Light Spectrum Sensor guidelines

The Aranet Light Spectrum Sensor (LSS) is a wireless device designed for greenhouse environments, supporting light monitoring and control applications. Its primary function is to enable dynamic adjustment of artificial light intensity and spectral distribution, helping maintain appropriate lighting conditions for plant growth while minimizing unnecessary spectral components. This sensor is designed for trend monitoring and relative spectral control, and is not intended to replace high-resolution spectrometers

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Introduction

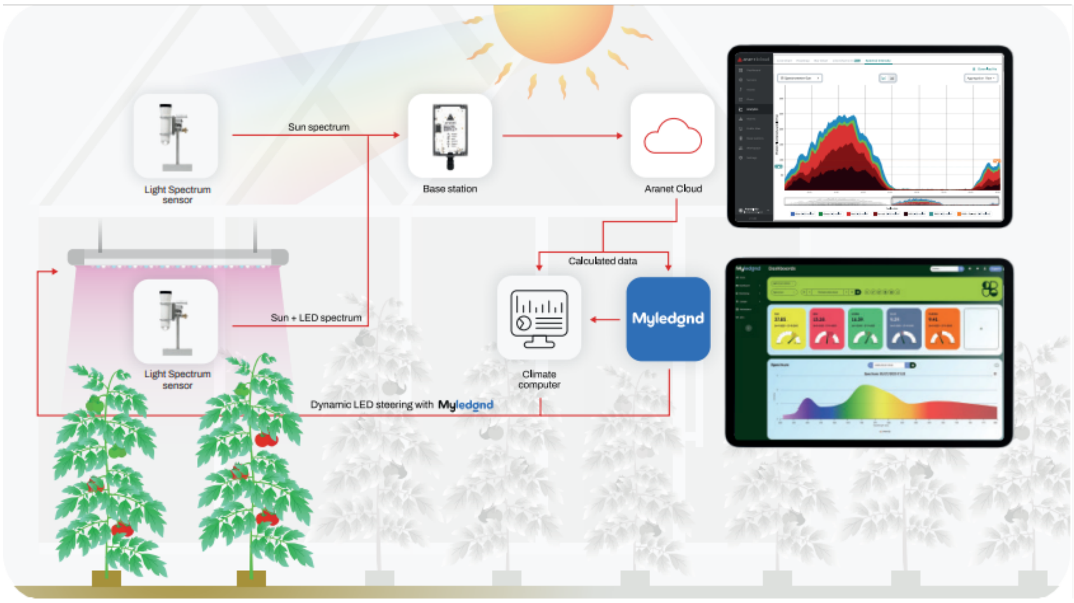
Application of this sensor

The Aranet Light Spectrum Sensor (product numbers TDSKSP01 and TDSKSPU1) is a wireless sensor designed for use in greenhouse environments. Artificial lighting accounts for a significant part of greenhouse operating costs. This sensor helps improve efficiency by enabling the adjustment of lighting based on plant requirements.

The solution consists of two parts:

1. **Hardware** – the Light Spectrum Sensor (LSS) performs measurements, and the Aranet base station collects the data and uploads it to Aranet Cloud.

2. **Aranet Cloud** – a data processing and visualization tool used for analysis. The Cloud also allows integration with third-party software platforms via API for data analysis and greenhouse lighting control. For example, integration with MyLedgnd platform provides more detailed insights about light data to dynamically stir LED lights.



This document explains the operating principles of the sensor, describes experiments performed by Aranet in a laboratory environment, and outlines the sensor's strengths and limitations compared to other light measurement solutions. It also describes how the sensor can be used in greenhouse environments to adjust artificial lighting.

Many greenhouses use single-spectrum LED lighting to supplement natural sunlight. However, multi-channel LED systems are becoming more common, allowing continuous adjustment of the light spectrum. This enables switching specific spectral components on or off, which can reduce energy consumption and potentially extend the lifespan of the lighting system.

Light conditions within a greenhouse are not uniform and can change over time. As plants grow, light levels at the lower parts of the canopy decrease. In addition, light source intensity may vary over time. To avoid insufficient light exposure, regular monitoring and timely adjustments are required.

Light Sensor Working Principle

Several sensor technologies are used to measure light in greenhouse applications. For simplicity, they can be grouped into three categories: photodiode sensors, spectrometers, and multichannel sensors. These technologies differ in measurement detail, cost, and suitability for continuous and distributed monitoring.

