Software Manual

Converter801

TechnoTeam Bildverarbeitung GmbH

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Content

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2 Introduction

The program *Converter801* is used for converting ray data in the TechnoTeam format (TTR) into other file formats. Furthermore, it provides functions for converting luminous intensity distributions as well as various calculation algorithms.

Various expert settings are required for the conversion of ray data. The TTR file typically embeds these settings to create a universal exchange file, which users without knowledge of the measurement system and the measurement itself can use.

Chapter 3 explains the fundamentals of ray data and its measurement using the RiGO801 measurement program. Chapter 4 covers general functionalities such as displaying and editing measurement files. The conversion of ray data into external file formats is explained in Chapter 5. Chapter 6 includes documentation of various additional features, such as the export of luminous intensity distributions and simple calculation functions.

The *Converter801* program is free of charge and available on our website:

https://www.technoteam.de.

3 Fundamentals

3.1 Ray data

The *Converter801* program processes ray data. However, what exactly are ray data? In geometrical optics, which is also known as ray optics, lines or rays are used to simplify the propagation of light. This model enables the calculation of light propagation in optical systems with sufficient accuracy. When photometric or radiometric properties are assigned to these rays, it enables not only a geometric calculation but also an energetic calculation of light propagation in optical systems.

When studying the path of rays from a light source through an optical system to a target surface, it is necessary to represent the light source with a sufficient number of rays. This collection of rays is referred to as *ray data* or *ray set*, also known as a *ray file*.

Optical simulation programs based on the principles of geometrical optics use ray data. Either these can be synthetically generated based on a physical model of the light source, or they can be measured using a near-field goniophotometer, such as our RiGO801 measurement systems.

Each ray is assigned an energy component. This could be luminous flux, radiant flux with a specific wavelength, or even complete spectral radiant flux data. The use of spectral properties allows for a more realistic calculation of dispersion effects. However, the size of ray data increases drastically, and the measurement acquisition is possible only with limitations. Ray data with additional spectral properties are referred to as *spectral ray data* or *spectral ray files*.

3.2 Ray data - Measurement Principle

3.2.1 *Luminance distribution*

The starting point for measuring ray data is the measurement of the luminance distribution of a light source. Luminance describes the spatial and directional dependence of the emitted luminous flux from a light source. It is the luminous flux emitted from an area element into a solid angle (direction), relative to the projected area. This relationship is described using the photometric fundamental law in differential form:

$$L_{\mathrm{v}}\left(x,y,z,\vartheta,\varphi\right)=\frac{\partial^{2}\Phi_{\mathrm{v}}\left(x,y,z,\vartheta,\varphi\right)}{\partial A_{\mathrm{E}}\left(x,y,z\right)\cdot\cos\varepsilon\cdot\partial\Omega\left(\vartheta,\varphi\right)}$$

Luminance is therefore already a vector quantity or a vector field that describes the complete emission characteristics of a light source.

3.2.2 *Measurement of the luminance distribution*

In its differential definition, luminance refers to infinitesimal small surface elements and solid angles, constituting a continuous function. For measurement purposes, the luminance function is discretized by considering average luminances based on discrete surface elements and solid angles. This process is known as sampling.

The measurement is conducted using a luminance measurement camera (ILMD - Imaging Luminance Measurement Device), which is moved around the Device Under Test (DUT). A goniometer unit is employed for this purpose, upon which the camera is mounted.

The pixel areas of the image sensor capture the average luminances of the corresponding surface elements of the light source. Each pixel defines a direction and a solid angle through the lens. The underlying camera coordinate system is depicted in the following illustration.

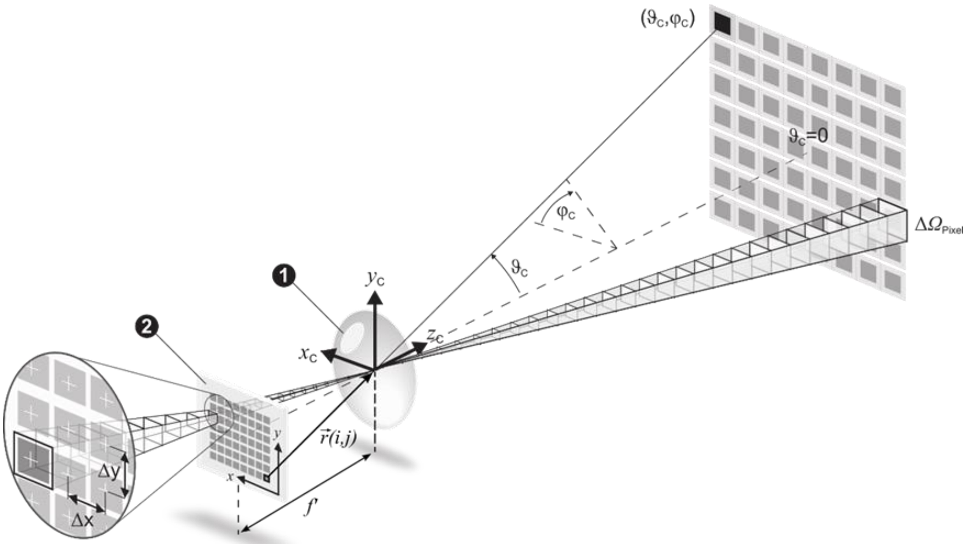


Figure 1: Camera coordinate system

3.2.3 *Calculation of ray data*

A ray with a luminous flux component is now calculated from the luminance.

$$\Delta\Phi_v(x,y,z,\vartheta,\varphi) = L_v(x,y,z,\vartheta,\varphi)\cdot\Delta A\cdot\cos\varepsilon\cdot\Delta\Omega$$

When calculating rays for the entire measured luminance distribution, the set of ray data is generated. The initial coordinates and directions of the rays are output in the central coordinate system (D – Device coordinate system) of the goniophotometer.

$\Phi_v(x_D, y_D, z_D, \vartheta_D, \varphi_D)$ - Ray data

Thus, each ray has an originating point and a direction within the goniometer coordinate system.

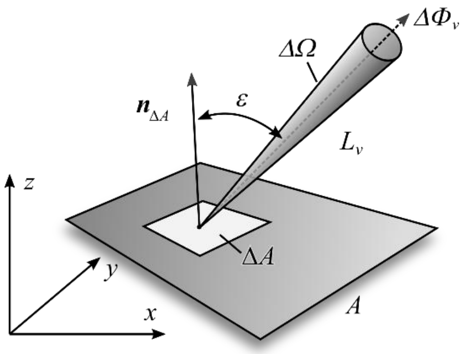


Figure 2: Ray

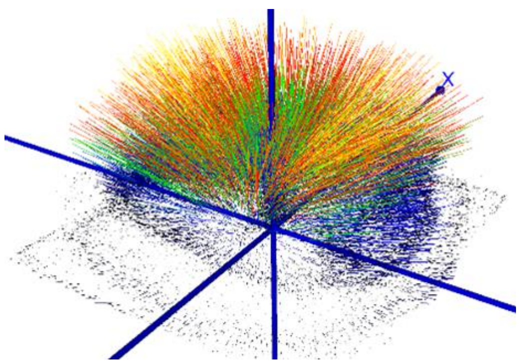


Figure 3: Example of a ray data distribution of an LED.

3.3 Luminous intensity distribution

For the simplified description of the emission characteristics of a light source or luminaire, the luminous intensity distribution is employed. Luminous intensity I_v represents the luminous flux emitted into a solid angle by a point light source. The luminous intensity distribution is derived from the intensities in all directions. Hence, a spatially extended light source is simplified as a point light source.

The luminous intensity distribution can be easily calculated from the ray data.

$$I_v(\vartheta_k,\phi_l) = \frac{\sum_{x,y,z} \Delta\Phi_v(x_D, y_D, z_D, \vartheta_D, \phi_D)}{\Delta\Omega(\vartheta_k,\phi_l)}.$$

3.4 Coordinate systems of the RiGO801 Goniophotometers

3.4.1 *Goniometer coordinate system*

The motion units of the various RiGO801 goniophotometer systems implement a spherical coordinate system. The position of the camera is defined using the angles Theta (ϑ_D) and Phi (φ_D), along with the distance from the rotation center. A spherical coordinate system is also always associated with Cartesian coordinates $(z_D, \vartheta_D, \varphi_D)$.

The coordinate systems of the RiGO801 systems 801-LED and 801-L are shown in Figure 5.

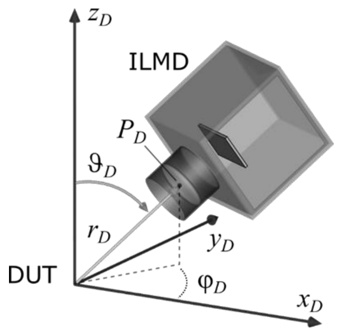


Figure 4: Goniometer coordinate system

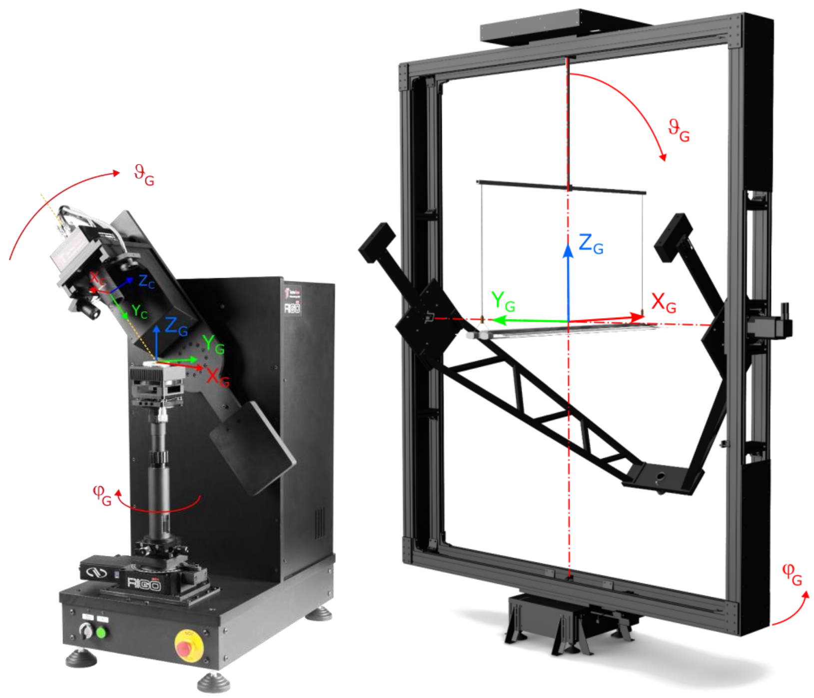


Figure 5: Coordinate systems RiGO801-LED und RiGO801-L

3.4.2 *C-plane coordinate System*

Luminous intensity distributions are provided by the RiGO801 goniophotometers in the C-Plane coordinate system. The angles of luminous intensities are given by γ - Gamma and C. The conversion from goniometer coordinates to C-Plane coordinates is carried out using

$\gamma = 180° - \vartheta_D$ and $C = \varphi_D$.

In the *Converter801* program, both coordinate systems are utilized.

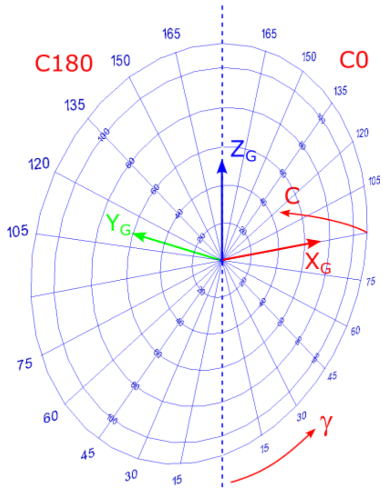
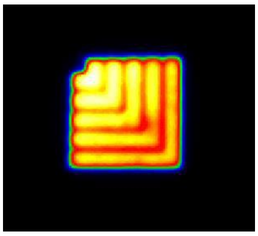


Figure 6: C-plane coordinate system

3.5 Processing ray data in the RiGO801 Measurement Program

3.5.1 *Measurement*

The fundamental principle for measuring ray data was already explained in Section 3.2. However, the practical implementation in the RiGO801 measurement program differs slightly. Initially, a luminance image is captured at a specific position. The luminance of each pixel is then converted into luminous flux components (see 3.2.3). Subsequently, the data volume is reduced by weighting it with the luminous flux. The result is a so-called *ray data image*, where each pixel is associated with a luminous flux.



$$\Delta\Phi_v(i,j) = L_v(i,j)\cdot\Delta A\cdot\cos\varepsilon_{i,j}\cdot\Delta\Omega_{i,j}$$

i, j - Image coordinates

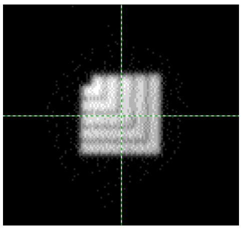


Figure 7: Transformation from Luminance Image to Ray Data Image

The direction of each ray originating from a pixel in the ray data image is calculated using the calibration data of the camera coordinate system (see 3.2.2) and the position of the camera in the goniometer coordinate system. These data are used only at this point for the continuous calculation of the luminous intensity distribution during the measurement (see 3.3) and are subsequently discarded.

