Measurement of Ray Data of an LED Using the Goniophotometer RiGO801-LED

This Application Note discusses the measurement of ray data using a white LED of the type *ams OSRAM LCW CP7P*. After a brief introduction to the measurement principle, the setup and execution of the measurement are explained in detail. Further information can be found in the documentation of the measurement program [1]. Finally, an overview of the measurement results is provided. The further processing of the data is described in a separate Application Note.

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Measurement Principle of the Goniophotometer RiGO801 – LED

All RiGO801 goniophotometers utilize the near-field measurement principle, where a luminance measurement camera (ILMD, see [2]) is moved around the light source to capture the spatial luminance distribution. This distribution is then converted into ray data and the luminous intensity distribution (LID) (see [3], [4], [5], [6], [7]).

Ray data, also commonly referred to as ray files, consist of vectors with associated luminous flux components. A sufficiently large number of rays accurately represents the radiation characteristics of a light source. They are frequently used for realistic simulation of optical components.

The goniophotometer **RiGO801 – LED**[1] is specifically designed for measuring ray data from LEDs and LED modules. The luminance measurement camera **LMK 6-5**[2] moves along a circular arc (Theta-axis) around the test object, which is mounted on the vertical rotation axis (Phi-axis).

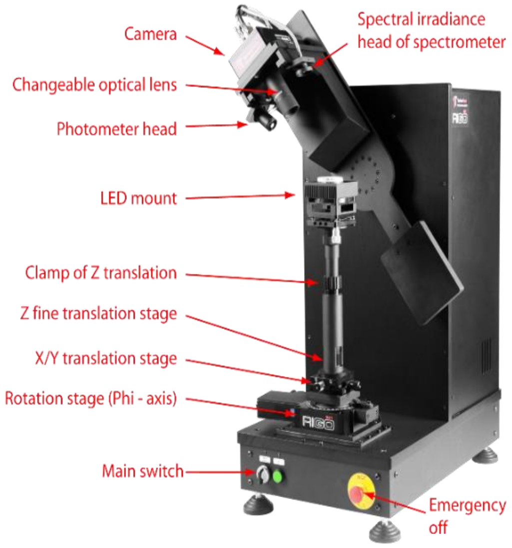


Figure 1: Goniophotometer RiGO801-LED

The measurement of a single ray is exemplified in Figure 2. A pixel of the image sensor, together with the center of the lens, defines the starting point (P_x, P_y, P_z) and direction (n_x, n_y, n_z) of the ray. The luminous flux component $\Delta\Phi$ is calculated from the luminance of the pixel and the corresponding solid angle. The rays from all luminance images collectively form the ray dataset.

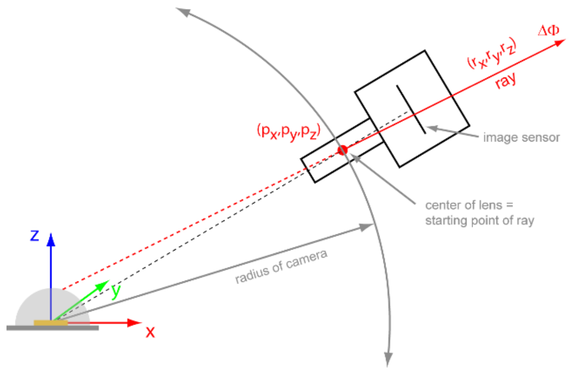


Figure 2: Measurement of a Ray

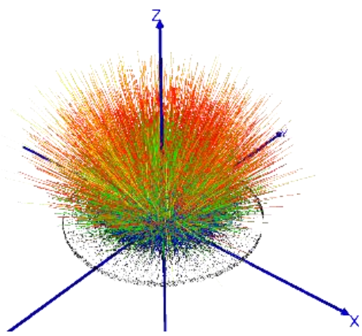


Figure 3: Ray Dataset

[1] https://www.technoteam.de/products/goniophotometer_rigo801/rigo801__led/index_eng.html
[2] https://www.technoteam.de/products/imaging_photometer_colorimeter/lmk_6_color/index_eng.html

Preparation of the Measurement

Before the measurement, the LED is mounted onto the goniophotometer's test fixture (see Figure 4). The test fixture includes a heat sink (75 mm x 75 mm) with a threaded grid plate, a fan, and a leveling unit. The heat sink ensures stable thermal conditions during the measurement, with the fan being activated for higher power losses if necessary.

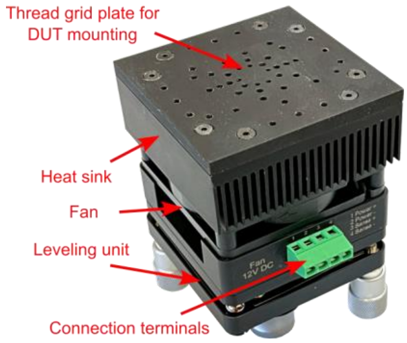


Figure 4: Test fixture

The LED should be soldered onto a circuit board with appropriate mounting holes for attachment to the grid plate. Obstructive components or other interfering elements should be avoided. In particular, the viewing angles required for aligning the LED in the goniometer must remain unobstructed (see the following section). In this Application Note, an LED mounted on a star board is used, which can be easily attached to the grid plate (see Figure 5).

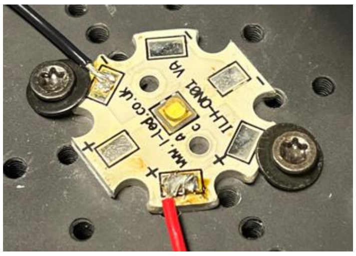


Figure 5: Mounted LED Board

The connecting wires are routed to the lateral terminal block of the test fixture. For stable LED operation, the use of constant current is recommended. When measuring ray data, the nominal parameters are typically not the primary focus, so the operating current may deviate from the nominal values. However, it should be selected such that the LED operates in a stable mode. Too low a current can cause undesired behavior in high-power LEDs, while excessive current can increase thermal stress.

The test fixture is now mounted on the goniophotometer's telescopic axis, and the height and rotation are preliminarily adjusted by sight.