1. **Photodiode sensors**
   The most common types are PAR and extended PAR (ePAR) sensors. These sensors use a photodiode combined with an optical filter to measure light within a specific spectral range and provide a single aggregated value. A typical example is PAR measurement covering the 400–700 nm range. These sensors are widely used due to their simplicity, but they provide limited information about spectral distribution and do not support detailed spectral control.

2. **Spectrometers**

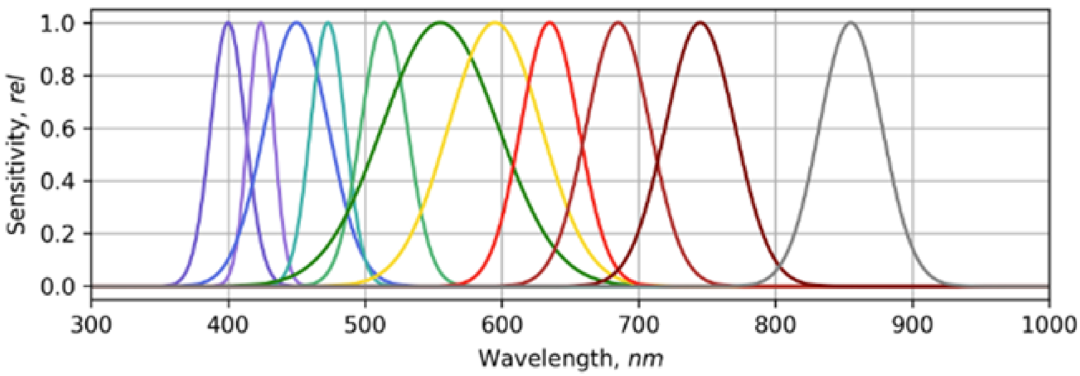
Spectrometers used in greenhouse environments are typically high-precision instruments. They provide full spectral distribution data, usually with a resolution of 1–3 nm. This allows detailed analysis of spectral composition and accurate calculation of metrics such as PAR and ePAR.
However, their use for continuous monitoring across multiple locations is limited. Greenhouse environments often require measurements at multiple points due to spatial variation in light conditions, and deploying spectrometers at scale leads to high investment and increased installation complexity. In addition, spectrometers typically provide raw data that requires further processing before it can be used for control decisions.

3. **Multichannel sensors**
   Multichannel light sensors use several sensing elements (channels), each measuring light intensity within a defined spectral range. These ranges can span from tens to hundreds of nanometers and may overlap.
   The Aranet Light Spectrum Sensor belongs to this category and uses an 11-channel sensor. This type of sensor provides more spectral information than photodiode sensors while remaining suitable for continuous and distributed monitoring across a greenhouse.
   Due to overlapping spectral sensitivities, raw data can be complex to interpret. Therefore, measurement data is processed into simplified, actionable metrics: blue, green, red, far-red, and near-infrared ranges, as well as Photosynthetically Active Radiation (PAR) and extended PAR (ePAR). These metrics allow users to make practical decisions and support automated lighting control without requiring detailed spectral analysis.

Data Processing concept

The Light Spectrum Sensor uses an 11-channel sensing element. The wavelength ranges and relative widths of these channels are shown in the figure below in a normalized view. Some channels overlap, while other parts of the spectrum are covered by a single channel. This is an important aspect affecting sensor performance and is discussed in later sections.

This section describes the data processing algorithm implemented in Aranet Cloud since April, 2026.



To calibrate the sensor, multiple light sources with different spectral characteristics are used. This calibration process produces a calibration matrix, which is applied to estimate a continuous spectrum (internally represented at 1 nm resolution).

The reconstructed spectrum may differ from measurements obtained with high-precision spectrometers, with some wavelength regions showing larger deviations than others. However, the data quality is sufficient for spectral integration and calculation of derived metrics - color bands with a 100 nm range.

