TechnoTeam Bildverarbeitung GmbH

**Application Note**

AN 2003
2025

# Generation and Processing of Ray Data from an LED Measured with the RiGO801-LED Goniophotometer

This Application Note explains how ray data can be generated from the TTR file of a measured LED and exported in various file formats. It provides all the necessary fundamental knowledge and concludes by demonstrating how the TTR file can be prepared for general applications using the free conversion software *Konverter801*.

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# TechnoTeam Ray Data in TTR File Format

The *TechnoTeam RiGO801 Goniophotometer* utilizes the near-field measurement principle in combination with an Imaging Luminance Measurement Camera (ILMD, see [1]) to measure ray data. This data is initially stored in the proprietary TechnoTeam TTR format. Using the free *Konverter801*[1] software, the ray data can subsequently be converted into common standard formats, such as *IES TM-25* [2], *ASAP, Speos, LightTools, LucidShape, Zemax* and *TracePro*.

A detailed description of ray data measurement using an LED as an example can be found in Application Note AN2002 [3]. The following sections focus exclusively on the post-processing of the measured data.

## *Ray data*

A ray in this context refers to the luminous flux or radiant flux emitted from a (virtual) surface element of a light source in a specific direction. In addition, a ray can be associated with further properties, such as spectral data. A sufficiently large number of such rays allows for an accurate representation of the light source's emission characteristics. The resulting dataset is referred to as *ray data*, commonly known as *rayfile* or *ray set*.

Ray data is a fundamental component in the development of optical systems, as it provides a realistic representation of light sources within the optical system, enabling precise simulations and design.

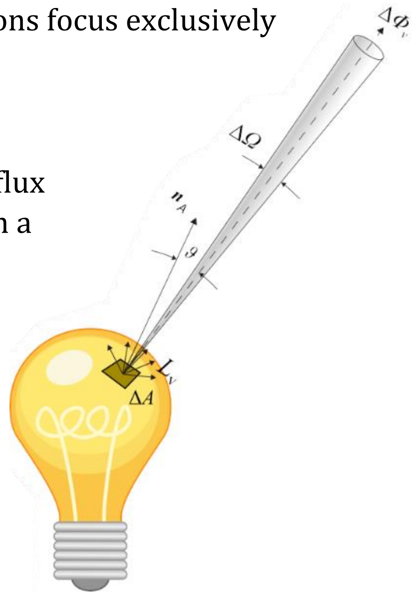


*Figure 1: Illustration of a Ray*

## *Generation of Rays from the TTR File Format*

In a TTR file, the measured ray data is stored in a preprocessed format as a sequence of images (see Figure 2). Each image is associated with a specific camera position within the goniometer coordinate system.

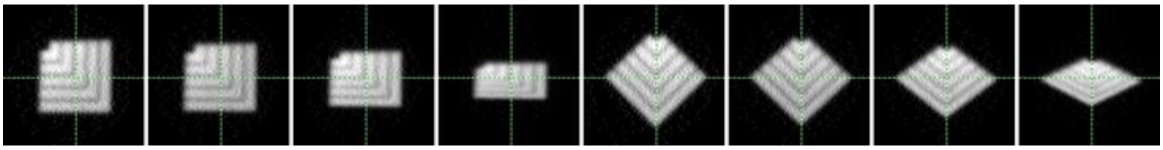

*Figure 2: Sequence of ray data images*

To calculate a vector from the image coordinates of a ray, both the camera position and the precise definition of the camera coordinate system are required (see Figure 3). The center of the camera coordinate system corresponds to the projection center of the lens. Through a coordinate transformation, a vector is generated in the goniometer coordinate system, with its starting point located on a spherical surface. This spherical

[1] https://www.technoteam.de/produkte/goniophotometer_rigo801/rigo801_software/konverter_801

surface is defined by the distance between the lens projection center and the coordinate system origin (camera radius, see Figure 4).

Each ray is assigned a portion of luminous flux, which is calculated from the luminance image. All the necessary information for ray calculation, including camera and coordinate data, is fully contained in the TTR file.