3.5.2 *Saving Data in the TTR File*

Depending on the measurement resolution, as many as over 10^9 rays can be measured. For the sake of efficiency, it is necessary to store only the ray data images generated during the measurement sequence in the TTR output file.

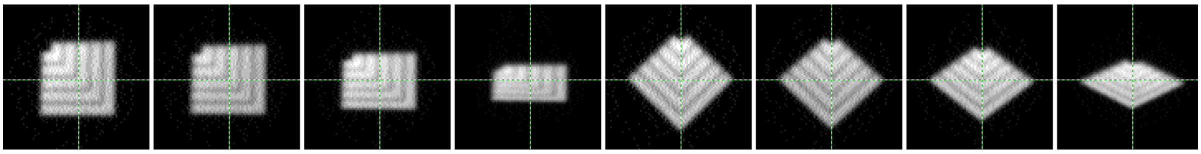


Figure 8: Sequence of Ray Data Images

The geometric calibration data of the camera system required for calculating the starting positions and directions of the rays, along with the corresponding camera positions and additional parameters, are also stored in the TTR file. Therefore, the *Converter801* program is capable of computing the complete ray data using the information from the TTR file.

3.6 Ray conversion with Converter801

3.6.1 *Loading the TTR file*

When opening the TTR file using *Converter801*, the essential data required for the computation of ray data is initially loaded. These include primarily the geometric calibration data of the utilized lens and the camera distance R_C.

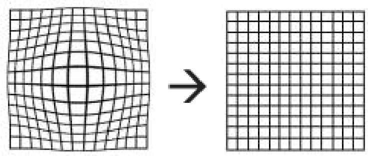


Figure 9: Geometric calibration data of a lens

3.6.2 *Reading ray data images and ray calculation*

The ray data images are sequentially loaded from the TTR file. After applying geometric transformation steps, the position and direction of the rays in the goniometer coordinate system are determined. The starting point of a ray is initially placed on the spherical surface defined by the lens distance (see Figure 10).

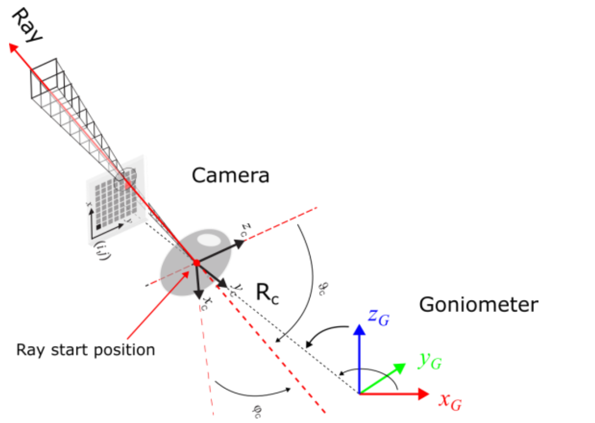


Figure 10: Position and direction of a ray in the goniometer coordinate system

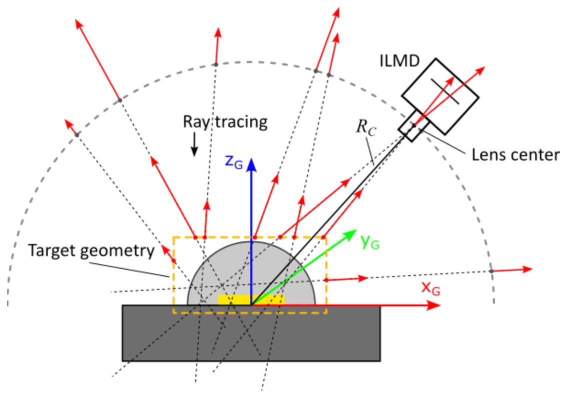


Figure 11: Raytracing auf eine Hüllfläche

3.6.3 *Ray tracing onto a target geometry (envelope surface)*

Without further transformation, all ray starting points lie on the spherical surface described by the lens center, for example, with a radius of 160 mm. For the application of ray data in simulations, this is generally unfavorable since the rays do not originate in front of the optical components being simulated. Therefore, the starting points are shifted as close as possible to the light source along the ray directions. This is achieved by defining an envelope or target geometry and calculating the intersection points (ray tracing).

Rays that do not intersect with the target geometry are not used. Therefore, the choice of geometry must be made carefully, aiming to avoid both excessively large distances from the light source and excluding relevant areas of the light source.

3.6.4 *Ray tracing into the volume of an envelope surface (volume mode)*

As an alternative to shifting the starting points onto an envelope surface, the points can also be placed within the volume of an envelope surface. In this approach, the entry and exit points of the rays are calculated, and the starting points are positioned at the center. This concentrates the starting points within the volume of the target geometry, which may offer advantages in handling the ray data in simulations.

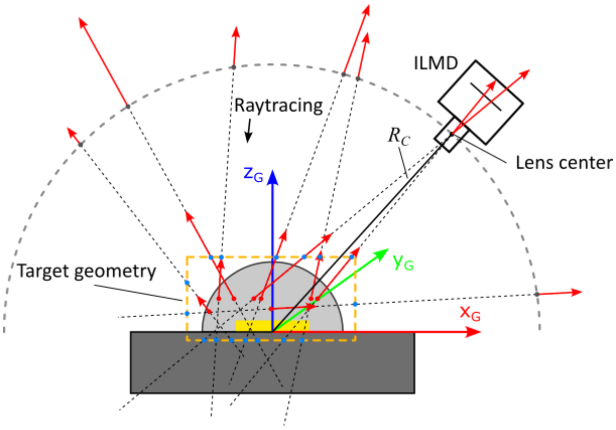


Figure 12: Ray tracing into the volume of an envelope surface (volume mode)

3.6.5 *Coordinate transformation*

The coordinate system in which the ray data is computed is the goniometer coordinate system. The position and orientation of the coordinate center with respect to the light source were established through the positioning process before measurement. If a different coordinate system is desired, a so-called *target coordinate system* can be chosen.

<ins>After</ins> ray tracing onto the target geometry, all rays are transformed into this target coordinate system.

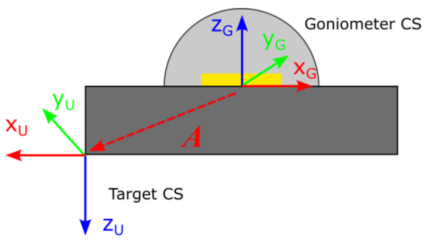


Figure 13: Target coordinate system

3.6.6 *Spectral ray data*

By default, rays are assigned a luminous flux computed from the luminance. As explained under 3.1, rays can also be assigned spectral information. Ideally, each ray would have a spectral radiant flux, meaning a complete spectral distribution. However, from a measurement perspective, achieving this is not feasible.

Instead, the spectral range is possibly divided into segments using specific filters. In the case of RiGO801 goniophotometers, measurements of white phosphor-converted LEDs are commonly conducted using the X1 (blue) and X2 (yellow) filters of the color camera. The wavelengths and amplitudes of the rays are then distributed according to the spectral distributions (see Figure 14).

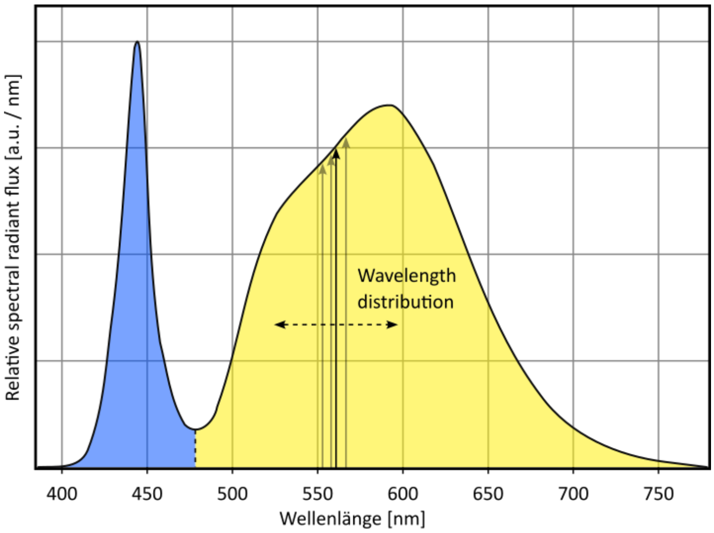


Figure 14: Distribution of the ray wavelengths

3.6.7 *File export*

At the end of the processing chain, the rays are output in the desired file format. The various formats share a strong resemblance. A common feature among all formats is the representation of rays as a starting point (x, y, z), a direction vector (e_x, e_y, e_z), and an amplitude. The interpretation of the amplitude as a photometric or radiometric quantity, as well as additional information, is specific to each format.

4 General program properties

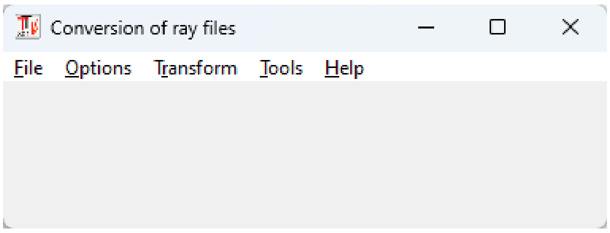


Figure 15: Main program window

4.1 Loading a TechnoTeam Ray File (*.ttr)

The menu option *[File | Open ...]* opens a file selection dialog with the default setting for *.ttr files. After selection, the dialog displaying the measurement results opens, showing the available contents of the TTR file (see 4.2). When the dialog is closed using *Close*, the TTR file remains open in the background.

If the TTR file contains specifications for the target geometry and target coordinate system, and the option *[Options | Apply parameters when opening the file]* is enabled, these parameters will be adopted, replacing the previous global parameter set.