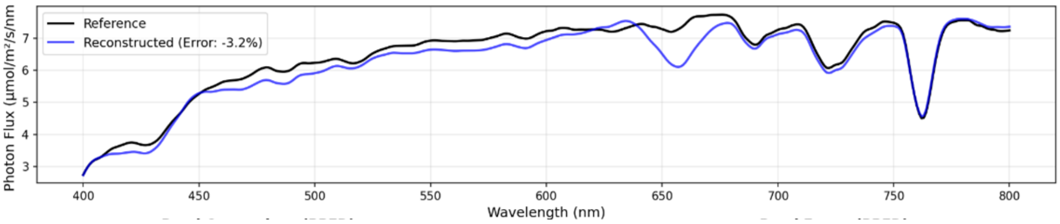
Sensor provides the following derived metrics:

1. Blue: 400-500 nm
2. Green: 500-600 nm
3. Red: 600-700 nm
4. Far-red: 700-800 nm
5. Near infrared: 800-900 nm
6. PAR: 400-700 nm
7. PAR plus far-red (ePAR): 400-800 nm

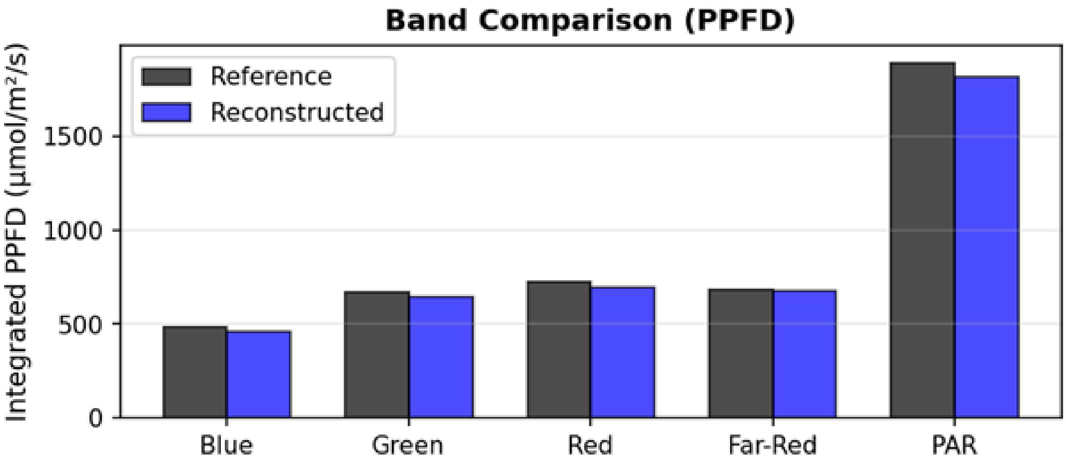
This material does not include the near-infrared metric, as calibration for this part of the spectrum is performed differently. The near-infrared measurement has lower accuracy and should be used primarily as an indicative value.

For the explanation of sensor operation, the reconstructed spectrum is used. In Aranet Cloud, users are provided with derived metrics (color-based values) rather than the full reconstructed spectrum.

The figure below shows an example of a reconstructed spectrum from the Light Spectrum Sensor compared to a reference device (UPRtek PG200N spectrometer) under sunlight conditions.



As a result, users in Aranet Cloud see derived color-based metrics rather than the full spectrum. The figure below shows these metrics in comparison with reference measurements.



Due to differences in measurement technology between the Light Spectrum Sensor and high-precision spectrometers (used as reference devices), some variation in results is expected. The objective is to achieve close agreement with reference values across light spectra typical for greenhouse environments.

Sensor performance depends on how accurately the spectrum is reconstructed under specific lighting conditions. As shown in the Sensor Performance section, the sensor provides reliable results across most common light sources and spectra. It enables accurate estimation of color ratios and PAR[%] and ePAR[%] values, which are relevant for adjusting LED channel composition in greenhouse applications.

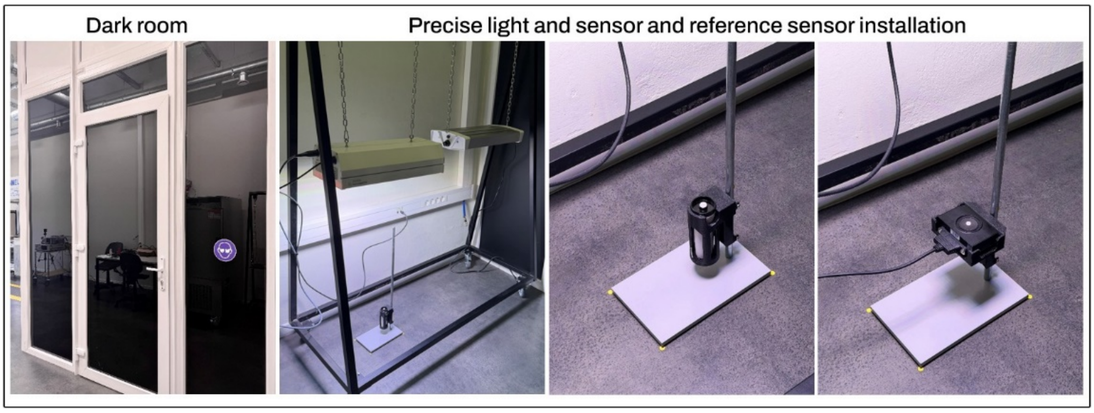
Sensor Performance

Accurate evaluation of sensor performance requires minimizing experimental errors. To achieve reliable results, several factors must be considered:

1. Minimize the influence of external light sources
2. Ensure precise and repeatable sensor positioning
3. Use multiple sensors for comparison
4. Use a calibrated reference sensor
5. Test across a range of light spectra and intensity levels
6. Ensure experimental repeatability

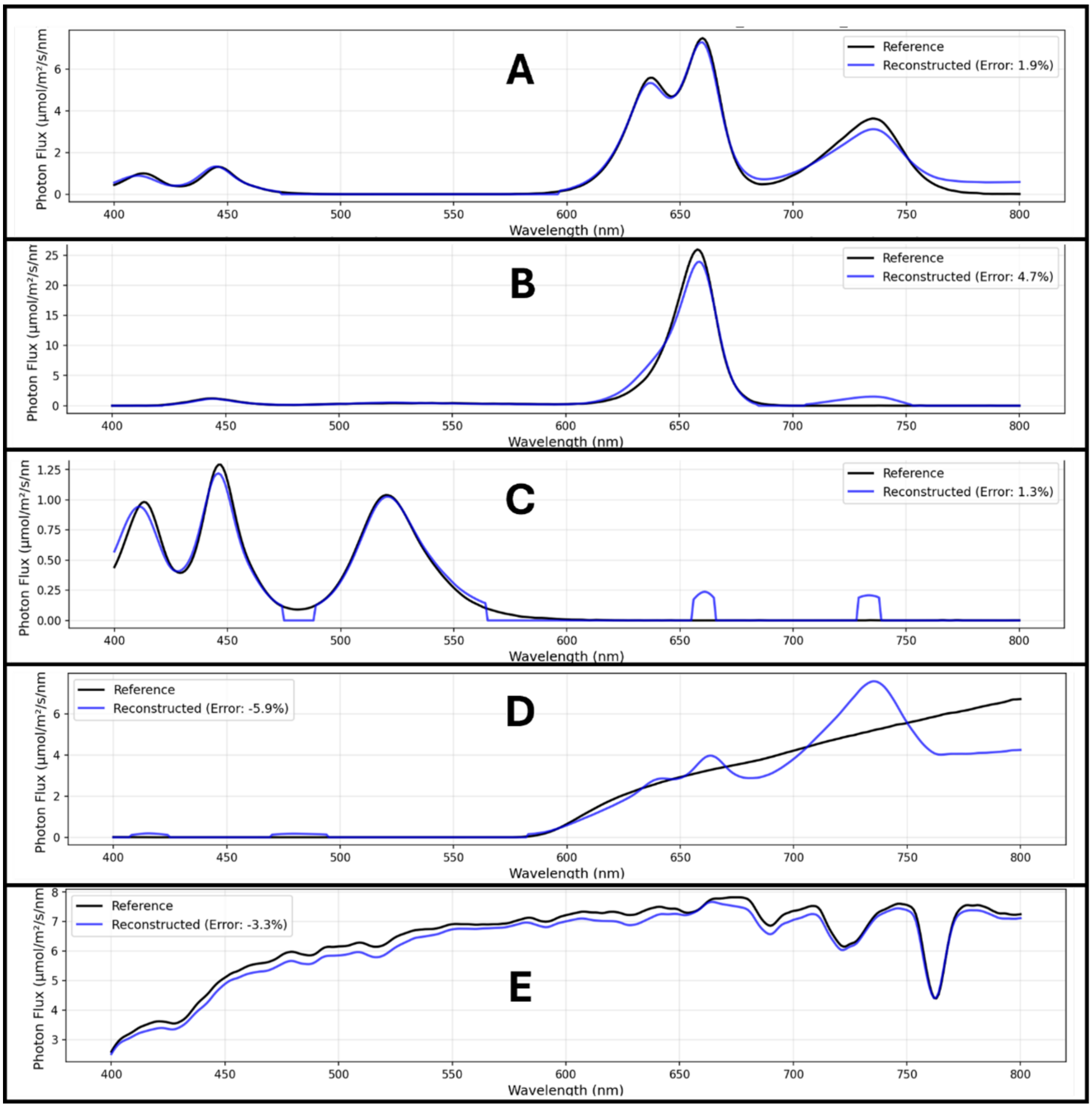
To reduce the impact of external factors, experiments are performed in a controlled dark room environment. Dedicated equipment is used to ensure consistent sensor positioning and repeatable test conditions.