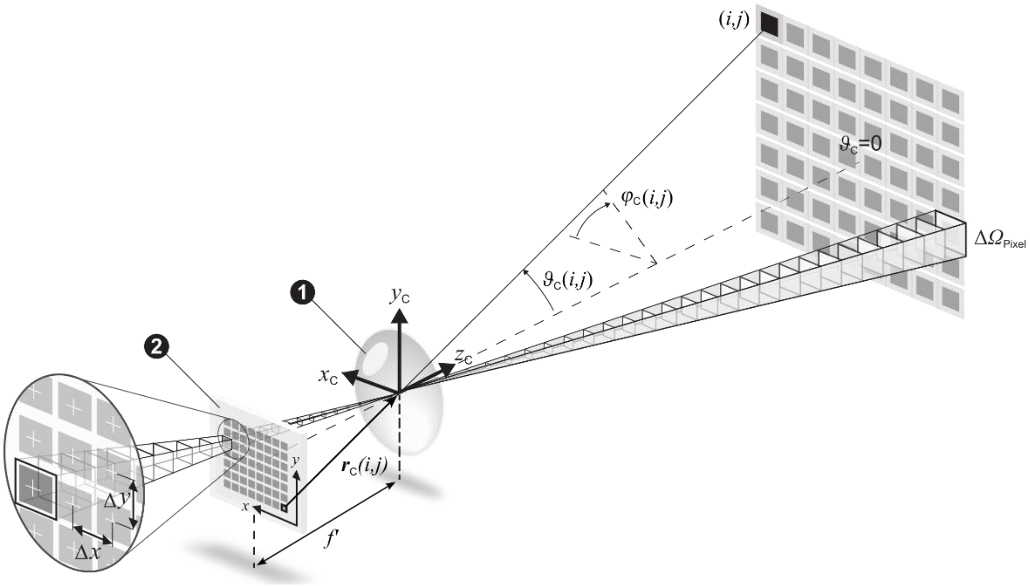


*Figure 3: Camera coordinate system*

The calculated rays initially originate from a spherical surface that is relatively far from the light source. While this distance is irrelevant for describing the emission characteristics of the light source, it can become problematic during raytracing in optical simulations. Optical components are usually located in close proximity to the light source, so the ray starting points should ideally be positioned in front of these components.

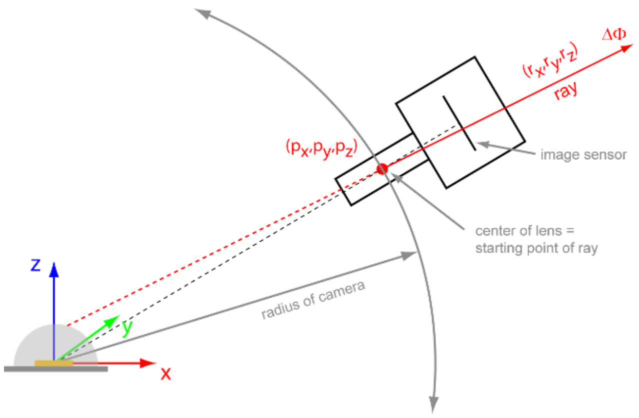


*Figure 4: Ray in the goniometer coordinate system*

When generating rays from a TTR file, the starting points can be shifted to a so-called *target geometry* using raytracing algorithms. Available target geometries include *sphere*, *cuboid*, and *cylinder*. The target geometry should be defined as a bounding surface that closely encloses the light emission volume. However, care must be taken to avoid intersections (undercuts), as rays that do not intersect with the target geometry will be discarded.

To define the starting points of the rays relative to the target geometry, two modes are available:

1. **Surface Mode** (Default): In this mode, the starting points of the rays are shifted to the surface of the target geometry (see Figure 5). This is the most common approach, as it positions the rays on a clearly defined boundary surface.
2. **Volume Mode:** In this mode, the starting points are shifted to the midpoint between the entry and exit points of the rays through the target geometry (see Figure 6). This approach is particularly useful when the positioning of rays inside the volume of the target geometry is required.

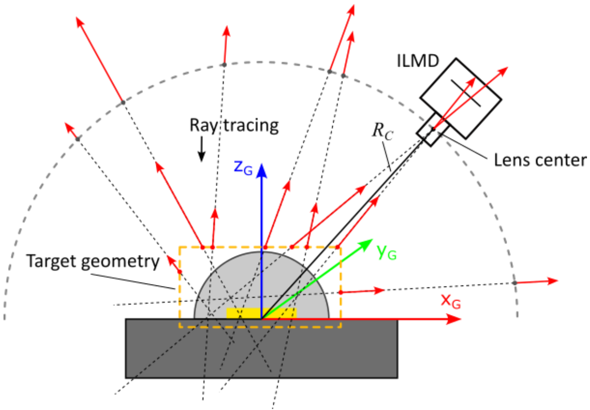


Figure 5: Raytracing on target geometry in surface mode

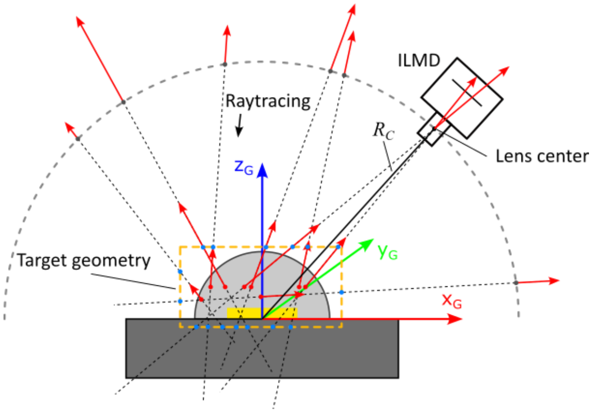


Figure 6: Raytracing on target geometry in volume mode

As the final step of the coordinate transformation, the rays can, if necessary, be transferred to a *target coordinate system* through rotation and translation. This transformation ensures that the rays are precisely aligned with the requirements of specific optical simulations or the coordinate system of the target application.