4.2 Dialog Measurement results.

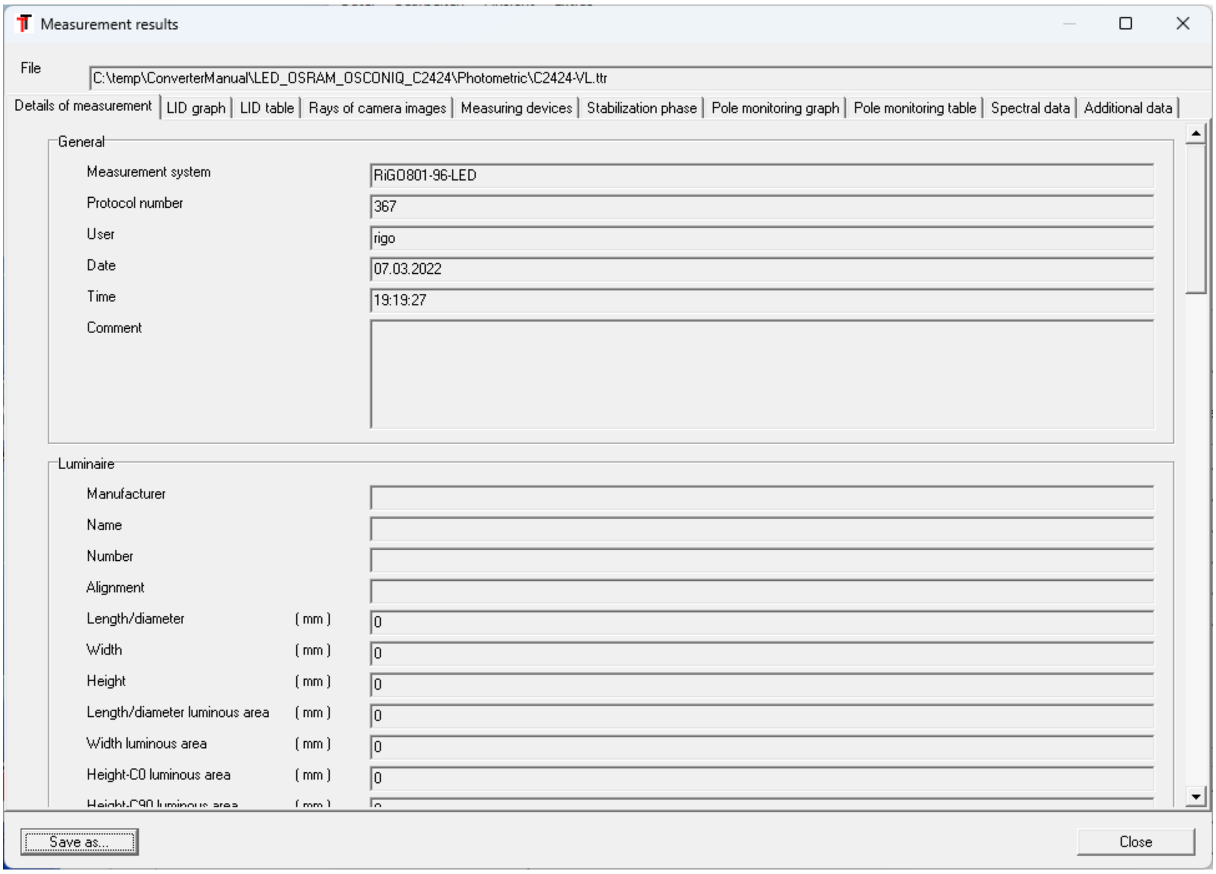


Figure 16: Dialog "Measurement results"

The display of data from the currently opened TTR file via the *Measurement results* dialog can be accessed at any time using *[File | Display …]*. The available contents are presented in the subordinate tabs.

4.2.1 *Details of measurement*

The *Details of measurement* tab displays a list of sections with subordinate details. The information includes details about the measurement system, the measured object, the measurement itself, and the measured luminous flux.

Figure 17: Details of measurement - LID

The section *Export of ray data: Target geometry and coordinate system* may include specifications of these parameters. For further information, refer to Section 4.3.1.

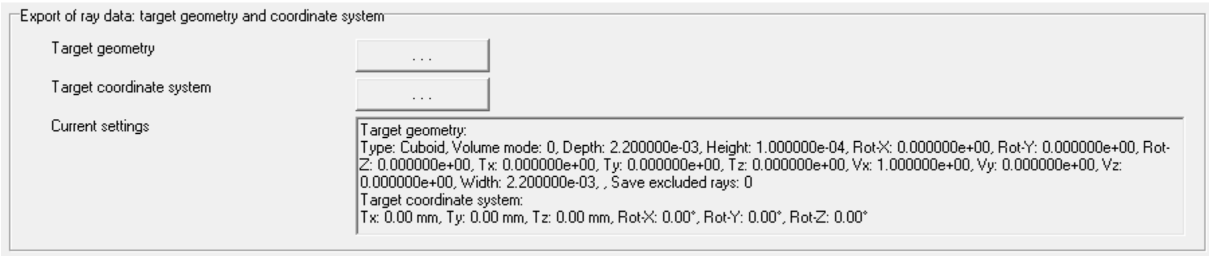


Figure 18: Details of measurement – Target geometry and target coordinate system

4.2.2 *LID graph*

The *LID graph tab* displays a polar diagram of the Luminous Intensity Distribution (LID). The combo boxes on the right allow you to choose the C-planes to be displayed. Color adjustments can be made by clicking on the color fields.

The *Print* button initiates the printing of the graph on the current default printer. The default printer can be changed using the *Printer...* button. The printed representation will be the same as currently displayed on the screen.

The checkbox *Standardization cd / klm* determines whether the absolute luminous intensities are shown in cd or relative luminous intensities normalized to 1000 lm lamp luminous flux in cd / klm.

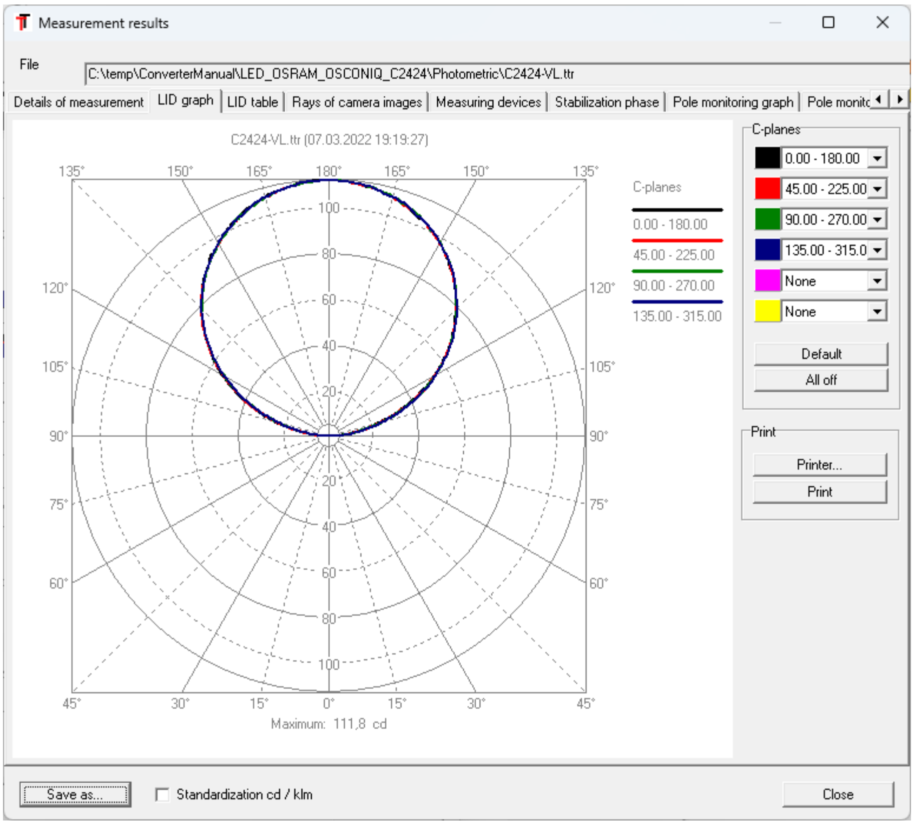
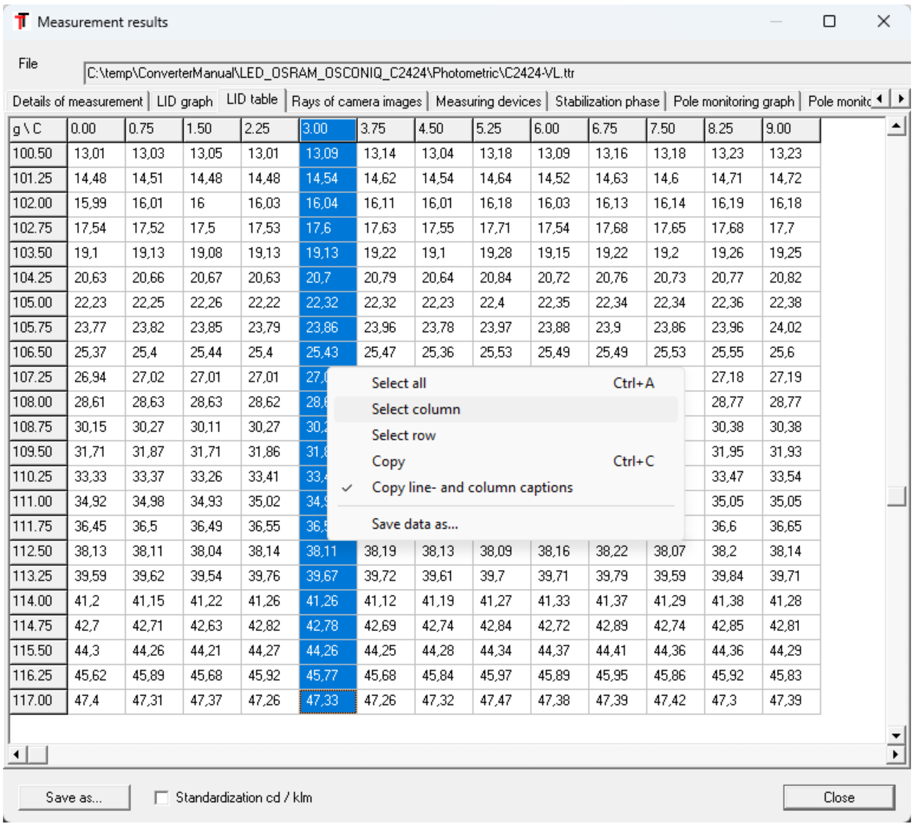


Figure 19: LID polar diagram

4.2.3 *LID Table*



g \ C	0.00	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50	8.25	9.00
100.50	13,01	13,03	13,05	13,01	13,09	13,14	13,04	13,18	13,09	13,16	13,18	13,23	13,23
101.25	14,48	14,51	14,48	14,48	14,54	14,62	14,54	14,64	14,52	14,63	14,6	14,71	14,72
102.00	15,99	16,01	16	16,03	16,04	16,11	16,01	16,18	16,03	16,13	16,14	16,19	16,18
102.75	17,54	17,52	17,5	17,53	17,6	17,63	17,55	17,71	17,54	17,68	17,65	17,68	17,7
103.50	19,1	19,13	19,08	19,13	19,13	19,22	19,1	19,28	19,15	19,22	19,2	19,26	19,25
104.25	20,63	20,66	20,67	20,63	20,7	20,79	20,64	20,84	20,72	20,76	20,73	20,77	20,82
105.00	22,23	22,25	22,26	22,22	22,32	22,32	22,23	22,4	22,35	22,34	22,34	22,36	22,38
105.75	23,77	23,82	23,85	23,79	23,86	23,96	23,78	23,97	23,88	23,9	23,86	23,96	24,02
106.50	25,37	25,4	25,44	25,4	25,43	25,47	25,36	25,53	25,49	25,49	25,53	25,55	25,6
107.25	26,94	27,02	27,01	27,01	27,(							27,18	27,19
108.00	28,61	28,63	28,63	28,62	28,(							28,77	28,77
108.75	30,15	30,27	30,11	30,27	30,:							30,38	30,38
109.50	31,71	31,87	31,71	31,86	31,{							31,95	31,93
110.25	33,33	33,37	33,26	33,41	33,:							33,47	33,54
111.00	34,92	34,98	34,93	35,02	34,!							35,05	35,05
111.75	36,45	36,5	36,49	36,55	36,!							36,6	36,65
112.50	38,13	38,11	38,04	38,14	38,11	38,19	38,13	38,09	38,16	38,22	38,07	38,2	38,14
113.25	39,59	39,62	39,54	39,76	39,67	39,72	39,61	39,7	39,71	39,79	39,59	39,84	39,71
114.00	41,2	41,15	41,22	41,26	41,26	41,12	41,19	41,27	41,33	41,37	41,29	41,38	41,28
114.75	42,7	42,71	42,63	42,82	42,78	42,69	42,74	42,84	42,72	42,89	42,74	42,85	42,81
115.50	44,3	44,26	44,21	44,27	44,26	44,25	44,28	44,34	44,37	44,41	44,36	44,36	44,29
116.25	45,62	45,89	45,68	45,92	45,77	45,68	45,84	45,97	45,89	45,95	45,86	45,92	45,83
117.00	47,4	47,31	47,37	47,26	47,33	47,26	47,32	47,47	47,38	47,39	47,42	47,3	47,39

Figure 20: LID table

In the *LID Table* tab, the measurement values of the individual C-planes are presented in tabular form. By pressing the left mouse button and dragging the cursor, or through the context menu (right mouse button), a data range within the table can be selected and transferred to the operating system's clipboard using the *[Copy]* context menu entry. Using *[Save data as…]* also allows the output of the data as a *.txt ASCII file.