The figure below shows the Aranet dark room and experimental setup.



To calibrate and evaluate sensor performance, more than 45 different light spectra are used. These include LED fixtures with multiple light channels, as well as natural sunlight and other representative lighting conditions. All experiments are performed using multiple Light Spectrum Sensors, typically more than nine units per test.

The figure below shows five examples of reconstructed spectra from the Light Spectrum Sensor under different lighting conditions. These examples illustrate the reconstruction capability of the 11-channel sensor compared to a high-precision spectrometer with 1 nm resolution.



Examples A, B, C, D, and E are selected to represent different spectral conditions across various parts of the spectrum. In the figure, “Reference” refers to measurements obtained using the UPRtek PG200N spectrometer, while “Reconstructed” refers to measurements from the Light Spectrum Sensor (LSS). The table below presents measurement errors in comparison to the reference device.

For example:

- “Band error [%] – Blue” represents the difference between the blue metric measured by the Light Spectrum Sensor and the integrated spectral range of 400–500 nm measured by the reference device.
- “Band / PAR error [%pt] – Red” represents the difference between the Red/PAR ratio measured by the Light Spectrum Sensor and the corresponding Red/PAR value calculated from the reference device.

Example	Band error [%]					Band / PAR error [%pt]		
	Blue	Green	Red	Far-red	PAR	Blue	Green	Red
A	0.60%	66.90%*	0.50%	5.90%	0.10%	0.10%	0.30%	0.30%
B	7.20%	1.10%	1.20%	>100%*	1.50%	0.30%	0%	0.30%
C	3.80%	2.00%	>100%*	>100%*	0.80%	1.70%	0.50%	2.20%
D	>100%*	19.10%	6.40%	6.60%	3.60%	2.40%	0.30%	2.80%
E	5.10%	3.30%	3.30%	2.20%	3.80%	0.30%	0.20%	0.20%

*Not meaningful due to near-zero reference intensity.

The Light Spectrum Sensor has been calibrated and verified across more than 45 different light spectra and intensity conditions, using at least nine sensors in each test. The experimental results, including the examples shown, demonstrate the following:

1. In certain cases, the reconstructed spectrum does not fully follow the reference spectral distribution, particularly in the 650–800 nm range, where only two sensor channels are available.
2. Band errors data represented in red are highlighted to represent situations when high errors might confuse the user. While this error is significant, the actual intensity of that specific part of the spectrum is very low and, in a real-life greenhouse situation, would not matter.
3. The “Band / PAR error” data shows that the relative contribution of each spectral band to PAR is estimated with good accuracy, typically within 3%pt.
4. PAR measurement accuracy varies depending on the light conditions, but is typically within 5%.