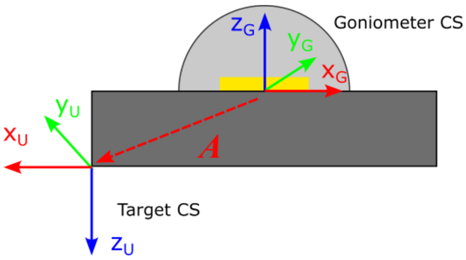


Figure 7: Target coordinate system

## Export of Ray Data into Various File Formats

The calculated rays in the desired quantity can be exported into various standard formats. The formats used by popular simulation programs (e.g., *LightTools*, *Zemax*, *TracePro*, and *ASAP*) are generally similar in structure. These files primarily consist of a file header followed by a list of rays, including:

- Starting coordinates
- Direction vectors
- Amplitudes
- Optional additional data

To optimize storage and processing efficiency, the data is typically stored in binary format.

The *IES TM-25* format [2] was developed to standardize the diverse range of file formats and reduce the associated effort. It provides a universal standard that enables the efficient and consistent use of ray data across various simulation applications.

## Generation of Ray Files for the Measured LED

This section provides a detailed explanation of the steps involved in generating a ray file. The process is based on the TTR measurement data of a white LED, specifically the *ams OSRAM LCW CP7P* (see Application Note AN2002 [3]). Using this data, the procedure for generating and processing ray data up to the creation of a ray file is outlined step by step.

### *Opening the TTR File*

Using "*File → Open …*", the desired TTR measurement file is selected, in this case, "*Osram-LCW-CP7P-Photometric.ttr*". Once opened, a window appears that provides an overview of all the information contained in the TTR file (see Figure 8). This window offers a structured display of the data, including detailed information about the measurement parameters and the captured ray data.

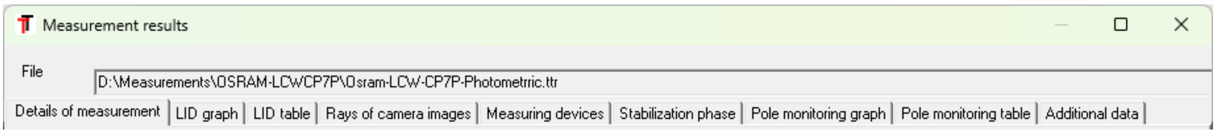


*Figure 8: Window (upper section) with TTR Data Overview*

A detailed description of the individual tabs can be found in other documents (AN2002 [3], Measurement Manual [5], *Konverter801* Software Manual [6]) and will not be covered here. For the further procedure, the images of the LED alignment within the goniometer coordinate system, included in the *additional data*, are particularly relevant.

### *Defining the Target Geometry and Target Coordinate System*

To define the target geometry of the ray data, precise knowledge of the LED's position within the goniometer coordinate system is essential. This information can be obtained from the images of the LED alignment. These images are either provided as external files or, as in this case, embedded as additional data directly within the TTR file. They illustrate the exact position and orientation of the LED during the measurement, ensuring an accurate definition of the target geometry.

The additional data contains several images, initially numbered sequentially (see Figure 9). Each image is available in two versions: a screenshot in *.bmp* format, which shows the view as used by the operator, and a complete camera image in *.pus* format, which includes additional information such as the coordinate system. The *.pus* format provides enhanced detail, making it particularly useful for further analysis or adjustments.

Using the camera image is often recommended, as settings such as zoom, scaling, and color palette can be adjusted flexibly if needed. In the further course of this Application Note, these data will be processed to optimally prepare the TTR file for external use.

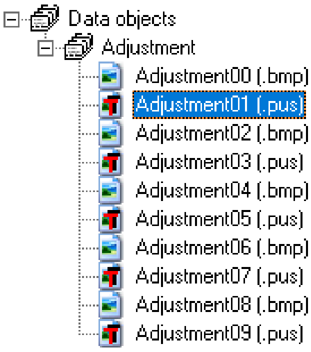


*Figure 9: Alignment images in TTR additional data*

Figure 10 illustrates the position of the LED within the goniometer coordinate system using the two essential alignment images: top view and side view. The orientation and positioning of the coordinate axes are displayed in the top-left corner. The Z-axis points in the direction of the LED's emission, while the X/Y plane lies on the top surface of the LED housing.