4.2.4 *Rays of camera images*

In the *Rays of camera images* tab, the so-called ray data images (see 3.5.2) are displayed. A ray data image is an intermediate step between the luminance image and rays. It includes only pixels from which rays originate. The value of a pixel represents the number of rays starting from it, with the luminous flux unit amplitude of the rays within an image being managed internally.

The images are listed in the order of measurement. The measurement position in the goniometer coordinate system associated with the current image is indicated on the right side under *Capture position* (*Theta* and *Phi* text fields). The nearest measurement grid position is displayed under *Grid position*. The images can be navigated through the entire measurement sequence using the scroll bar or by directly entering the grid position.

The *Metric coordinate system* option switches between pixel coordinates and the metric coordinate system on the current image plane at the coordinate center. The metric coordinate system is a linear coordinate system with a fixed pixel/mm ratio. This approximation disregards lens aberrations and the nonlinear scaling of central projection. Furthermore, the coordinate system is only valid within the plane at the center of the goniometer coordinate system. For smaller opening angles of the utilized lens, which are primarily used for ray data measurements of light sources, the deviations are negligible.

By default, a coordinate grid with scaling is displayed, and the coordinate center is visualized by a yellow axis cross. The menu option *[View | Coordinate system]* toggles the display of the grid. In orthogonal viewing directions, two axes of this coordinate system correspond to two axes of the go-

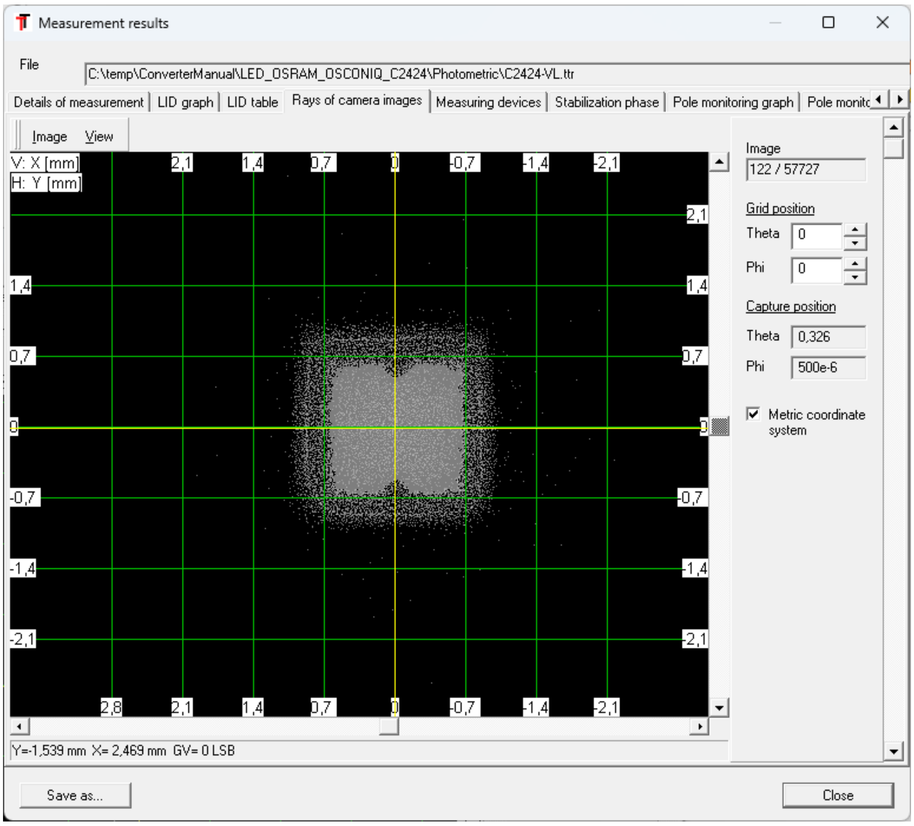


Figure 21: View of ray data images

niometer coordinate system. The correspondence of the three axes in the image is indicated in the upper left corner. In this screenshot (see Figure 22), the vertical image axis corresponds to the X-axis, and the horizontal image axis corresponds to the Y-axis.

For easy measurement of dimensions in the image, a rectangular region can be drawn by holding down the left mouse button. The dimensions of the region will then be displayed in the status bar.

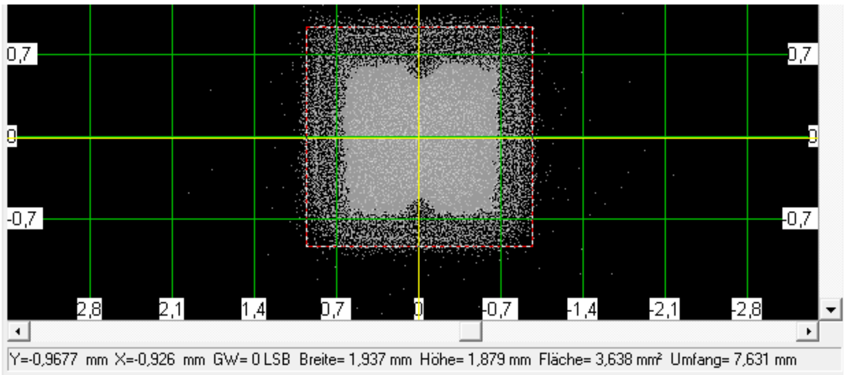
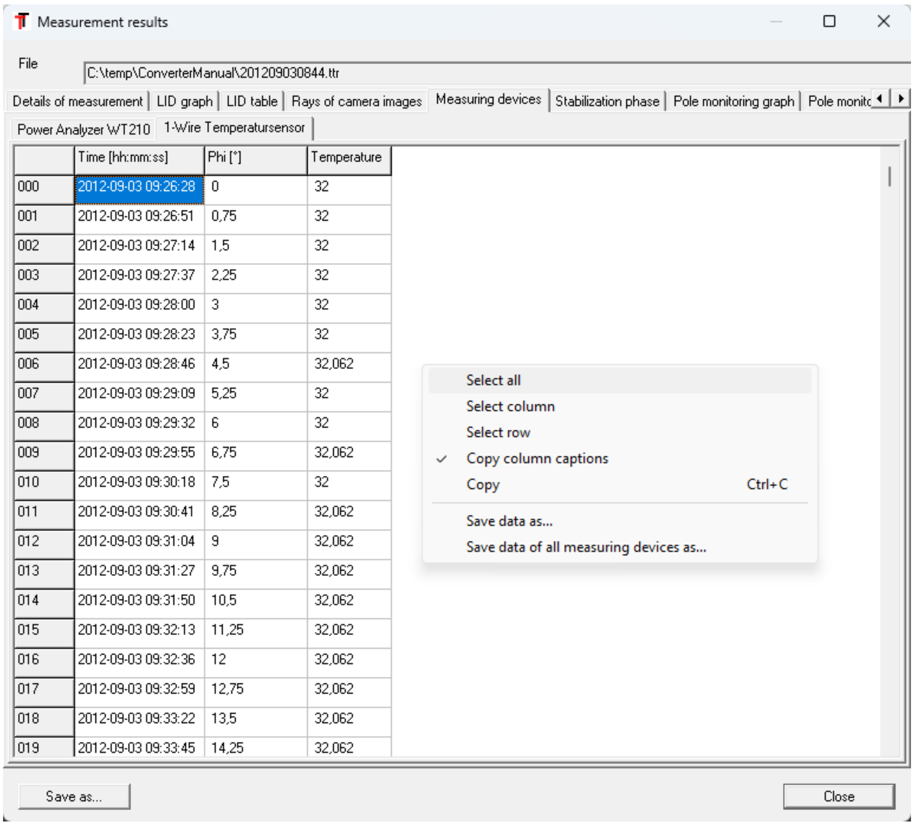


Figure 22: Measurement of dimensions in ray data images

4.2.5 *Measuring devices*

The RiGO801 measuring program can capture data from external measuring devices (temperatures, electrical parameters) during the measurement process and store them in the TTR file. These data are listed in the *Measuring devices tab*. For each device, there is a subordinate tab. The data is displayed in a table where each row includes the measurements taken before the start of the respective C-plane.



	Time [hh:mm:ss]	Phi [°]	Temperature
000	2012-09-03 09:26:28	0	32
001	2012-09-03 09:26:51	0,75	32
002	2012-09-03 09:27:14	1,5	32
003	2012-09-03 09:27:37	2,25	32
004	2012-09-03 09:28:00	3	32
005	2012-09-03 09:28:23	3,75	32
006	2012-09-03 09:28:46	4,5	32,062
007	2012-09-03 09:29:09	5,25	32
008	2012-09-03 09:29:32	6	32
009	2012-09-03 09:29:55	6,75	32,062
010	2012-09-03 09:30:18	7,5	32
011	2012-09-03 09:30:41	8,25	32,062
012	2012-09-03 09:31:04	9	32,062
013	2012-09-03 09:31:27	9,75	32,062
014	2012-09-03 09:31:50	10,5	32,062
015	2012-09-03 09:32:13	11,25	32,062
016	2012-09-03 09:32:36	12	32,062
017	2012-09-03 09:32:59	12,75	32,062
018	2012-09-03 09:33:22	13,5	32,062
019	2012-09-03 09:33:45	14,25	32,062

Figure 23: Measurement results – External measuring devices

With the right-click context menu, you can access functions for selecting table areas, copying to the clipboard, and saving the table as a *.txt file. The usual keyboard shortcuts for these actions are also available.

4.2.6 *Stabilization phase*

If the measurement was started with an automatic stabilization process, the data logged during the stabilization phase can be viewed in this tab. Using the context menu of the chart (right-click), you can save the chart as an image file or the underlying data as an ASCII file.

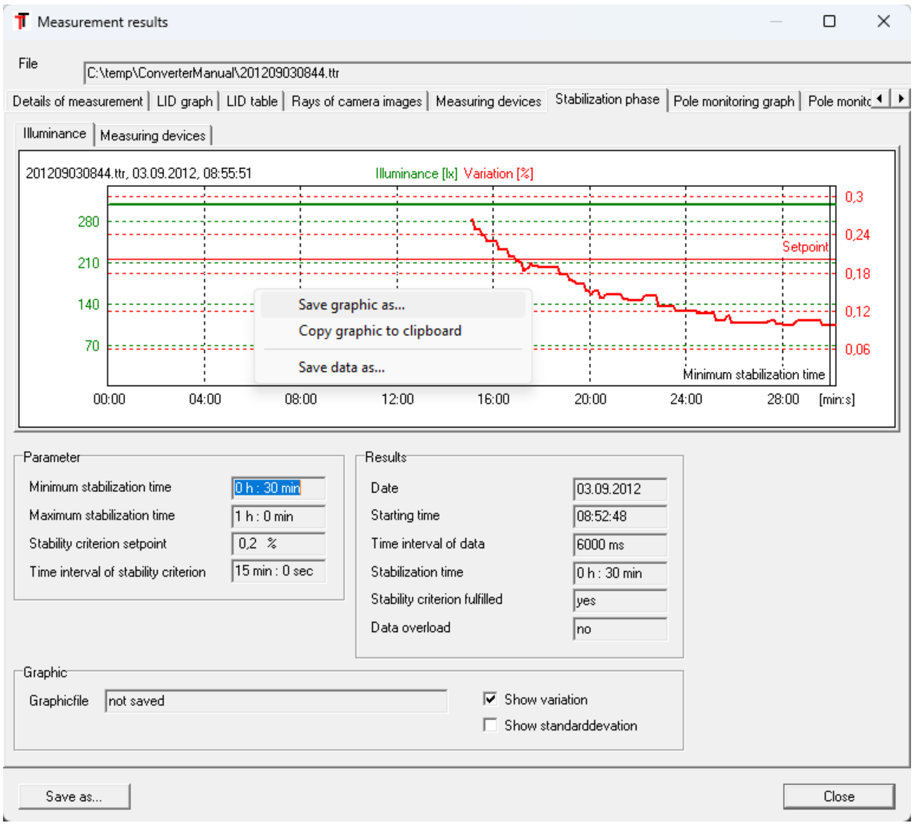


Figure 24: Measurement results – Stabilization phase

4.2.7 *Pole monitoring*

If available, the pole monitoring data includes the illuminances at the pole of each C-plane. This allows for the assessment of the light source's stability during the measurement. The *Pole monitoring graph* and *Pole monitoring table* tabs visualize these data as a chart and a table. Using the context menus, you can save the chart or data as usual or copy them to the clipboard.