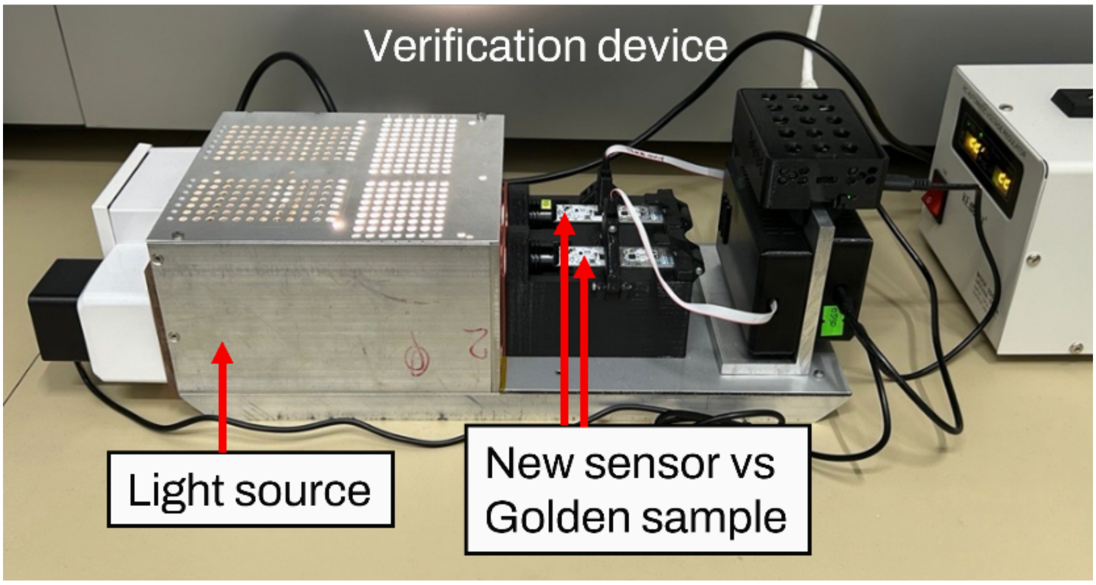
Quality Control

Each sensor undergoes a quality control procedure after manufacturing. This includes testing the microcontroller, measuring power consumption, evaluating Aranet radio performance and signal strength, and verifying measurement accuracy.

During verification, each device is compared against a Golden Sample sensor under defined light conditions. This process validates the performance of all 11 light channels used by the Light Spectrum Sensor. For each channel, the average measured value of the device under test must remain within ±20% of the corresponding value measured by the Golden Sample sensor.

The Golden Sample sensor is verified using a high-precision reference device (UPRtek PG200N spectrometer). If the sensor measurements match those of the Golden Sample within the defined accuracy range, the sensor is approved.

The figure below shows the setup used for sensor verification.

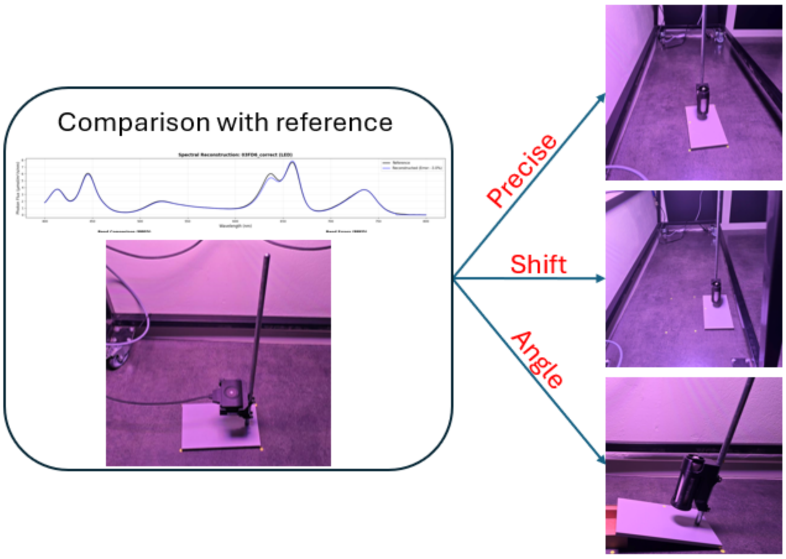


Sensor Usage

Installation tips for Light Spectrum Sensor:

- Always install sensor by using sensor holder (included with sensor). It will allow the sensor to stay steady over time and adjust the sensor angle.
- Install sensor at place of interest - above LED fixtures to measure natural light, at plant level to measure the light the plant receives. Install several sensors various heights to check light distribution over height, directly below, or shifted from LED fixture to see the lighting distribution.
- For installation, use screws or zip ties to mount the sensor holder to the greenhouse structure securely
- Check level – use the adjustment screw on sensor holder to adjust sensor level. A slight angle can significantly influence measurement accuracy.
- Use a soft microfiber cloth to periodically clean the sensor's optical window and remove dust or other contaminants that may accumulate over time. Check regularly to avoid the leaf coverage.

To illustrate the importance of proper installation and consistent measurement conditions, consider the experimental results shown below. The figure compares spectrum measurements from a reference sensor and the Light Spectrum Sensor (LSS). When both sensors are positioned identically, band error remains below 5%. However, even small shifts in position or changes in angle can lead to significantly higher errors. In this example, the shift is 10cm and the tilting angle is 8 degrees.