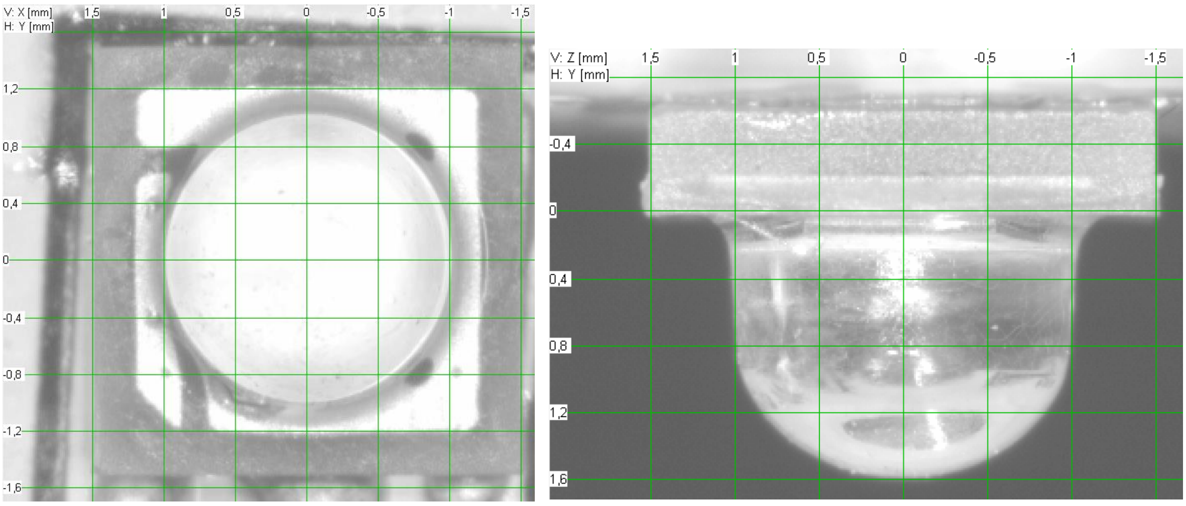


*Figure 10: Alignment images of the LED in the goniometer coordinate system*

A cylinder or a sphere can be used as the target geometry. For initial investigations, a cylinder is defined that encloses the LED lens. The cylinder has a diameter of 2 mm and a height of 1.6 mm. Due to uncertainties in the LED's positioning and its actual dimensions, it is recommended to add an additional margin, such as 0.1 mm. This results in a cylinder with a diameter of 2.2 mm and a height of 1.8 mm.

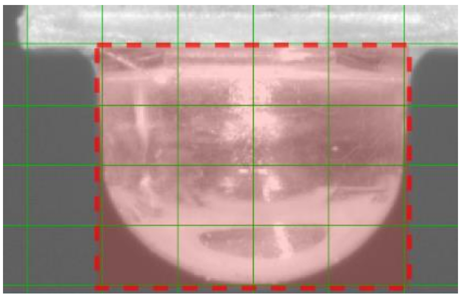

*Figure 11: Outline of the cylinder target geometry*

The center of the cylinder is positioned on the Z-axis at Z = 0.8 mm. These settings can be configured under "*Options → Target Geometry …*", as shown in Figure 12.

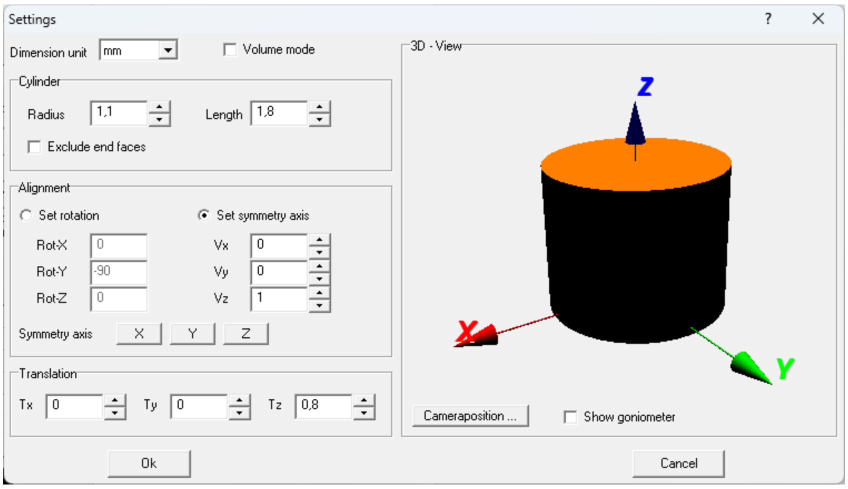


*Figure 12: Configuration of the cylinder target geometry*

Finally, if needed, the target coordinate system for the ray data can be specified. This configuration is set under "*Options → Target Coordinate System*" and depends on the requirements and preferences for handling ray data in the chosen simulation programs. In this case, no additional transformations are applied.

## Verification of the Target Geometry

To verify whether the chosen parameters for the target geometry are suitable, a test dataset of ray data is generated, for example, in *LightTools* format (*Convert → LightTools Ray File (*.ray)*). It is recommended to initially use a ray count of 1 million.