Figure 6: Mounted test fixture

Aligning the LED in the Goniometer Coordinate System

The Theta and Phi axes of the goniophotometer define a spherical coordinate system, which is linked to a Cartesian coordinate system (see Figure 7). The measured ray data are output in this goniometer coordinate system. Therefore, it is crucial to precisely know the position of the test object within the coordinate system to ensure the correct use of the data.

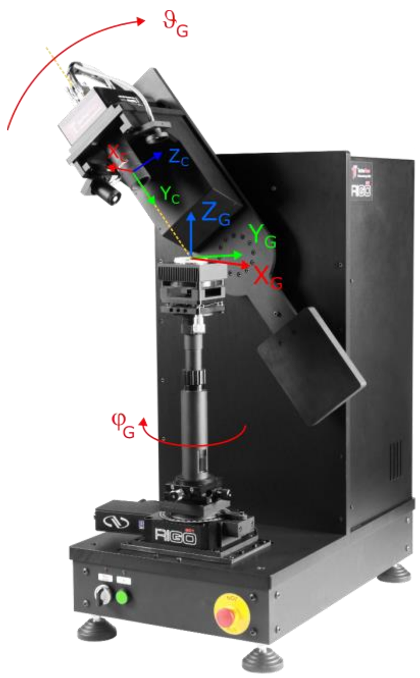


Figure 7: Goniometer Coordinate System

It is recommended to align the test object as precisely and traceably as possible within the coordinate system and to document this alignment carefully. This is done using the "*Measurement -> Align Test Object*" function. A dialog opens, displaying the camera image with selectable grid lines and the coordinate system. It also provides controls for the goniometer axes and the option to activate an incident light illumination (see Figure 10).

The camera is typically positioned to view along the axes of the Cartesian coordinate system to capture suitable images for positioning, leveling, and rotating the LED.


Figure 8: X/Y adjustment unit and Z fine adjuster

The horizontal positioning of the LED is achieved using the X/Y adjustment unit of the telescopic axis. The height adjustment can be made by moving the telescopic tube over a wide range and fine-tuning it with the fine adjuster. Rotation is enabled by turning the telescopic tube with the clamp slightly loosened. Leveling of the LED is performed using the leveling unit integrated into the test fixture.

The following aspects should be considered during positioning:

- The center of the light-emitting area should ideally be positioned in the middle due to the limited depth of field of the lens.
- The rotation and leveling of the LED should be based on clearly identifiable edges or contours whenever possible.
- The features used for alignment should correspond to those found in the datasheet drawings or CAD data. This ensures the position of the coordinate center can be precisely related to the LED.


Figure 9: Leveling unit of the test fixture

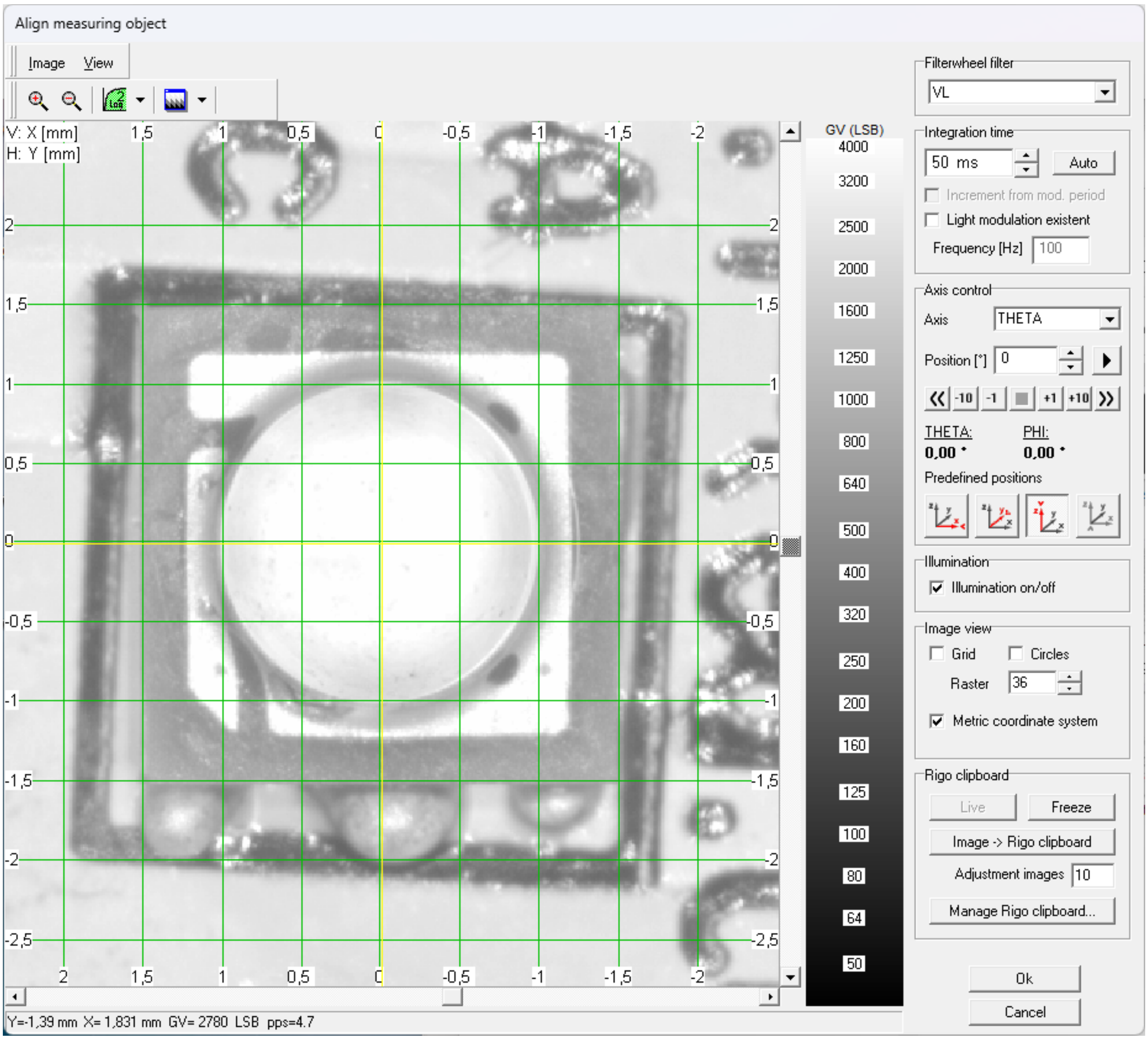


Figure 10: Dialog for Aligning the LED in the Goniometer Coordinate System

For the LED used, the square housing is aligned symmetrically to the center of the coordinate system in the top view. In the side views, the height and tilt are adjusted in the respective planes. The top of the housing is positioned to lie within the x/y plane (see Figure 11).