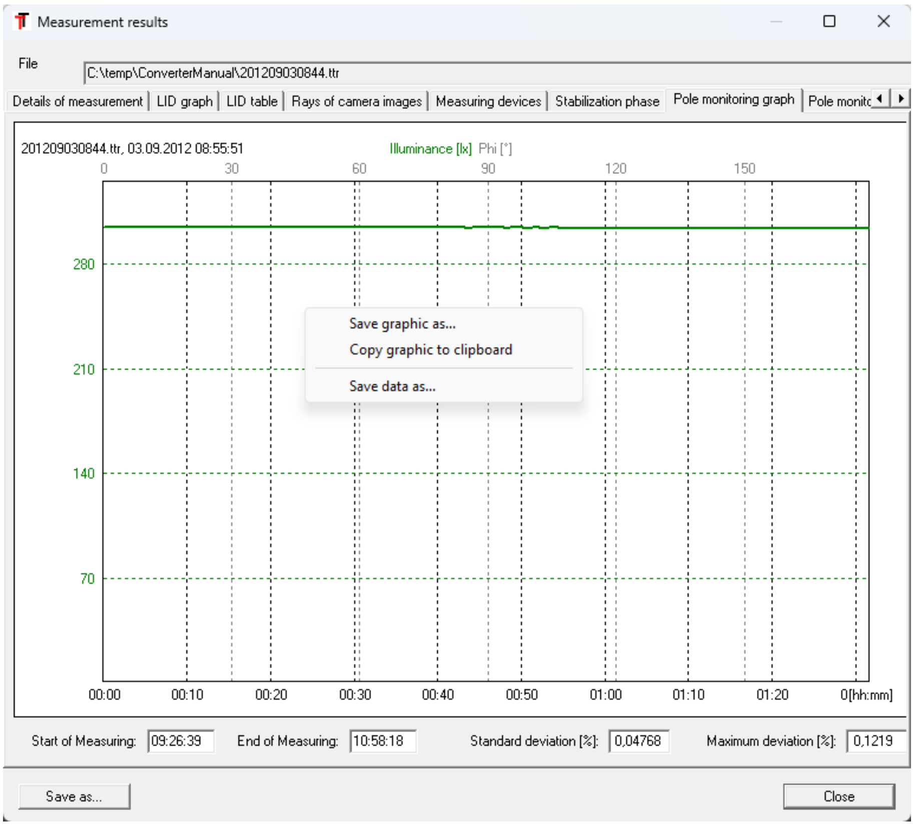


Figure 25: Measurement results – Pole monitoring

4.2.8 *Spectral data*

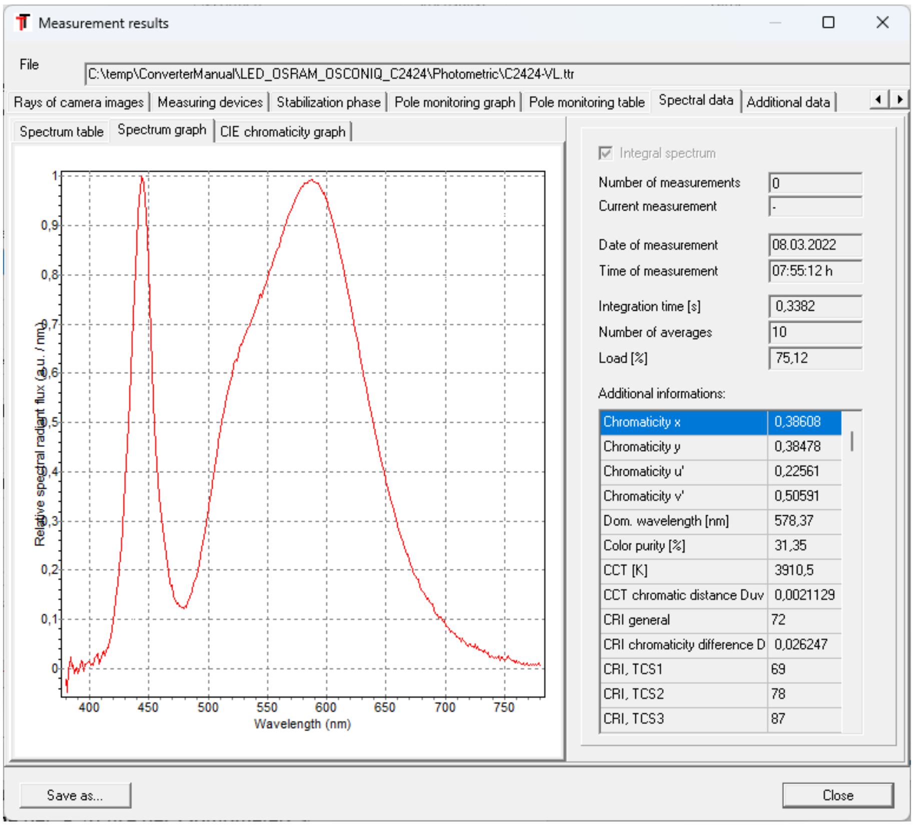


Figure 26: Measurement results – Spectral data - graph

A TTR file can be associated with a spectrum. The display of this spectrum is available in the *Spectral data* tab. Subsequently, there are sub-tabs for the output as a table, spectral distribution, and CIE chromaticity graph. Additional information about the spectral data and derived results, such as color coordinates and color rendering indices (CRI and TM30), are provided on the right-hand side.

When converting a ray data file, this spectrum can be utilized for generating spectral data (see 3.6.6).

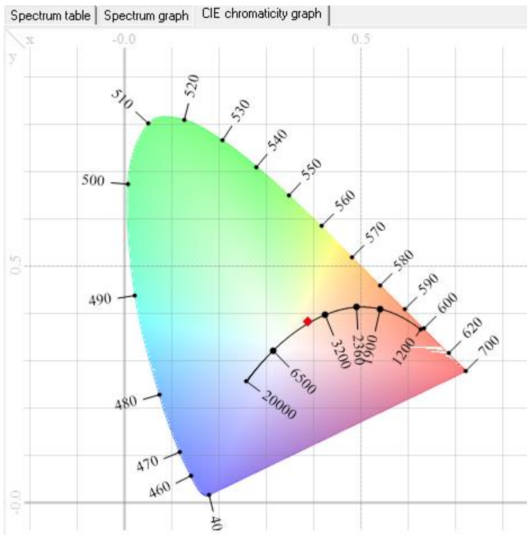


Figure 27: Measurement results – Spectral data - CIE chromaticity graph)

4.2.9 *Additional data*

The TTR file format provides the option to include various additional data. This can encompass datasheets, images of the alignment of the measurement object, luminance images, goniospectrometric measurement data, or any other desired files. A detailed explanation is provided in Section 4.3.4.

4.3 Editing TTR files

The potential contents of a TTR file have been elucidated in the preceding sections. Not all of the contents are initially stored in the TTR file by the measurement program. They can be included during subsequent editing within the *Konverter801* program through the *[File | Edit]* menu. It is also possible here to integrate the expert settings necessary for ray conversion (see Section 3.6 and Chapter 5) into the file. It is only through this editing process that a TTR file becomes an easily manageable exchange file. It is advisable to keep a separate backup of the original file.

The menu item *[File | Edit]* opens the *Measurement results* dialog (Figure 16) in an expanded view mode. The editing functions will be explained in the following sections.

4.3.1 *Editing general measurement information*

The tab *Details of measurement* provides the following functions:

- Editing the contents of all input fields with a white background
- Deleting entire sections
- Inserting default parameters for the target geometry and the target coordinate system

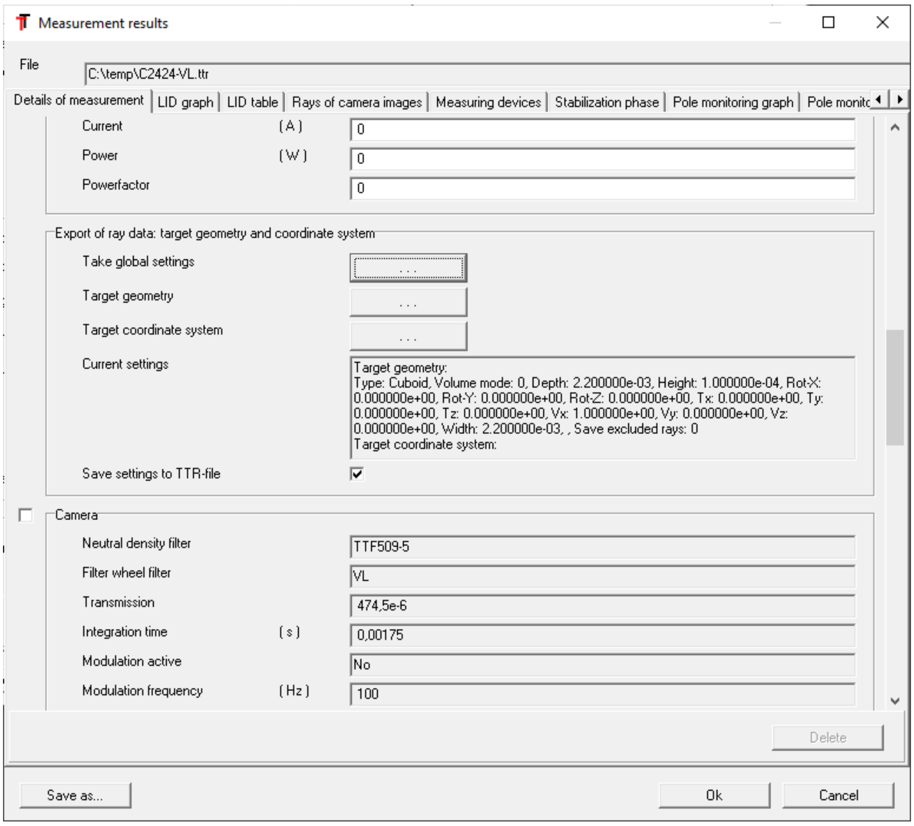


Figure 28: Edit – Details of measurement

Deleting entire sections is useful, for example, when providing a TTR file to external users who should not have access to unnecessary or internal information. This typically includes settings of the measurement system (*Camera* section, *Photometer*, etc.) that are not relevant to external users. Unwanted sections can be enabled via checkboxes and then deleted, using the *Delete* button.

An important function is the specification of default parameters for the target geometry and target coordinate system (see 0 and 3.6.4). If these data are included in the TTR file, the user can conveniently utilize them during the ray generation process. Typically, the suitable parameters are initially tested (see Section 5) and then adopted using the function *Take global settings* (button "*...*"). Direct editing is also possible via the "*...*"-buttons next to the target geometry and target coordinate system fields. The option *Save settings to TTR File* must be enabled, otherwise the data will be deleted.

4.3.2 *Measuring devices, Stabilization phase and Pole monitoring*

If the data from external measuring devices (see 4.2.5), the stabilization phase (0), or the pole monitoring (see 4.2.7) needs to be deleted, this can be done in the respective tabs using the *Delete* button.

4.3.3 *Spectral data*

In the *Spectral data* tab (see 4.2.8), a spectral distribution can be loaded or existing data can be deleted. This distribution is taken into account during ray generation when this TTR file is specified as the source for the spectral signature (see 5.3.1).

The following file formats can be loaded:

- TechnoTeam spectral data (*.tsd, binary)
  This file format can contain individual spectra or a complete goniospectrometric measurement according to IES LM79-19 or CIE S 025. If goniospectrometric measurement data suitable for calculating the relative integral radiant flux is available, the integral spectral distribution will be used when loading, otherwise simply the first spectrum in the file.
- Instrument Systems spectral data (*.isd)
  The file can contain multiple spectra. Only the first spectrum will be used.
- Optis spectral data (*.spectrum)
  Individual spectrum.
- TechnoTeam luminous intensity distribution data (*.ttl)
  A TTL file can also contain a spectrum like a TTR file and therefore it can be specified as a source file for a spectrum.
- TechnoTeam Spectral Data (*.tts, ASCII)
  Single or multiple spectra. Integral spectrum calculation is supported.
- Text file spectral data (.txt)
  Single spectrum

4.3.4 *Additional data*

The display of additional data was briefly mentioned in section 4.2.9. Here, a more detailed explanation will be provided.