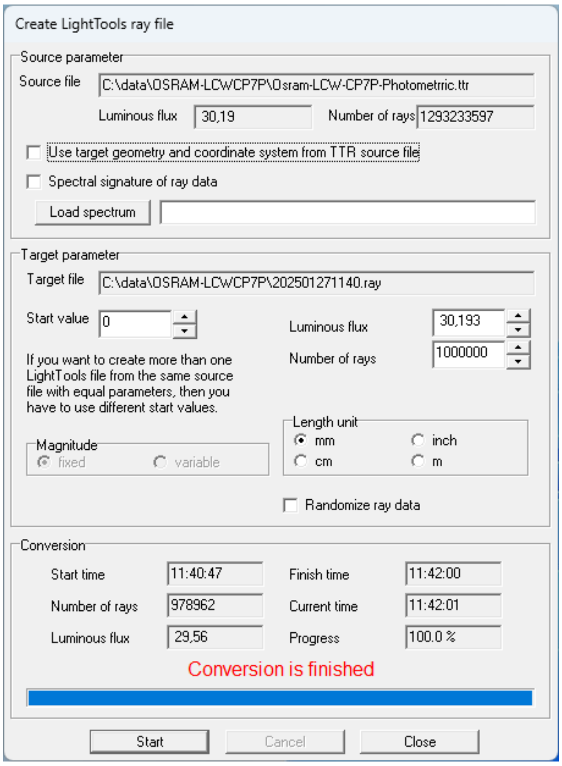


*Figure 13: Dialog for generating a rayfile*

After the conversion process is complete, the "*Number of Rays*" field in the *Conversion* section displays the actual number of rays written to the file. Rays that do not intersect with the target geometry are excluded from the file. This count serves as a key indicator of the suitability of the chosen target geometry.

If the deviation between the desired and the actual number of exported rays exceeds 1%, the origin of the excluded rays should be investigated. To do this, activate the option “*Save excluded rays*” in the target geometry settings dialog.

When this option is enabled, an additional file with the suffix “*_excluded*” is created. This file contains only the rays that did not intersect with the target geometry. These rays can be analyzed in a simulation program by tracing them back onto appropriate planes. This allows insights into the source and distribution of the excluded rays.

To ensure that the number of excluded rays is sufficient for meaningful analysis, a dataset with 100 million rays was generated in this case.

The result of raytracing these rays onto the x/y plane is shown in Figure 14. As expected, significant portions of the LED emission reflect off the LED housing and the PCB, particularly in the near-field region. If this ~2% of rays is to be included in the ray data, the target geometry needs to be expanded. In this case, a cuboid target geometry with dimensions 3.2 mm x 3.2 mm x 1.8 mm would be more suitable.

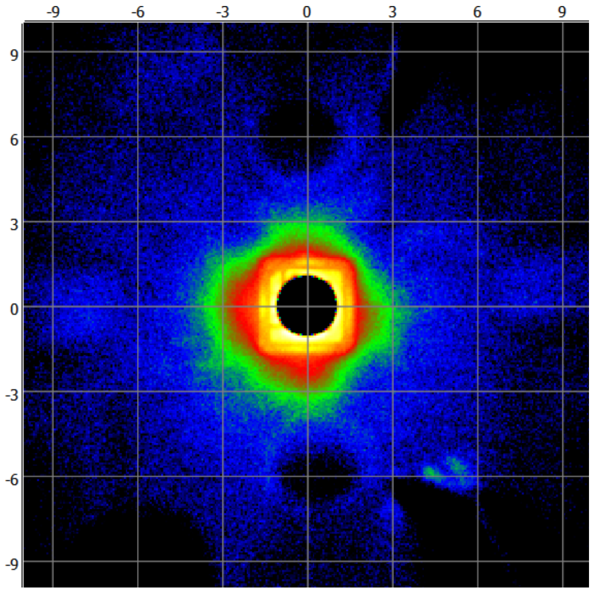


*Figure 14: Raytracing of excluded rays onto the X/Y plane*

A subsequent test conversion with these updated parameters resulted in only 1% excluded rays, indicating that this target geometry is appropriate. These parameters have been adopted for the final configuration (see Figure 15).