After completing the alignment, the views of the LED within the coordinate system should be saved for later processing of the measured ray data. This can be done either by saving screenshots or by storing the views in the measurement file (*Image -> RiGO clipboard*).

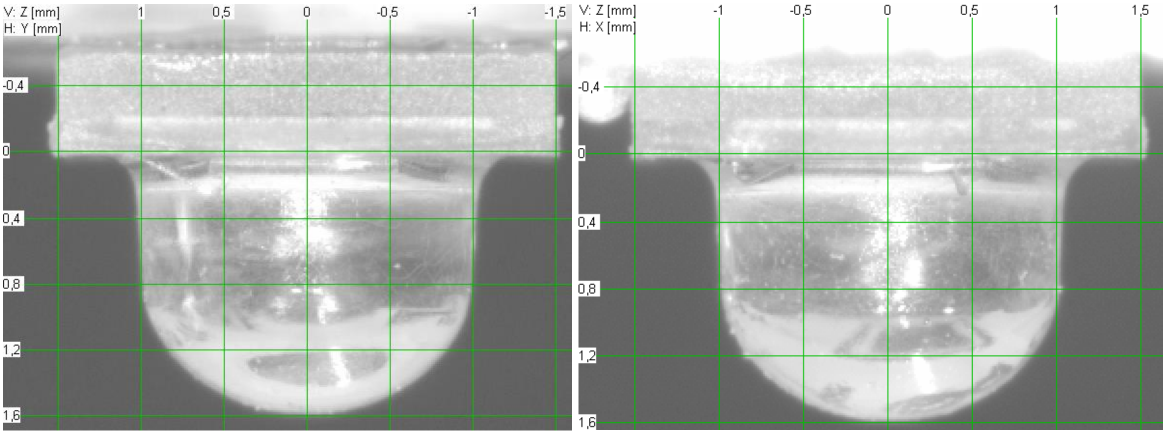


Figure 11: Side views of the LED during positioning

Setting Up the Measurement

The measurement setup is initiated via the menu option "*Measurement > Start Measurement...*". The measurement program then guides the user step by step through various dialogs where the settings and parameters for the measurement are configured (see Figure 12).

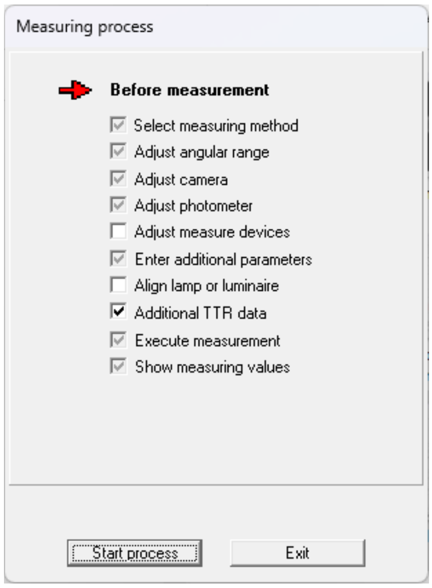


Figure 12: Steps for setting up the measurement

Selection of Measurement Mode and File Name

For the measurement of ray data, the camera mode is selected, and the option "*Save Ray Data*" is activated. Two output files are then defined: a TTL file for the luminous intensity distribution and a TTR file containing the ray data in TechnoTeam format.

Selection of Angular Range and Angular Resolutions

For the angular range, the entire area with relevant emission should be selected. This typically includes ±90°, but many LEDs, as in this case, emit over a larger angular range. Here, beyond 90°, higher luminance levels are observed, particularly around the lens. Although these may partially represent stray light, they are critical for a realistic emission characteristic and should therefore be captured. In this example, an angular range of ±100° was chosen, as beyond this point, shading from the circuit board or the test fixture occurs.

This consideration leads to the topic of proper, shadow-free mounting of the LED. For emissions beyond 90°, portions of the light are reflected by the circuit board rather than being measured accurately. To ensure a clear optical path, the mounting position of the LEDs should be elevated in such cases. In the present example, this was not implemented, and therefore these effects should be taken into account and evaluated during the analysis.

The angular measurement resolutions of the two goniometer axes are typically 0.5° or 0.75°, enabling particularly high-quality sampling of the luminance distribution. This high resolution has minimal impact on the measurement duration, as the measurement is performed on-the-fly and is completed relatively quickly, taking approximately 1.5 to 2 hours.