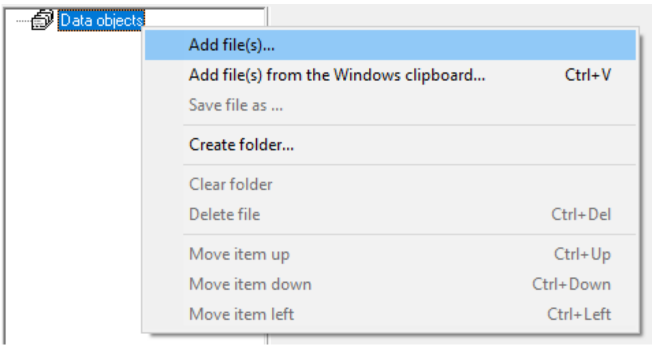


Figure 29: Additional data – Context menu

The term *Additional data* refers to a collection of files that can be embedded in a TTR file. These files can include PDF documents (datasheets), luminance images, adjustment/alignment images, regular image files, spectra, text files, or other binary files. The files can be organized in a hierarchical tree structure.

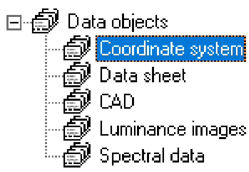


Figure 30: Additional data – Example folder structure

<u>Editing the data structure</u>

The data elements are organized in a tree structure. Figure 29 depicts the initial state with the root node *Data objects* and the context menu (right-click).

As an example, the structure with various data objects is illustrated below. The folders are created first using the menu option *[Create folder...]* (Figure 30).

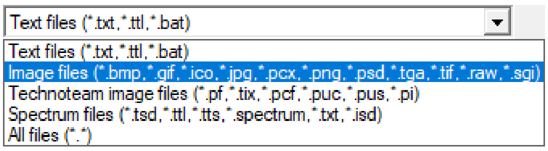


Figure 31: Additional data – File types

<u>Inserting images</u>

To insert regular image files, right-click on the “Coordinate system” folder and choose *[Add file(s)...]* from the context menu. In the file dialog, switch to the "Image files" file type (Figure 31). The image will then be displayed in the right area of the dialog (Figure 32). The image view element for typical image formats includes basic functions for selecting the image area. Zooming can be done using the mouse wheel (or in the menu), and you can shift the image by holding down the left mouse button. The setting of the image area is saved in the data and will be restored when the file is loaded. This allows you to prepare the presentation specifically for an external user, if needed.

The node name is based on the filename. Renaming a node is possible by left-clicking on the already active entry.

Below the image, there is a text input area where additional information can be provided if needed.

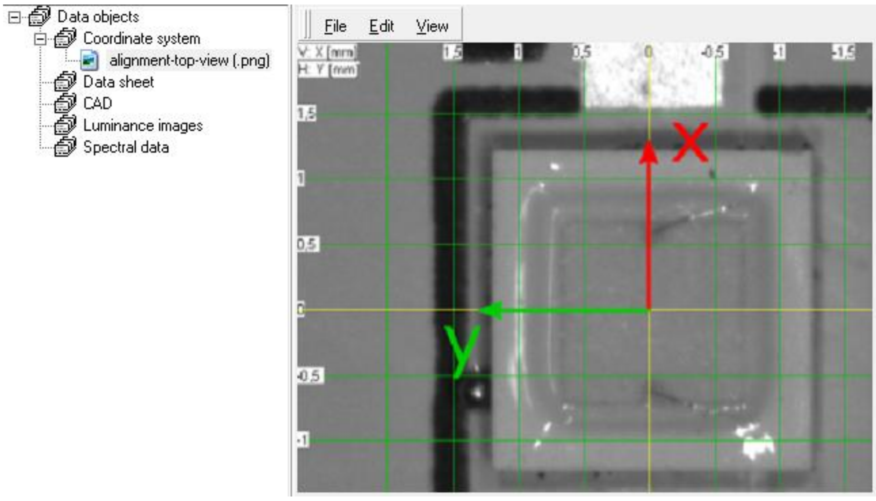


Figure 32: Additional data – Image view of conventional image files

Inserting of TechnoTeam Image types

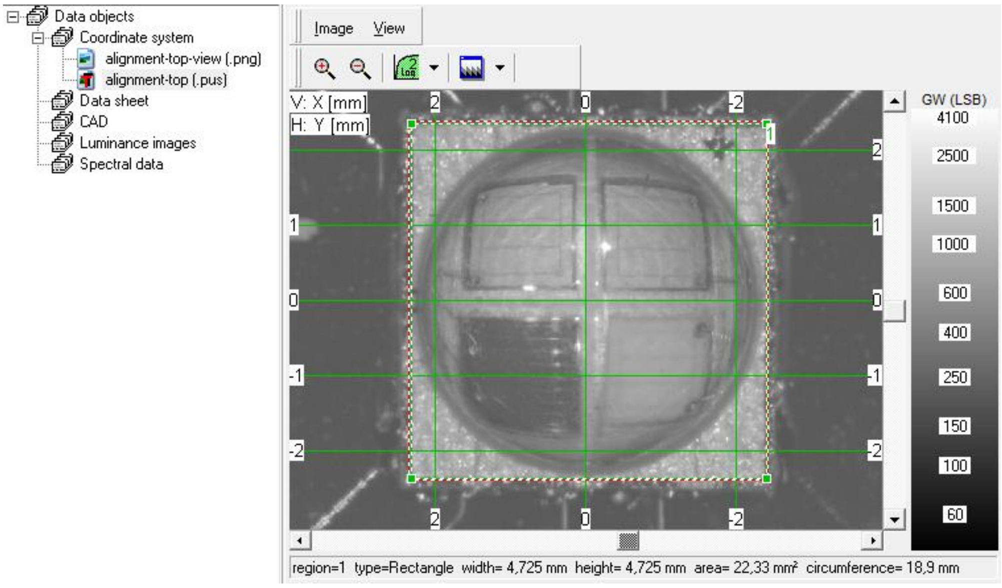


Figure 33: Additional data – Viewer element of TechnoTeam image files

A more specialized image display visualizes TechnoTeam image files. In Figure 33, an image saved during test sample alignment (file extension .pus) is shown. Advantages over a normal image file include the availability of the integrated coordinate system (activated using *[View | Coordinate System]*), as well as options for selecting color palettes and logarithmic scaling for better visualization.

Mouse cursor coordinates in the status bar can be used for dimension reading. A more convenient option is to create regions in the image (context menu), with parameters displayed in the status bar when the mouse cursor is positioned near an activated region.

Luminance distribution images in the .pf image format can also be displayed (Figure 34).

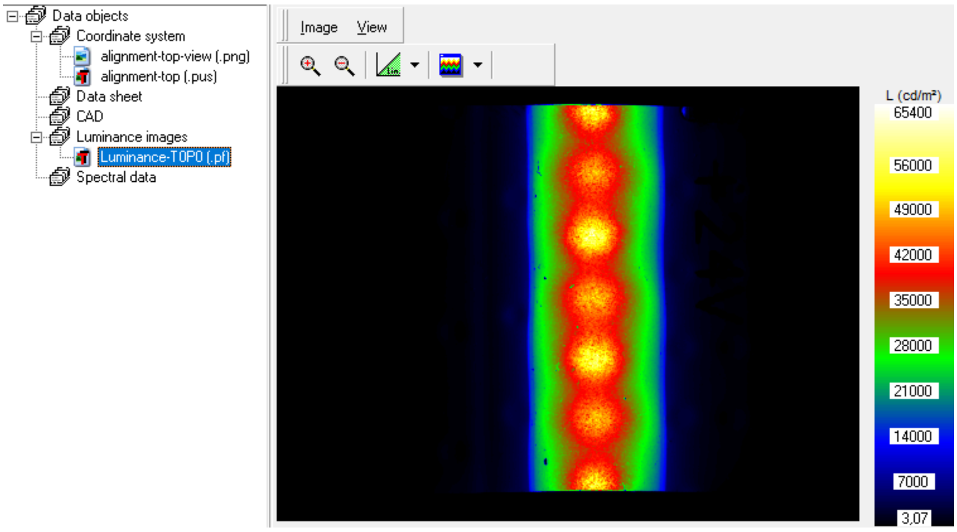


Figure 34: Additional data – Luminance image

Spectral data

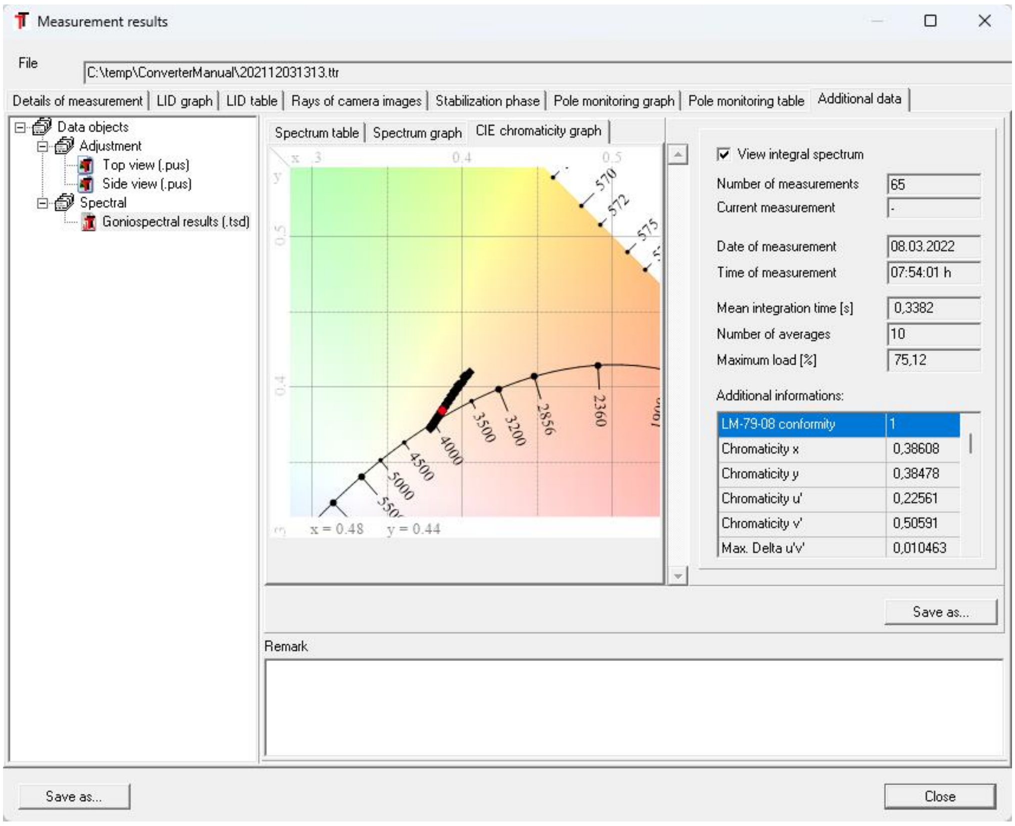


Figure 35: Additional data – Spectral data

A specialized view is also available for displaying spectral data. In contrast to the spectral data associated with a TTR file (see 4.2.8 and 4.3.3), which only includes one spectrum, complete goniospectrometric measurements can be displayed in the additional data. Figure 35 shows the chromaticity coordinates of such a measurement on a CIE color value diagram. Information from each spectrum or the integral spectrum is optionally available.

Adjustment images of the RiGO801 measuring program

Additional data can already be stored in the TTR file by the measurement program. There is a functionality of a specialized RiGO clipboard (see RiGO801 User Manual), where alignment images are typically cached during the alignment of the measurement object and then copied to the TTR file at the end of the measurement. Each alignment image is inserted into the "Adjustment" folder in two versions. A BMP image is a screenshot of the alignment display, while the PUS image is the camera image with the coordinate system (see Figure 36). The BMP image is actually redundant, as the view can always be reconstructed from the camera image. As part of data editing, the BMP images can be deleted when not required.

The view of the measurement object alignment can be configured for clear visibility of relevant details using the PUS view (e.g. logarithmic scaling, zoom area). Since the view settings are also stored in the TTR file, the same visualization will appear when the file is loaded.

A unique feature of these alignment images inserted by the RiGO801 measurement program is the indication of the capture position in the *Remark* text field. In orthogonal positions, the axis labels correspond to the visible axes of the goniometer coordinate system.