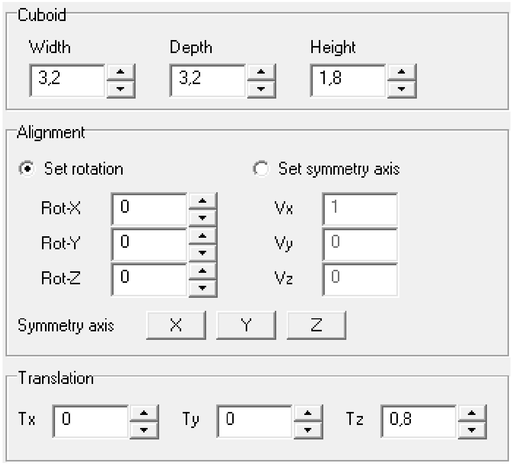


*Figure 15: Parameters of the final target geometry*

## *Defining Surface or Volume Mode*

By selecting the cuboid geometry and extending it to match the dimensions of the LED housing, the distances between the ray starting points and the actual light-emitting areas become significantly larger. This can be disadvantageous for simulations, making the volume mode potentially more suitable than the surface mode. However, positioning the ray origins inside the LED could raise additional questions, so the choice of raytracing mode should ideally be discussed with an experienced user of optical simulation software.

Figure 16 and Figure 17 visualize the starting points for both modes.

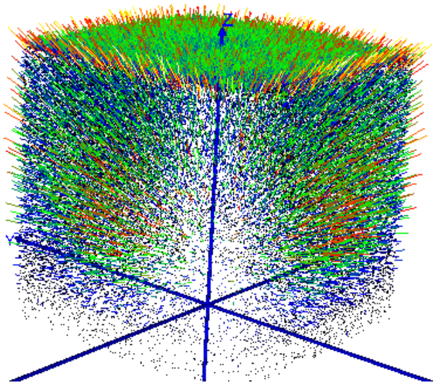

*Figure 16: Ray starting points in surface mode*

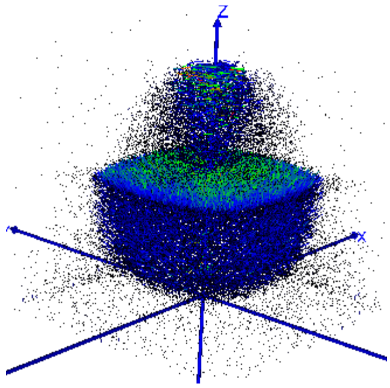

*Figure 17: Ray starting points in volume mode*

## Preparation of the TTR File for General Application

The previously defined settings are now to be embedded into the TTR file. To do this, navigate to the menu option "*File → Edit …*". This opens the familiar results window, but with extended functionality in this mode. The available options in this window are described in the following sections.

### *Details of measurement*

In this tab, all measurement details can be edited. This includes general information, such as the measured luminous flux, as well as internal details, like camera settings or file paths. If the TTR file is intended for use by parties outside the organization, it may be advisable to remove such internal information. The relevant sections can be selected using the checkboxes and deleted via the "*Delete*" button.

The most important setting on this page is the section "*Export of ray data: Target geometry and coordinate system*", where these parameters are defined for embedding into the TTR file. Typically, these parameters have already been defined and verified beforehand, so they can now be applied by simply clicking the "*Take global settings*" button (see Figure 18). Alternatively, it is also possible to manually enter the parameters directly in this section.

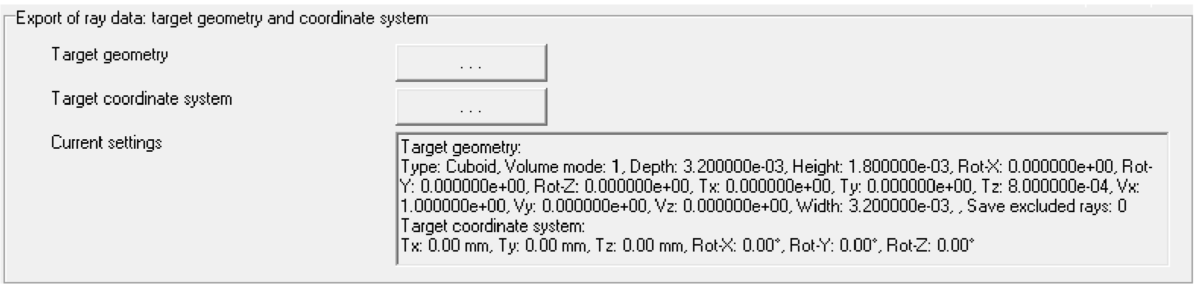


*Figure 18: Parameters of the target geometry and target coordinate system in the TTR File*

## *Removing Optional Data*

Certain data included in the measurement file are often not relevant to the general audience and can be removed from the file. To do this, select the corresponding tabs and click the "*Delete*" button. The following data types can be removed:

- **Measurement Devices:** Data captured by external measurement devices during the process, such as temperature or electrical parameters.
- **Stabilization Phase:** If the measurement was initiated using the automatic stabilization function, the data for this phase is displayed here.
- **Pole Monitoring (Graphics and Table):** This section contains illuminance values measured at the poles, which are only relevant for assessing the LED's stability during measurement.

## *Spectral Data*

This section allows the assignment of a spectral distribution (spectral radiant flux) to the TTR file. The spectrum can be utilized during the generation of spectral ray files or serve as an informative dataset for reference purposes.