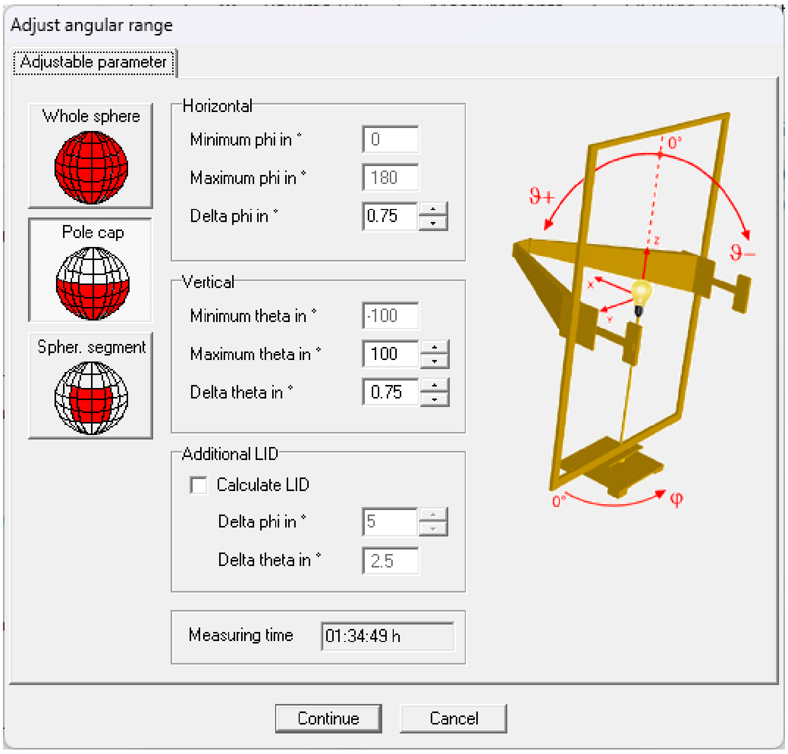


Figure 13: Setting the angular range and resolution

Camera settings

For the camera settings, the integration time, the ND filter used, and, in the case of a filter wheel camera, the appropriate filter are selected—specifically, the V(λ) filter for photometric measurements. Since the integration time remains constant during the measurement, it must be correctly set at the position of maximum luminance. The dialog provides the option of a maximum scan, which moves the camera to the position of maximum luminance.

At this position, the integration time is set, ensuring that the camera operates at around 90% utilization for an optimal dynamic range. In this case, a 10 ms integration time results in 90% utilization (see Figure 14).

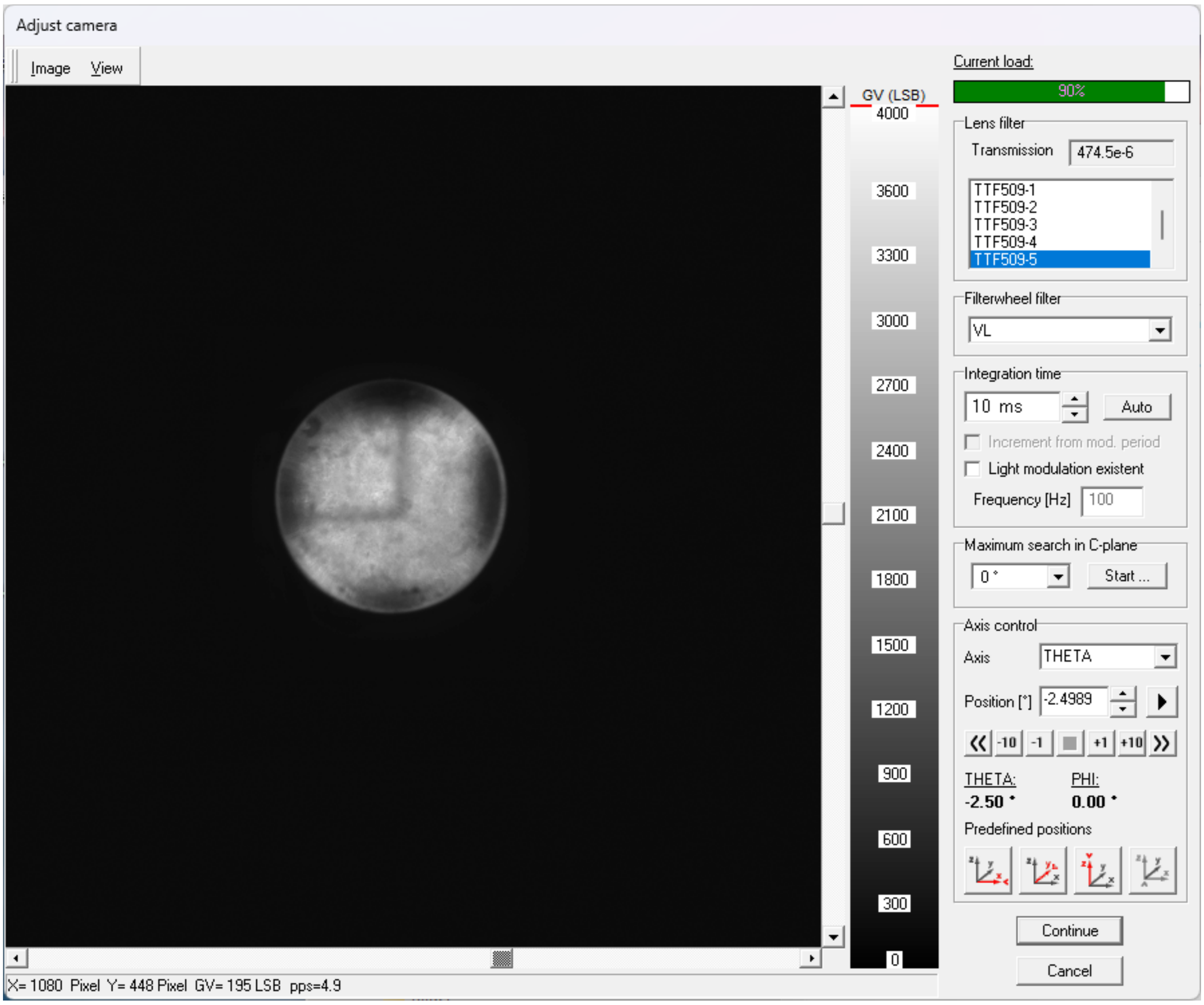


Figure 14: Camera settings

Photometer settings

As with the camera, the measurement range of the photometer remains constant during the measurement. Therefore, the measurement range must be set at the position of maximum utilization, corresponding to the maximum illuminance. Further details on this process can be found in the measurement manual.

Further Steps Before Starting the Measurement

Before the dialog for starting the measurement appears, an input form opens for various optional details about the measurement and the test object. Additionally, a dialog for editing data in the program's special clipboard is displayed. This includes the images of the LED alignment, which may have been added to the clipboard earlier. These data can be reviewed and edited at this stage if necessary. To include the data in the TTR file, the option "*Transfer Rigo Clipboard to TTR Additional Data*" must be activated.

Perform measurement

The light source must reach a stable operating state before starting the measurement. Two options are available for the start procedure:

1. **Delay Time:** Specifies a fixed time interval after which the measurement begins.
2. **Automatic Start Procedure with Stability Monitoring:** This method follows CIE S 025 [8] or IES LM-79-19 [9]. The temporal evolution of the illuminance is monitored, and a stability criterion is evaluated within a defined time window (typically 15 minutes). The measurement starts automatically as soon as the desired stability threshold is reached. A stability threshold of 0.2% is recommendable for LEDs.