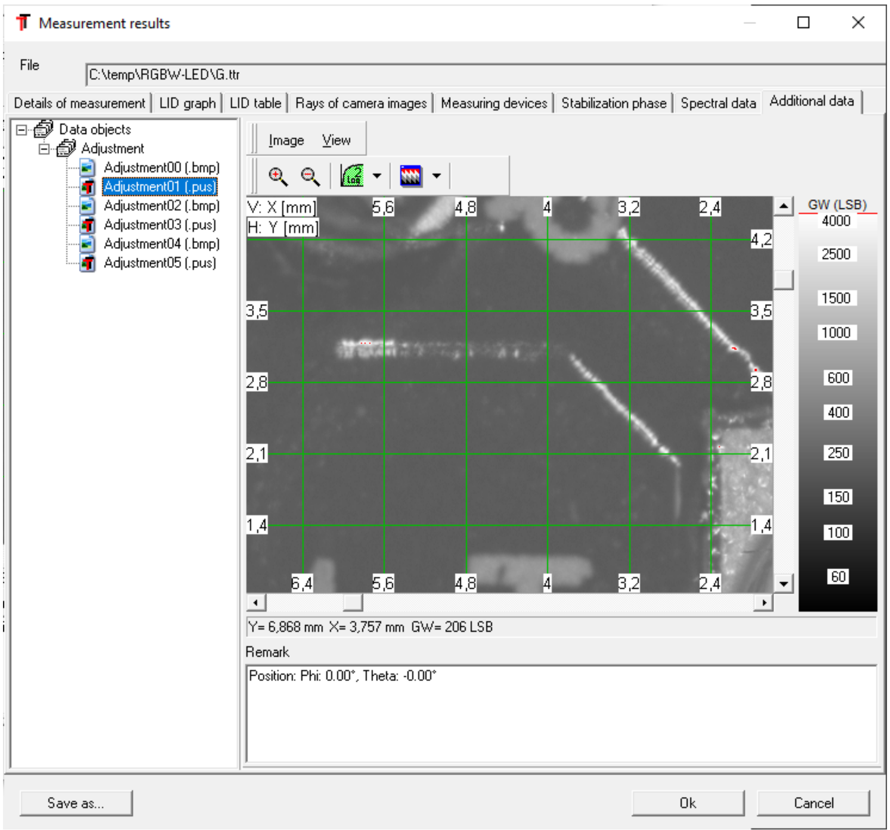


Figure 36: Additional data – Adjustment images from RiGO801 Measuring program

5 Conversion of ray data

The fundamentals of measurement and conversion of ray data were explained in chapter 3. Now, at this point, practical application follows.

5.1 Determining the Target Geometry

Without specifying a target geometry, all ray starting points are located on the sphere described by the lens center (see Section 3.6.3). Typically, the starting points are shifted along the ray directions using ray tracing to the envelope surface or into the volume (*Volume mode* option) of a target geometry. The *Konverter801* program supports the geometries of sphere, cuboid, and cylinder.

The geometry must encompass all relevant light-emitting regions of the light source. Rays originating from excluded areas that do not intersect with the geometry will not be considered! This may also be intentional to exclude, for example, measured reflections from external components (PCBs, parts).

The selection of the target geometry is done through the *Target geometry* dialog (menu item *[Options | Target geometry]*). The dialog for entering the geometry parameters is opened using the *Settings* button.

The position and orientation of the target geometry are always specified in the goniometer coordinate system.

More detailed information about the individual parameters will be provided in the following sections.

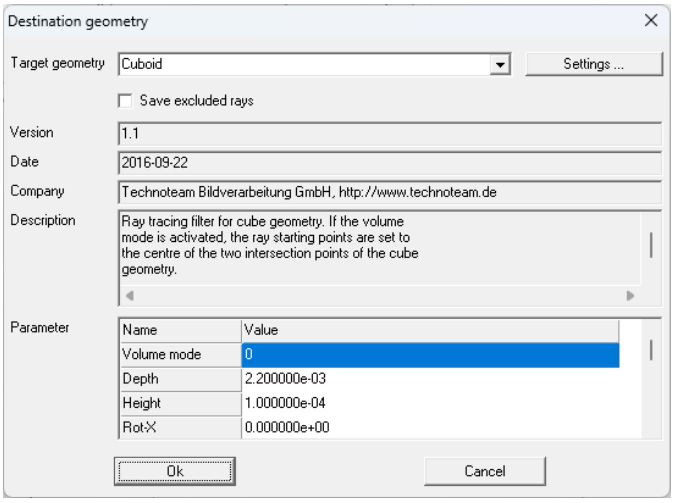


Figure 37: Dialog – Target geometry

The option to *Save excluded rays* allows for the output of ray data that is not captured by the target geometry in a separate file (filename extended with "_excluded"). This enables a more precise analysis of these areas.

The remaining text fields display the properties of the currently selected ray tracing module and the current parameters.

5.1.1 *Common settings*

In all parameter dialogs, the options for *Dimension unit* and *Volume mode* are available. The unit (mm, cm, inch, m) applies exclusively to the specifications of the target geometry and does not affect the measurement unit of the ray output or other measurements. The volume mode of a ray tracing module can be activated using the corresponding option. Instead of shifting the ray starting points onto the surface of the target geometry, they will be placed within the volume (as described in section 3.6.4).

For orienting a geometry, there are two available modes: *Set rotation* and *Set symmetry axis*. When using Rotation, it is important to note that the reference axis rotates sequentially from the X-axis to Y-axis to Z-axis. After rotation, translation is performed according to the specified parameters *Tx*, *Ty*, and *Tz*. If no translation is performed, the center of the geometry will be located at the origin of the goniometer coordinate system.

Dialogs with 3D visualization depict the position of the target geometry within the goniometer coordinate system. The size scaling of the 3D object compared to the axes is often somewhat small. For better visualization, larger geometry dimensions can be temporarily used (e.g., scaled by a factor of 10), and then scaled back down before confirming the inputs.

5.1.2 *Camera sphere*

In this setting, no ray tracing takes place, meaning that the rays originate on the sphere defined by the lens center.

5.1.3 *Sphere*

The sphere geometry is defined by the position of its center and its radius.

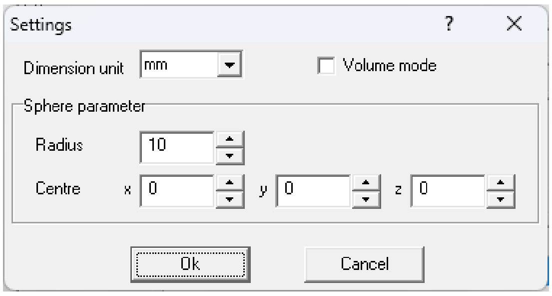


Figure 38: Target geometry - Sphere

5.1.4 *Cylinder*

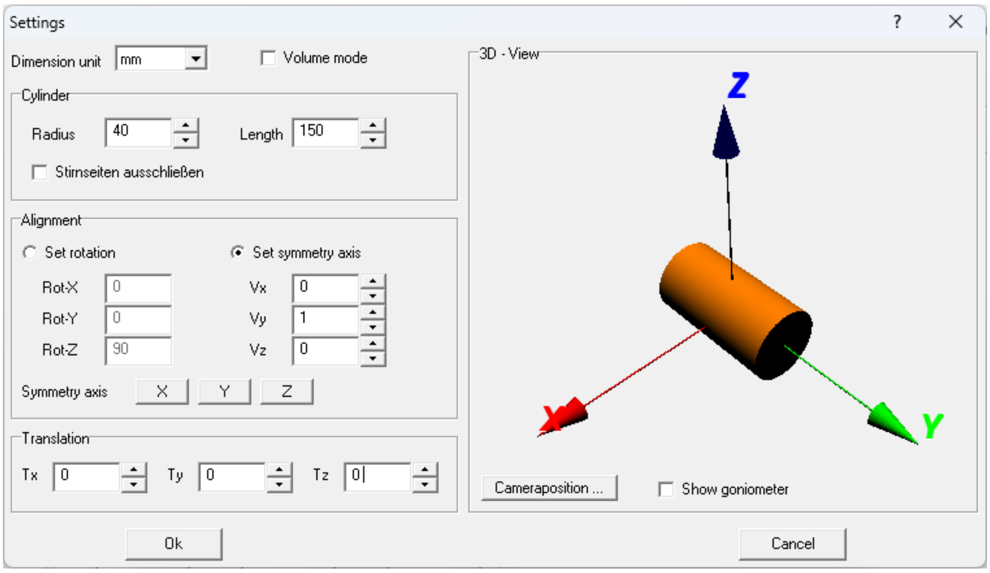


Figure 39: Target geometry - Cylinder

In the input area *Cylinder*, the dimensions of the cylinder are specified with the radius and the length (total length). The option *Exclude end faces* excludes rays that intersect with one of the end faces. This can be useful when, for example, a section of a rod light source has been measured.

5.1.5 *Cuboid*

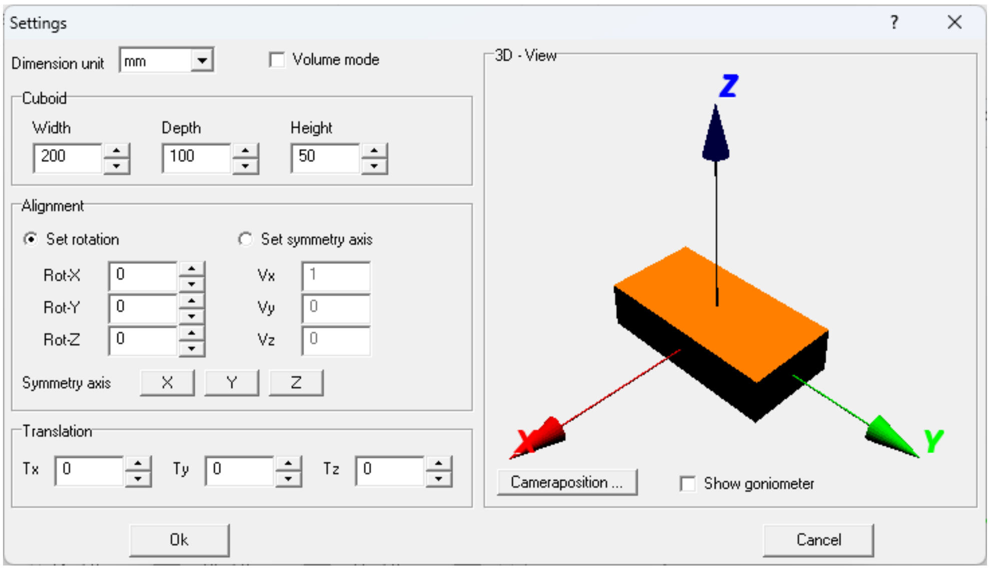


Figure 40: Target geometry - Cuboid

The dimensions of the cuboid are with respect to the reference axis. Without rotation, the reference axis corresponds to the X-axis, meaning that *Width* is the side length in the Y-direction, the depth is the length in the X-direction, and *Height* is the length in the Z-direction.

5.2 Coordinate system transformation (Target Coordinate System)

The orientation of the coordinate system of the rays or the luminous intensity distribution is often linked to the measurement object and its usage scenario. This means that the raw data available in the goniometer coordinate system must be transformed into the coordinate system of the measurement object (see 3.6.5). The necessary coordinate transformation can be parameterized in the program via the menu item *[Options | Target Coordinate System ...]* (Figure 41).

The parameters of the coordinate transformation define the position of the target coordinate system relative to the goniometer coordinate system. Sequentially, rotation is performed first, followed by translation of the coordinate system. The settings are applied by clicking the *Ok* button.

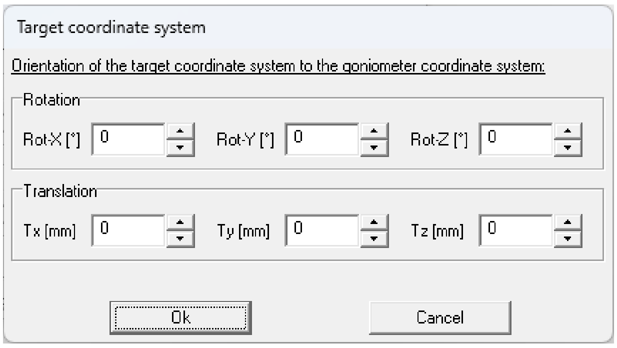


Figure 41: Dialog – Target coordinate system

5.3 Saving of ray files

For saving ray data, all common file formats are available. The basic information for all formats is identical (see 3.6.7). Many formats allow specifying spectral information for the rays. The *Konverter801* program supports assigning wavelengths to each ray (see 3.6.6). Additionally, there are format-specific features, such as setting the dimension unit.