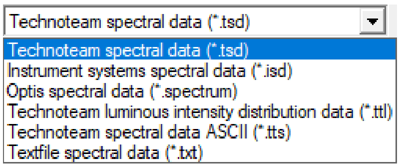


*Figure 19: Supported spectral data file formats*

By clicking the "*Load …*" button, a suitable spectral file can be opened (see supported formats in Figure 19). In this case, a goniospectrometric measurement in the TechnoTeam TSD format is loaded, and the relative spectral radiant flux is extracted for further use (see Figure 20).

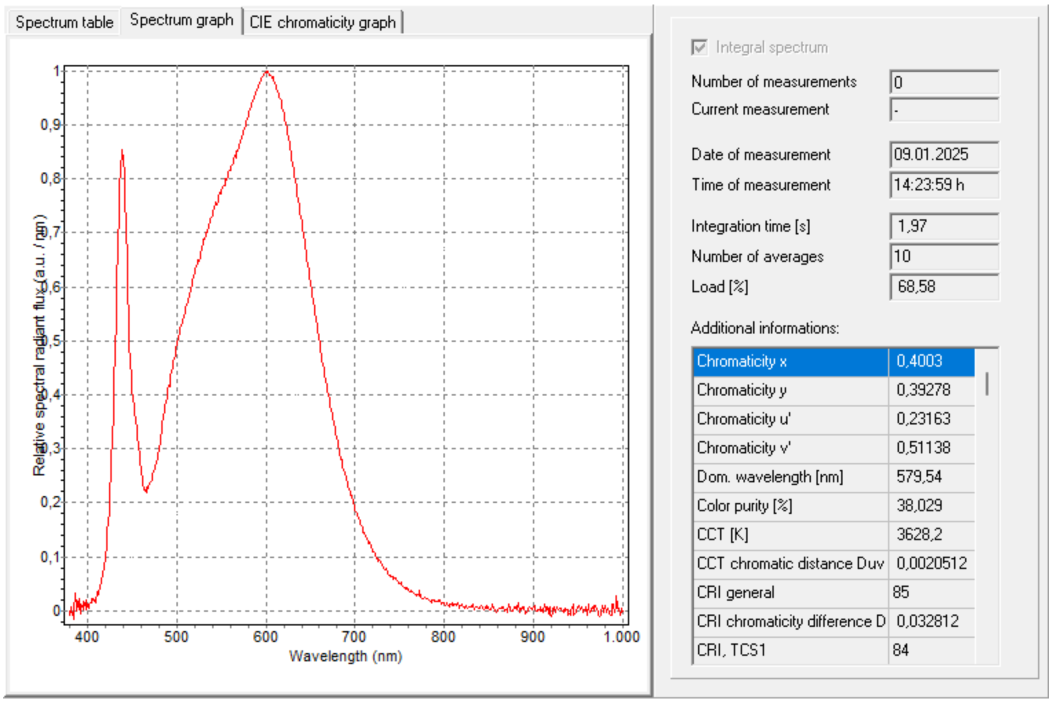


*Figure 20: Spectral data embedded in the TTR File*

## *Additional data*

The TTR additional data serves as a data container where various types of data can be structured and embedded. In the current measurement file, the LED alignment images are included. Depending on the target audience, it may be helpful to retain these images in the file or replace them with a processed document instead.

However, it would not be practical to include these images if the target coordinate system has been changed, as the LED's measurement position would no longer correspond to its position in the ray file's coordinate system.

Here, as an example, the list of images is reduced, and the two most important images are renamed. Additionally, two subfolders are created to include the complete goniospectrometric measurement data and the LED datasheet.

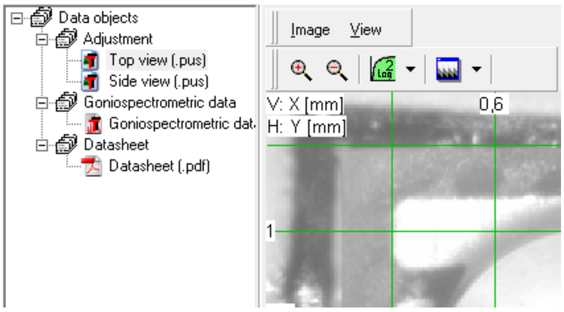


*Figure 21: Edited TTR additional data*

# Generating Ray Files with the Processed TTR File

## *Single Processing*

After loading the file, the conversion dialog for the desired format is selected. It is essential to activate the option "*Use target geometry and coordinate system from TTR source file*" to ensure that the embedded parameters are applied during the conversion process (see Figure 22).

To illustrate the outcomes, a large file containing 100 million rays is generated. These rays are then traced back to the X/Y plane for analysis.