The parameters used in this example are shown in Figure 15.

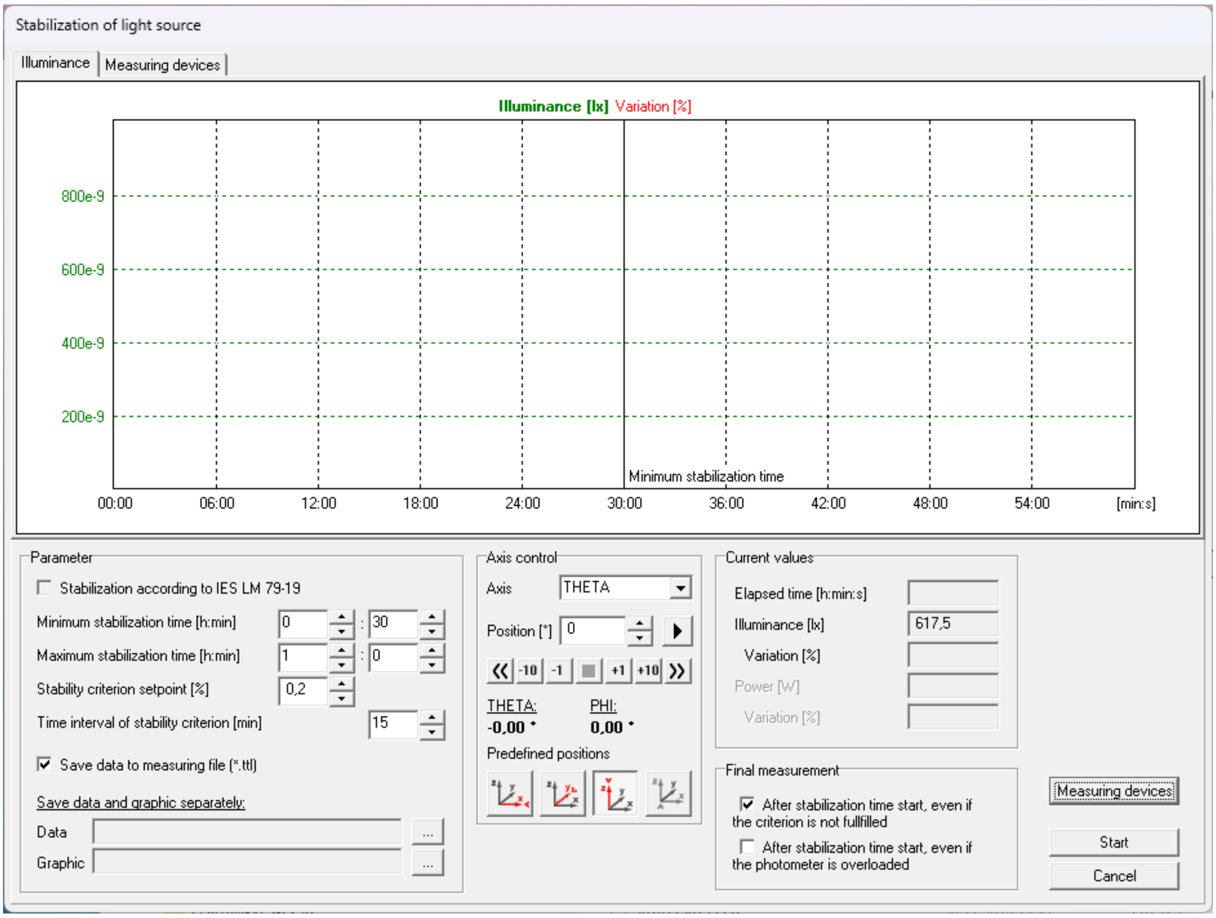


Figure 15: Automatic start of measurement after stabilization phase

Measurement results

After the measurement is completed, a window opens with multiple tabs displaying all the details and results of the measurement (see Figure 16).