Color (band)	Blue	Green	Red	Far-red	PAR
Band Error, %	2.7	2.3	3.2	3.4	2.9

Color (band)	Blue	Green	Red	Far-red	PAR
Band Error, %	13.6	13.0	14.4	12.5	13.9

Color (band)	Blue	Green	Red	Far-red	PAR
Band Error, %	9.3	8.6	9.8	9.3	9.4

Recommended Practices

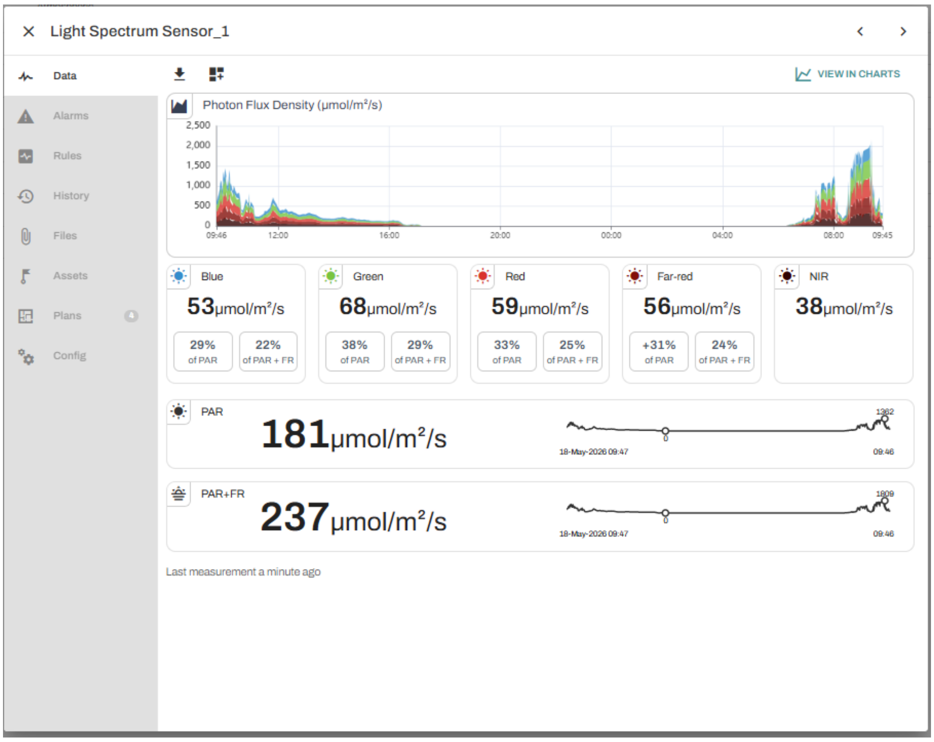
As demonstrated in the example above, light intensity in a greenhouse varies depending on location and measurement height. The following practices are recommended:

- Initially, test multiple measurement positions to evaluate light distribution and intensity variation. Light levels above and below the canopy can differ significantly.
- If the sensor data is used to control the LED lights, it is recommended to install at least two sensors above the lighting fixtures. Position the sensors separately and diagonally across the greenhouse. Use the highest reading from these sensors, as one or more sensors may occasionally be shaded, for example, by a greenhouse structures. This approach helps provide a more reliable assessment of natural light contribution and supports overall lighting control decisions.
- Install several sensors in different areas of the greenhouse, as light conditions may vary due to structure, lighting distribution, shading, and other factors.
- Use Aranet Cloud dashboards to monitor light conditions over time. Virtual sensors can be used to calculate DLI for color metrics, as well as PAR and PAR+FR values.
- Track trends over time — artificial lighting efficiency may decrease over time. As plants grow larger and shade the lower parts of the canopy, light intensity at the lowest canopy levels may become insufficient.

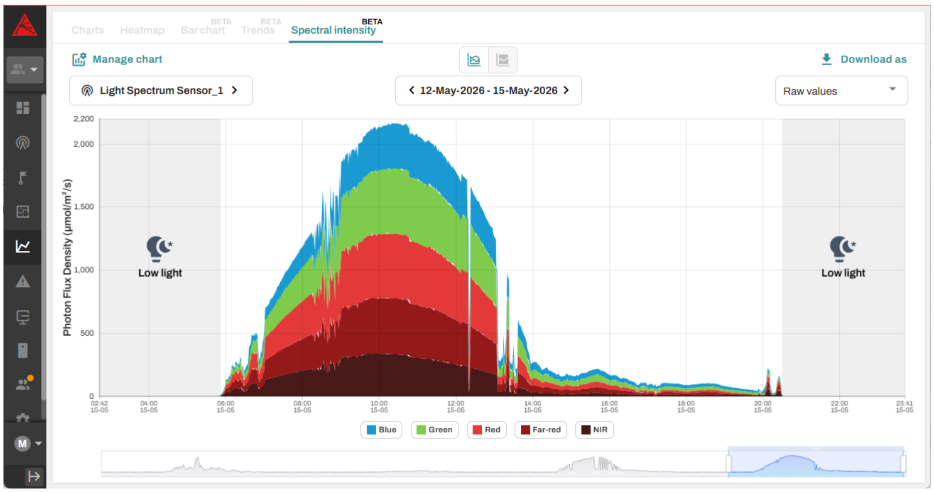
Data overview in Aranet Cloud

The Light Spectrum Sensor includes dedicated data visualization features for measurement overview and analysis.