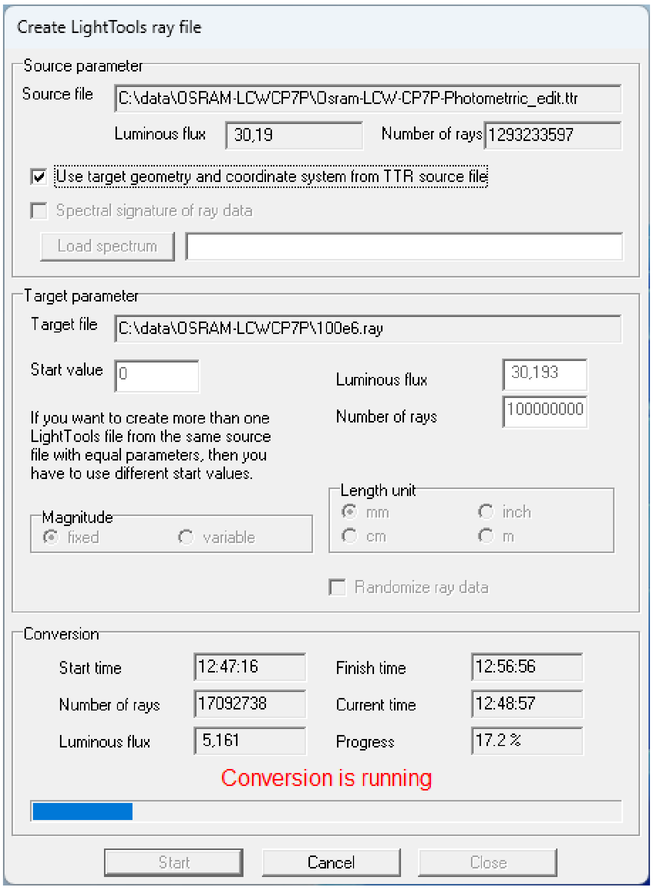


*Figure 22: Generating a ray file from the processed TTR file*

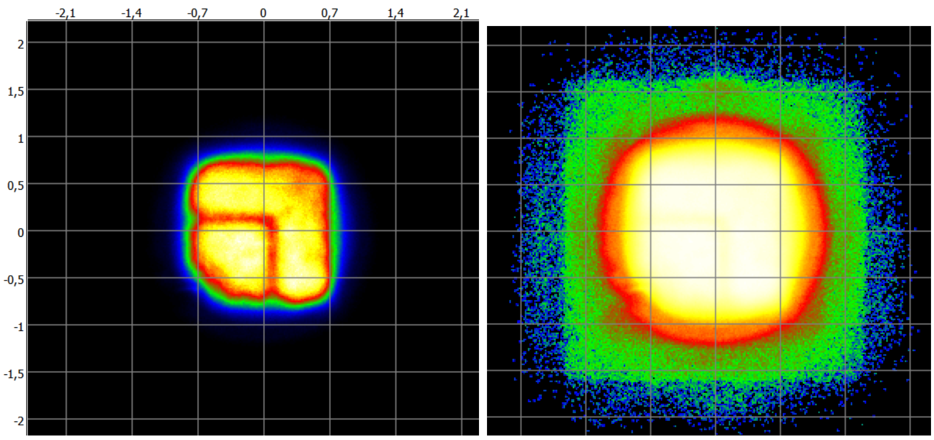


*Figure 23: Raytracing on the X/Y plane (Linear and Logarithmic representation)*

## *Batch processing*

If multiple file formats need to be generated, possibly with varying numbers of rays, single conversion can be time-consuming and tedious. To address this, the "*Convert → Batch Processing*" function offers a much more convenient alternative.

With batch processing, multiple conversions can be automated by predefining the desired parameters and target file formats. This saves time and reduces manual effort significantly.

A detailed description of this feature can be found in the *Konverter801* software manual [6], which provides a step-by-step guide to using batch processing effectively.

## Summary

This Application Note demonstrated how to generate ray data from a measured TTR file and export it into various file formats. All the necessary fundamental knowledge was provided, particularly the definition of the target geometry. Additionally, it was shown how to analyze data measured outside the LED's light-emitting volume, such as reflections from the LED housing or the PCB. Finally, the TTR measurement file was prepared to ensure its usability for general applications without requiring detailed knowledge of the measurement process.

A further topic is the generation of spectral ray data, particularly for white, phosphor-converted LEDs. This subject is covered in detail in a separate Application Note.

## References


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

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

[3] TechnoTeam Bildverarbeitung GmbH, „Application Note AN2002 - Measurement of Ray Data of an LED Using the Goniophotometer RiGO801-LED,“ https://www.technoteam.de/main/learn_more/application_notes/ray_data_measurement_of_an_led/index_eng.html.

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

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


**Kontakt**


**TechnoTeam Bildverarbeitung GmbH**
Werner-von-Siemens-Str. 5, 98693, Ilmenau, Germany
E-Mail: support@technoteam.de
Phone: +49 (0) 3677 / 4624-0
www.technoteam.de