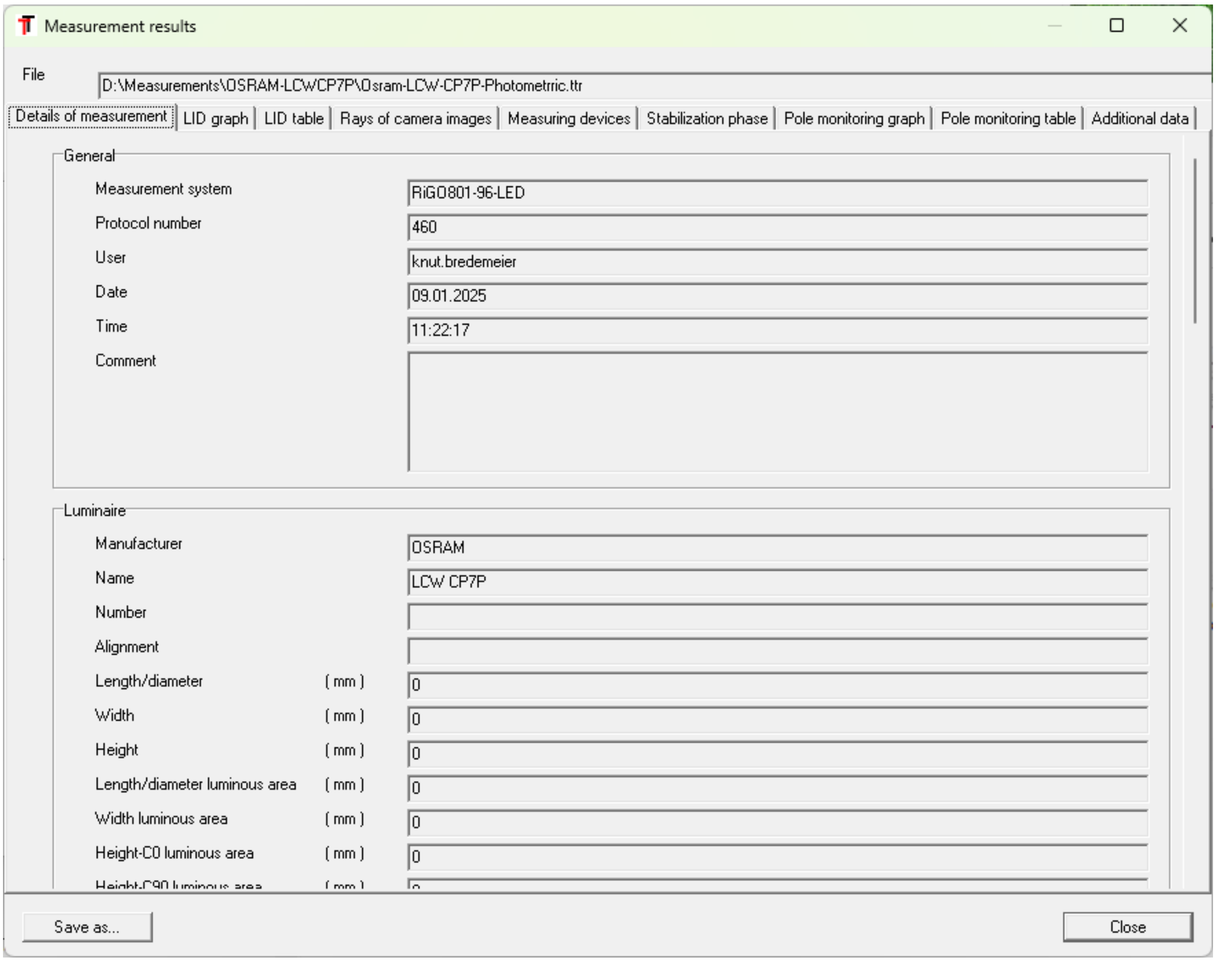
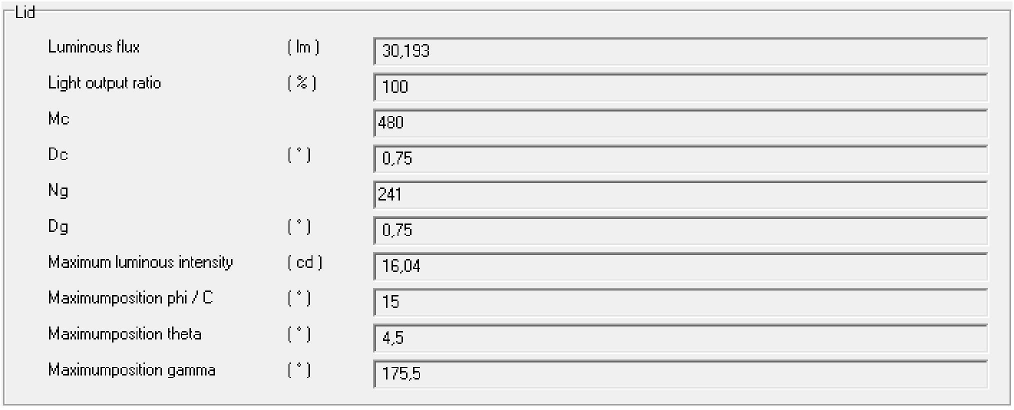


Figure 16: Overview of measurement details and results

General Information and Measured Luminous Flux

In this form view, the general information and measurement settings are displayed first. Further down in the list, under the "*LID*" section, the measured luminous flux and the maximum luminous intensity along with its corresponding angle are provided.



Lid		
Luminous flux	(lm)	30,193
Light output ratio	(%)	100
Mc		480
Dc	(°)	0,75
Ng		241
Dg	(°)	0,75
Maximum luminous intensity	(cd)	16,04
Maximumposition phi / C	(°)	15
Maximumposition theta	(°)	4,5
Maximumposition gamma	(°)	175,5

Figure 17: Measurement results: Luminous flux and maximum luminous intensity

Luminous Intensity Distribution Data

The data of the measured luminous intensity distribution are displayed in the "*LID-Graph*" tab as a polar diagram (Figure 18) and in the "*LID-Table*" tab as a data table.

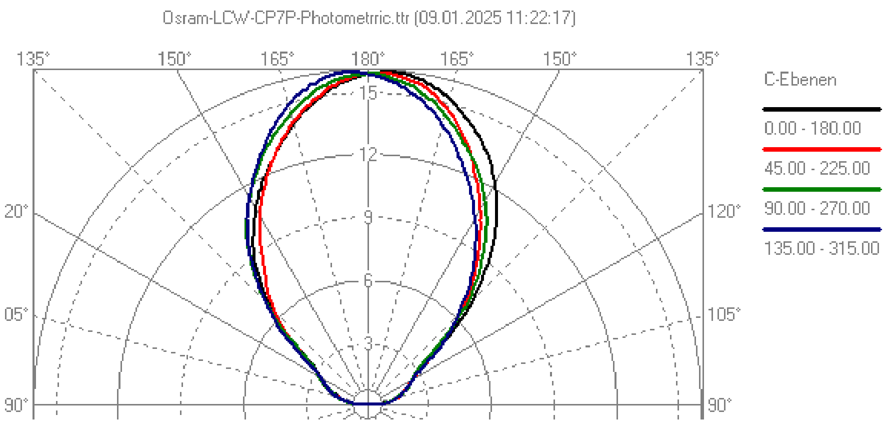


Figure 18: Polar diagram

A clear 3D representation of the LID can be created using the free TechnoTeam 3D-Viewer[3]. This view makes it easy to identify effects such as luminous flux variations during the measurement or other anomalies.

The 3D view of the measured LID (Figure 19) reveals an asymmetry and deformation in the luminous intensity distribution. This necessitates further examination and additional measurements to determine whether the observed deviations are due to variations in LED properties or specific issues with the measured LED.

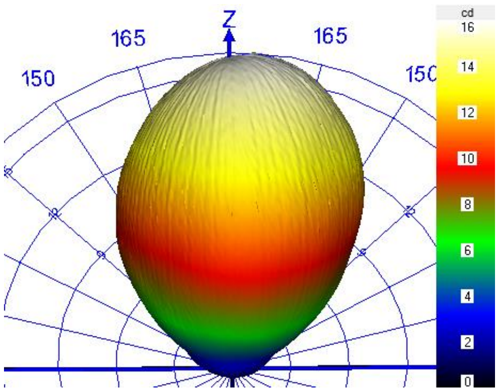


Figure 19: 3D view of the LID

[3] https://www.technoteam.de/products/goniophotometer_rigo801/rigo801_software/3d_viewer

In the present case, the issue could be caused by damage to the LED due to excessive thermal stress during the soldering process.

