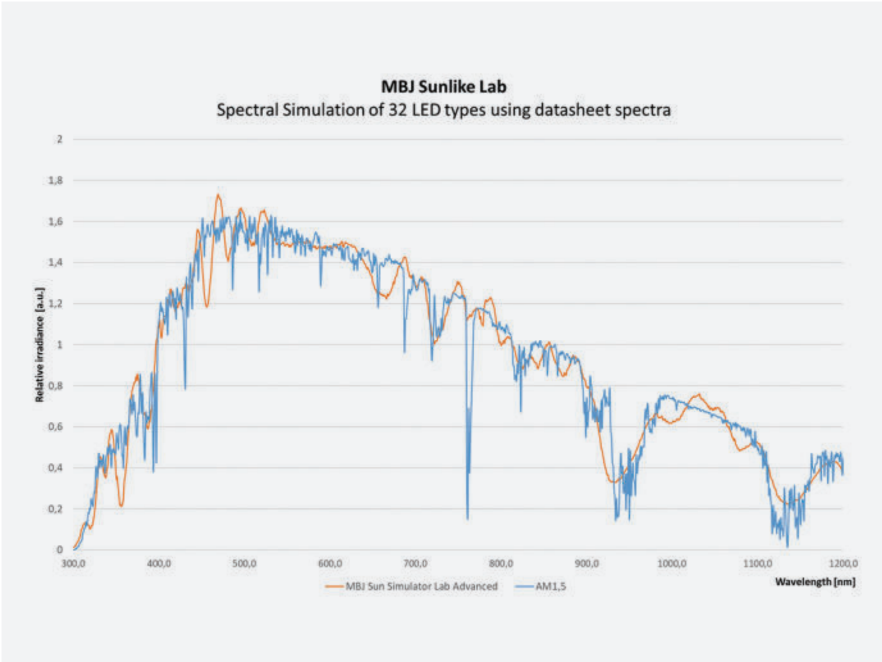
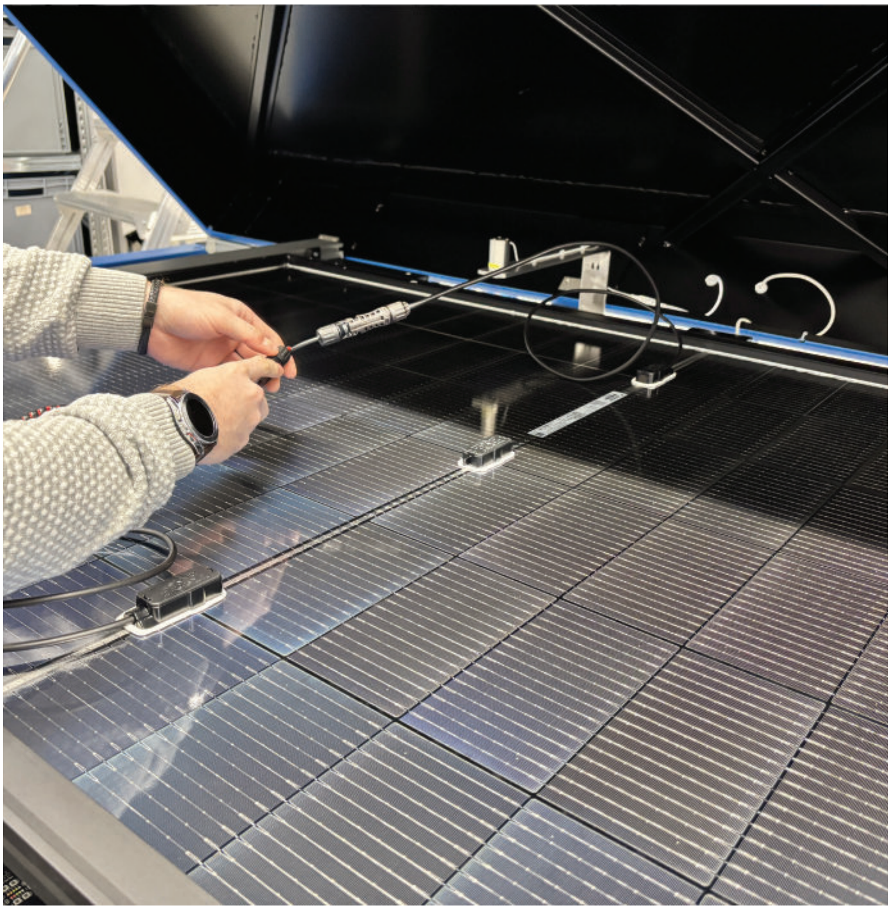



Figure 3: Spectral simulation of the 32 LED types using datasheet spectra

spectral responses (SR) are within 1.00 ± 0.01. This means that corrections of the test spectrum to match the IV characteristic under the AM1.5 reference spectrum are not necessary. This is extremely valuable for the laboratory. If needed, the spectrum of the light source can be easily adjusted of course.



For stabilization, we offer continuous light with up to 1000 W/m².

The MBJ Sunlike Lab offers the possibility of measuring the spectral sensitivity of solar cells in addition to those already described. An electroluminescence measurement is also integrated into the system. The EL cameras are equipped with two different filters so that the silicon cell and perovskite cell can be tested independently of each other.

In summary, the MBJ Sunlike Lab class A+A+A+ solar simulator has an almost perfect spectrum, a flash duration of 500 m and a continuous light mode for preconditioning. It is optimized for the measurement of perovskite-based and other tandem solar modules up to 2500 mm x 1400 mm in size and has a thermal chamber for a temperature range of 15 °C to 75 °C, an electroluminescence system and the ability to measure spectral responsivity (SR).

https://www.mbj-solutions.com/en/

[1] IEC, 'Photovoltaic devices – Part 1-1: Measurement of current-voltage characteristics of multi-junction photovoltaic (PV) devices', IEC 60904-1-1 Edition 1.0, 2017.

[2] Y. He et al., 'Composition engineering of perovskite absorber assisted efficient textured monolithic perovskite/silicon heterojunction tandem solar cells,' RSC Adv., vol. 13, no. 12, pp. 7886–7896, 2023, doi: 10.1039/d2ra05481g.

[3] IEC, 'Photovoltaic devices – Part 9: Classification of solar simulator characteristics', IEC 60904-9 Edition 3.0, 2020.