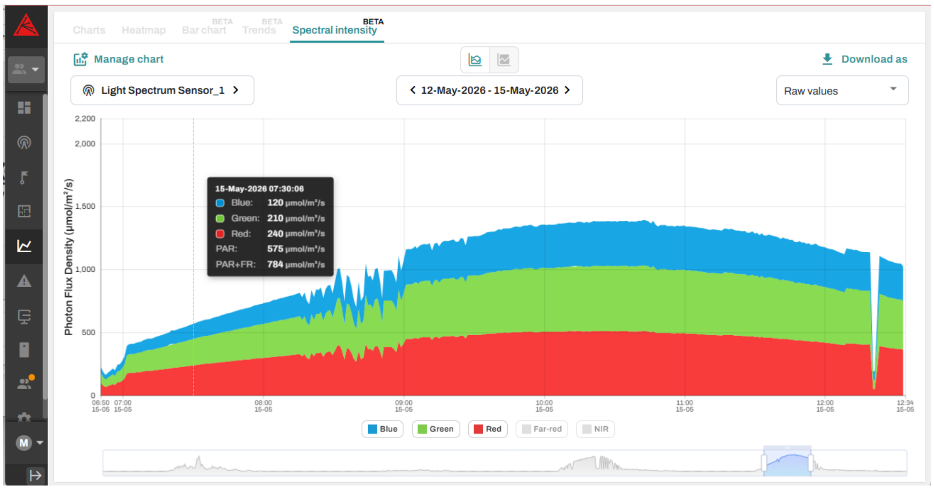
- Selecting a sensor from the sensor list opens the sensor card. The sensor card displays measurements from the last 24 hours, including absolute values for each color, PAR and PAR+FR values, as well as the percentage contribution of each color within the PAR or PAR+FR range.



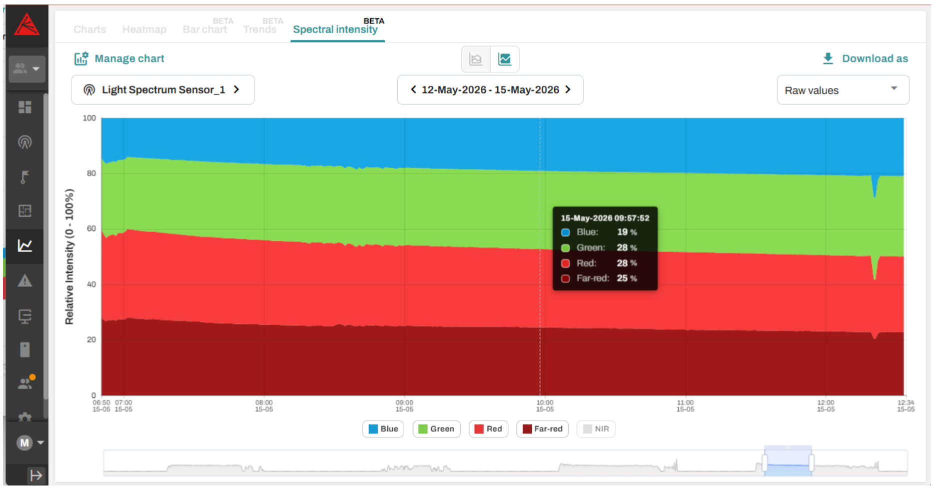
- Select View in Chartsto display a stacked graph of spectral channels over time. The displayed days can be managed using the Manage Chart feature. Select a specific time period using the bottom time navigation bar. A low-light regime is indicated when PAR+FR intensity falls below 5 µmol/m²/s, which is the sensitivity threshold of the sensor.



- Click the color legends to enable or disable specific spectral channels. For example, you can display only PAR spectrum channels such as blue, green, and red.



- Select Normalized View to visualize the relative intensity of all selected spectral channels over time.From the top of the graph to the Bottom of the graph



- Visualize data in Dashboards using Sensor widgets and Floor Plans. Select between absolute and relative intensity values according to your application needs.