Ray data

The "*Rays from Camera Images*" tab displays the generated ray starting points for each luminance image. Figure 20 shows an example of the ray data image for a side view. The LED lens and the optically distorted LED chip are visible. Outside the LED, some stray light components can be observed, which require further investigation. In this case, these are reflections from the circuit board, as previously discussed. A more detailed evaluation will be provided in a separate Application Note on the processing and analysis of the measured ray data.

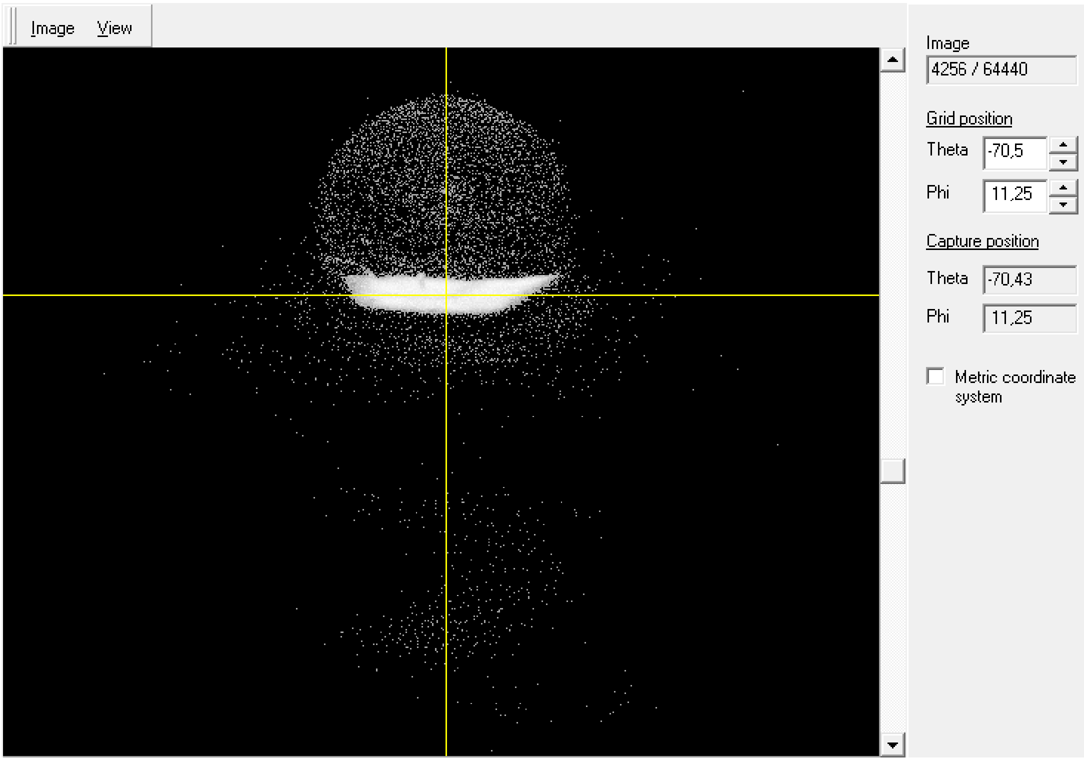


Figure 20: Ray Data of a camera image

Data from External Measurement Devices

The RiGO801 measurement program allows for the integration of external measurement devices such as power analyzers, voltmeters, temperature sensors, or other data loggers. During the measurement, data from the connected devices are recorded and stored in the TTL file. The "*Measuring devices*" tab displays this recorded data.

For the measurement discussed here, only the standard measurement parameters are available: the device temperature and the temperature of the test fixture. These should remain as constant as possible during the measurement (with changes of less than 1°C).

Data from the Stabilization Phase

If the measurement was started with automatic stability monitoring, the data recorded during the stabilization phase are stored in the TTL file. The "*Stabilization Phase*" tab visualizes this data (Figure 21).

In this case, the stability criterion for this LED dropped well below the threshold of 0.2% within a short time. However, due to the settings, a minimum waiting time of 30 minutes was observed. For higher operating currents, significantly longer stabilization times can be expected.

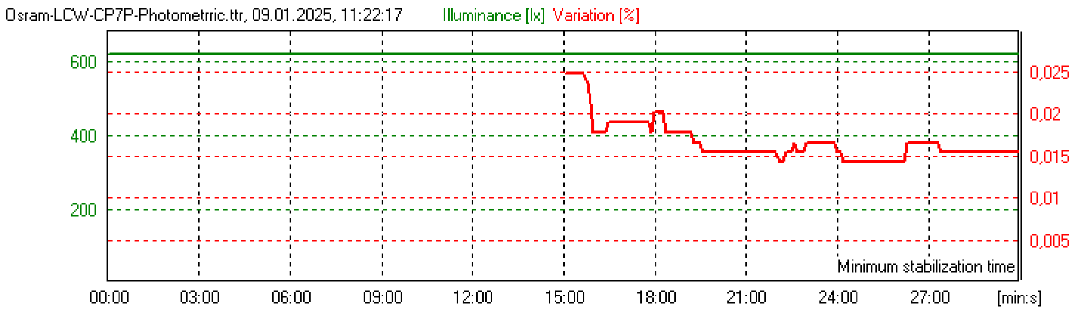


Figure 21: Data from the LED stabilization phase

Pole Monitoring

Another important criterion for evaluating the stability of the LED operating conditions during the measurement is the stability of the measured illuminance values at the pole of the spherical coordinate system. During each Theta scan of the goniometer, a pole value is recorded, and these values should ideally remain constant. The data are also stored in the TTL file and displayed in the "*Pole Monitoring Graph*" and "*Pole Monitoring Table*" tabs.

In this case, only a very slight drift of 0.16% was observed.

Zusatzdaten

The TTR file format allows embedding various additional data into the file. These may include luminance images, views of the LED alignment within the coordinate system, spectral measurement data, datasheets, or CAD data. The "*Additional Data*" tab displays these embedded items.

For the measurement performed here, several alignment views of the LED were copied into the TTR additional data and are now available for review in this tab (see Figure 22).

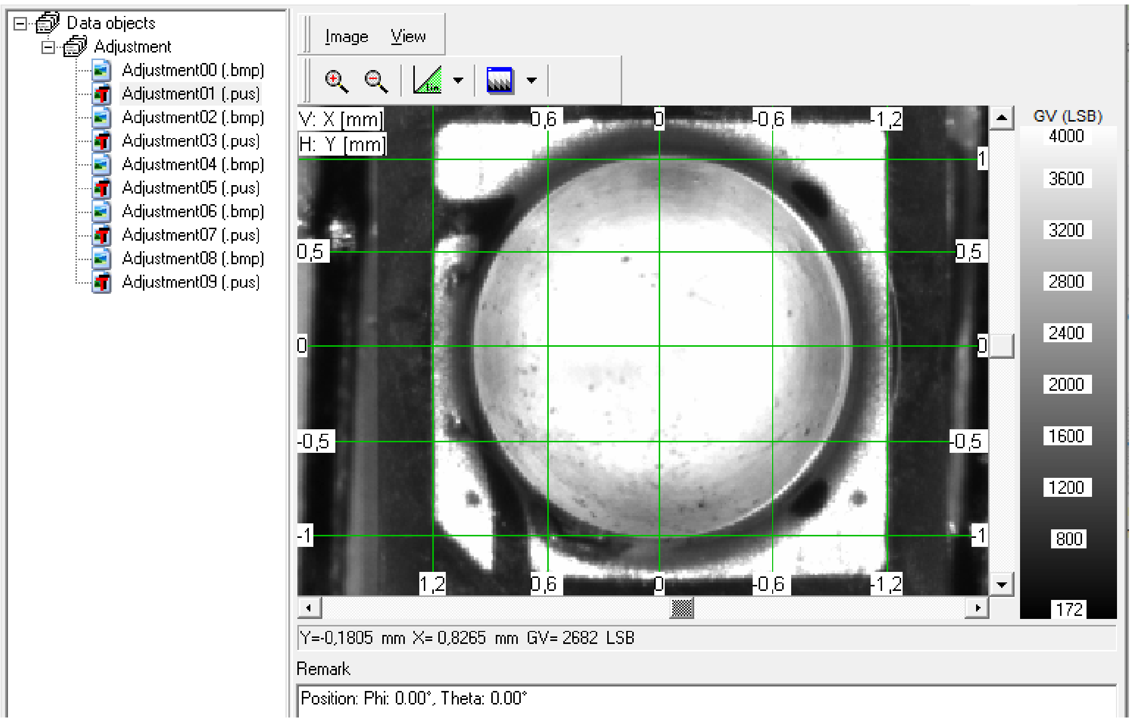


Figure 22: TTR additional data

Post-Processing of Measurement Data

The measurement results are provided in two files:

1. **TTL File:** This ASCII INI-format file contains the LID as well as all the details and parameters of the measurement. The LID can be exported in various formats, such as IES LM-63 [10], EULUMDAT[4], or ASCII. Detailed information is provided in the Measurement Manual [1] and the *Converter801* Software Manual [10].
2. **TTR File:** This file includes the measured ray data, optional additional data, and the contents of the TTL file. Post-processing is carried out using the free *Converter801*[5] software, whose primary function is to export the ray data in various formats, including IES TM-25 [11], ASAP, Speos, LightTools, LucidShape, Zemax, and TracePro.

To generate ray data, additional settings are required that necessitate a thorough understanding of ray generation and measurement. These parameters can be embedded in the TTR file, enabling external users to utilize the processed ray file without requiring additional knowledge. A detailed explanation of the associated concepts and settings is provided in a separate Application Note.

[4] https://en.wikipedia.org/wiki/EULUMDAT
[5] https://www.technoteam.de/products/goniophotometer_rigo801/rigo801_software/converter_801

References

[1] TechnoTeam Bildverarbeitung GmbH, "RiGO801 Measuring program," [Online]. Available: https://www.technoteam.de/products/goniophotometer_rigo801/rigo801_software/rigo801_measuring_software/index_eng.html.

[2] CIE, „CIE 244:2021 Characterization of Imaging Luminance Measurement Devices (ILMDs),“ CIE, Vienna, 2021.

[3] CIE 070-1987, „The Measurement of Absolute Luminous Intensity Distributions,“ CIE, 1987.

[4] R. Poschmann, M. Riemann und F. Schmidt, „Verfahren und Anordnung zur Messung der Lichtstärkeverteilung von Leuchten und Lampen“. DE Patent 41 10 574, 30 March 1991.

[5] M. Riemann und F. P. R. Schmidt, „Zur Bestimmung der Lichtstärkeverteilung von Leuchten innerhalb der fotometrischen Grenzentfernung mittels eines bildauflösenden Goniofotometers,“ *LICHT,* Nr. 7-8, pp. 592 - 596, 1993.

[6] I. Ashdown, „Near-Field Photometric Method and Apparatus“. USA Patent 5,253,036, 12 October 1993.

[7] I. Ashdown, "Near-field photometry: a new approach," *J. Illuminating Engineering,* vol. 22, pp. 163-180, 1993.

[8] CIE, „CIE S 025:2015: Test Method for LED Lamps, LED Luminaires and LED Modules,“ CIE, Vienna, 2015.

[9] IES, „IES LM-79-19 Optical and Electrical Measurements of Solid State Lighting Products,“ Illuminating Engineering Society, New York, 2019.

[10] IES, „IES LM-63-19: IES Standard File Format for the Electronic Transfer of Photometric Data and Related Information,“ Illuminating Engineering Society, New York, 2019.

[11] TechnoTeam Bildverarbeitung GmbH, „Software manual Converter801,“ https://www.technoteam.de/products/goniophotometer_rigo801/rigo801_software/converter_801/index_eng.html.

[12] IES, „IES TM-25: Ray File Format for Description of the Emission Properties of Light Sources,“ Illuminating Engineering Society, New York, 2020.

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