The format-specific dialogs for starting ray generation and file output are located in the menu *[Transform | …]*. In the following sections, the general dialog elements and basic usage will be explained first, followed by the format-specific elements.

5.3.1 *Source parameter*

In the *Source parameter* section, the complete TTR source file name is indicated, as well as the measured luminous flux and the total number of rays.

The option *Use target geometry and coordinate system from TTR source file* is available if these default parameters are present in the TTR file (see section 4.3.1). When this option is active, these parameters will be used; otherwise, the global parameters will be used (see section 5.1).

For ray data formats that support specifying wavelengths for the rays, the option *Spectral signature of ray data* is enabled. You can use the *Load spectrum* button to select a spectral file or a TTR file with an integrated spectrum (e.g., the TTR source file). The spectrum will then be used to generate spectral ray data (see section 3.6.6).

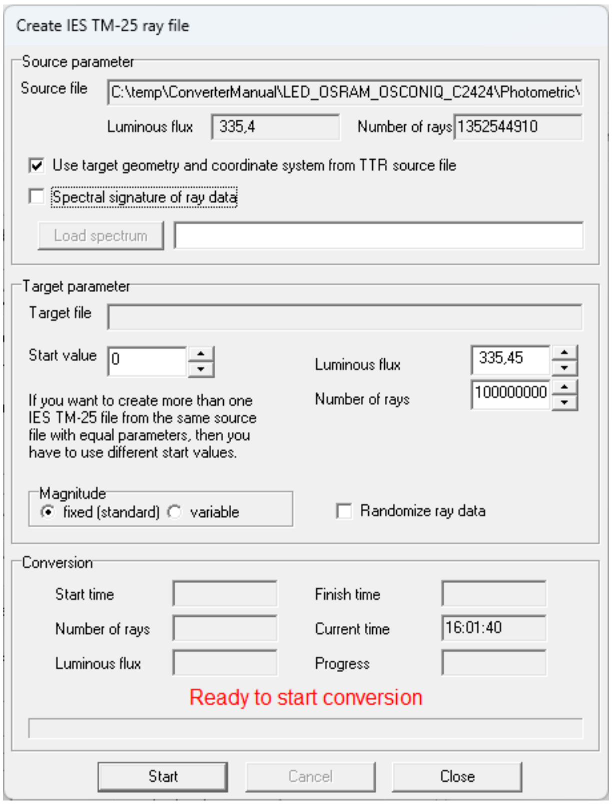


Figure 42: Dialog for the generation of ray files (IES TM-25)

5.3.2 *Target parameter*

The determination of the target file takes place after initiating the conversion by clicking the *Start* button. Prior to that, you need to specify the desired number of rays in the *Number of rays* input field. This number of rays will be extracted from the source file and processed using the ray calculation procedure (ray tracing, coordinate transformation). Rays that do not intersect with the target geometry will not be written to the target file (see section 0). As a result, there may be a discrepancy between the actual number of rays saved in the target file and the specified number (see section 5.3.3).

In the *Luminous flux* input field, a different value than the predefined measured luminous flux can be specified.

The option *Randomize ray data* is important when only a portion of the generated ray data file is used in the simulation. The order of ray conversion in the *Konverter801* program corresponds to the order of the camera images (see section 3.5.2). Therefore, if only the first half of the rays in a ray data file is simulated, it corresponds to half of the measurement. With this option enabled, the rays are randomly distributed within the file after conversion, ensuring that even a subset of the file covers the entire angular range of the measurement.

The selection of rays from the source file based on the specified ray count follows a deterministic algorithm. This means that a second conversion with the same parameters will yield the same rays as before. To generate a second set of ray data independent of the first one, you can make a change in the *Start value* field. This practice originated from times when multiple smaller ray data files were loaded into the simulation one after the other. Given the increased capabilities of modern workstations, this aspect is no longer relevant.

If a format supports specifying a unit of length, the ray starting points will be output in that unit.

5.3.3 *Starting the process and review of conversion statistics*

After pressing the *Start* button, you will be prompted to enter a filename for the target file. Then the conversion process will begin. The current values for the number of rays and luminous flux will be displayed in the output fields. At the end of the conversion, the achieved number of rays and luminous flux may differ from the specified values if rays did not intersect the target geometry (see 5.1). For significant discrepancies (e.g., > 5 %), a more thorough verification is recommended. The conversion parameters and results are also saved in a LOG file (filename + "_log.txt").

5.3.4 *Overview of supported file formats*

- ASAP (*.dis)
  - No spectral rays supported
- LucidShape (*.ray)
- LightTools (*.ray)
- TracePro (*.src)
- Speos (*.ray)
- SimuLux (*.ray)
  - No spectral rays supported
- IES TM-25 (*.tm25ray)
- Photopia (*.rir)
  - No spectral rays supported
- Zemax (*.sdf)

5.4 TechnoTeam Luminous intensity distribution (*.ttl)

The *RiGO801* measurement program generates a separate TTL file alongside the TTR ray data file, containing the luminous intensity distribution data. For the luminous intensity distribution (LID), the coordinate system of the goniometer and the angular resolution of the measurement are used for the angular grids of the C-planes and the luminous intensities within the C-planes.

The TTL file can be recalculated from the ray data in the TTR file at any time. This process now offers additional options.

- Incorporation of the target coordinate system specifications

- Modification of angular resolutions
- Smoothing
- Calculation of near-field LID

The dialog for calculating a luminance distribution from a ray set can be accessed using the menu item *[Transform | TechnoTeam luminous intensity (*.ttl)...]* (Figure 43).

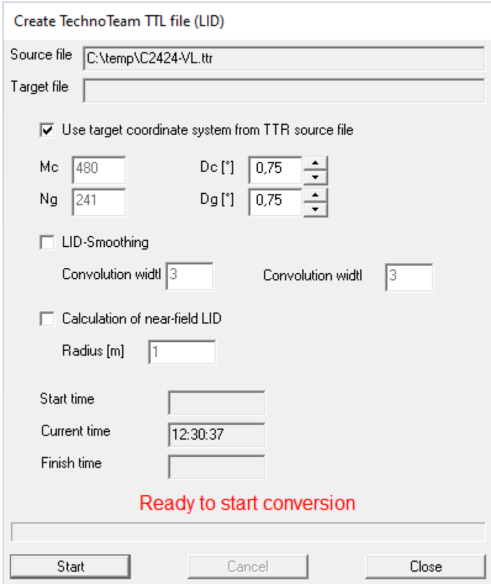


Figure 43: Dialog for calculating an LID and export as TTL file

In the input fields *Dc* and *Dg*, the angular step sizes are selected. The default setting is the measurement resolution.

Smoothing of the data is possible using the option *LID-Smoothing*, along with the two filter widths Phi (C-planes) and Theta (Gamma).

For specific applications, a near-field luminous intensity distribution (Near-Field LID) can be calculated with a freely definable detector distance (Option *Calculation of near-field LID* and text input field *Radius [m]*). The Near-Field LID represents the illuminance distribution at a short distance (virtual photometer), multiplied by the square of the distance. Unlike the far-field LID (point light source, detector distance infinity), the position of the light source in the goniometer coordinate system must be considered here, and it can even be intentionally adjusted using the parameters of the target coordinate system.

After clicking the *Start* button, a file selection dialog will open where you can enter the name of the target file. After that, the calculation process begins.

When recalculating a luminous intensity distribution, it is possible to work with a smaller angular resolution than the one used during the measurement. In most cases, this is not useful because it conflicts with the data sampling. However, in many cases, this can lead to a significant increase in noise. The reason is that each luminous intensity value of the distribution is calculated from a significantly smaller number of rays than in the originally generated distribution. For example, if a luminous intensity distribution is recalculated with an angular resolution of 0.5° from a 2.5° measurement, then each newly calculated luminous intensity value is based on an average of twenty-five times fewer rays than the values in the original distribution.

5.5 Batch processing

The *Konverter801* program provides a convenient way to perform multiple conversions through batch processing. Multiple conversion tasks can be compiled and executed together, eliminating the need to configure parameters for each individual conversion. Saved batch processing files can be modified or reused.

The menu option *[Transform | Batch processing...]* opens the main batch processing dialog (Figure 44).

5.5.1 *Edit jobs*

Existing conversion projects can be loaded or saved through the *[File]* menu.

Inserting new conversion tasks can be done using the *[Edit | New job ...]* menu item or via the right-click context menu. This action will open the *New job* - dialog, where you can select the source file (TTR ray data file), the target format, and you can store an optional note.

The parameters available for the chosen target format are listed in the *Parameter* section. Here, you can specify the target file using the *Select ...* button. All the conversion parameters available here have been explained in the previous sections.

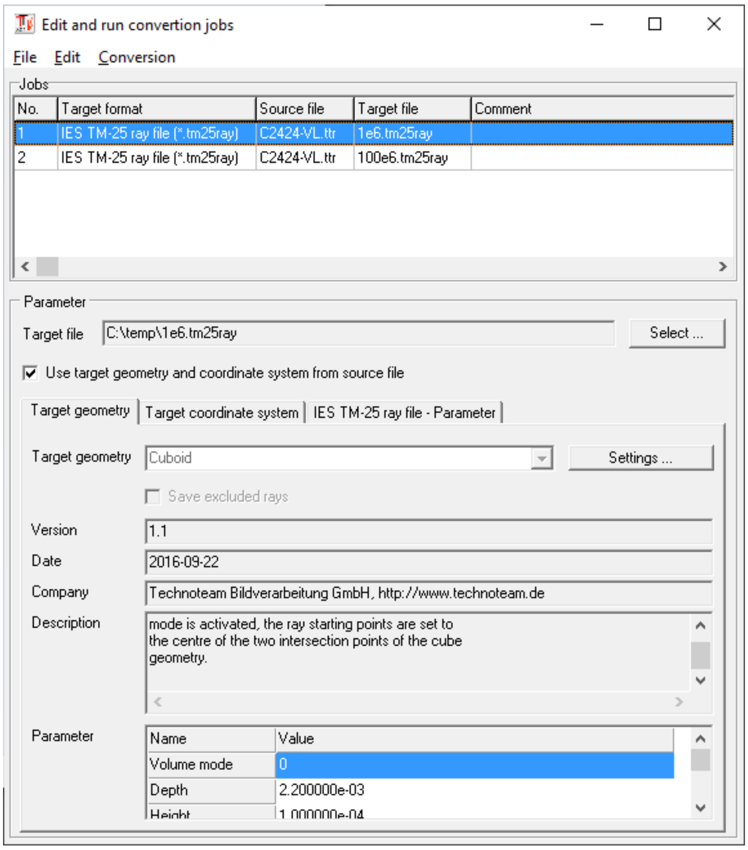


Figure 44: Batch processing

A new entry inherits the parameters of the current entry in the list. This allows for convenient compilation of tasks with minor parameter variations (e.g., ray count or target format) between them.

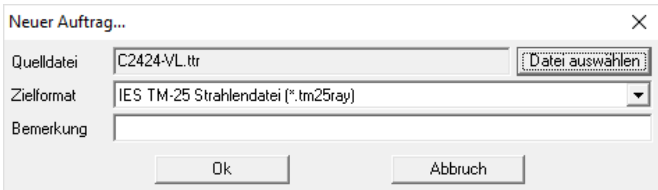


Figure 45: Batch processing – New job

Changing the order of conversion, as well as deleting or displaying the results dialog, can be done through the *[Edit]* menu or via the context menu.

5.5.2 *Execute jobs*

Executing conversion projects is done through the menu item *[Conversion | Start …]*. The *Execute jobs* dialog (Figure 46) displays the current conversion parameters and the progress of the conversion.

For each ray file, an ASCII-format log file is also generated, containing all the parameters and results of the conversion. The log file's name is composed of the target file's name, followed by the "_log" postfix and the ".txt" extension.

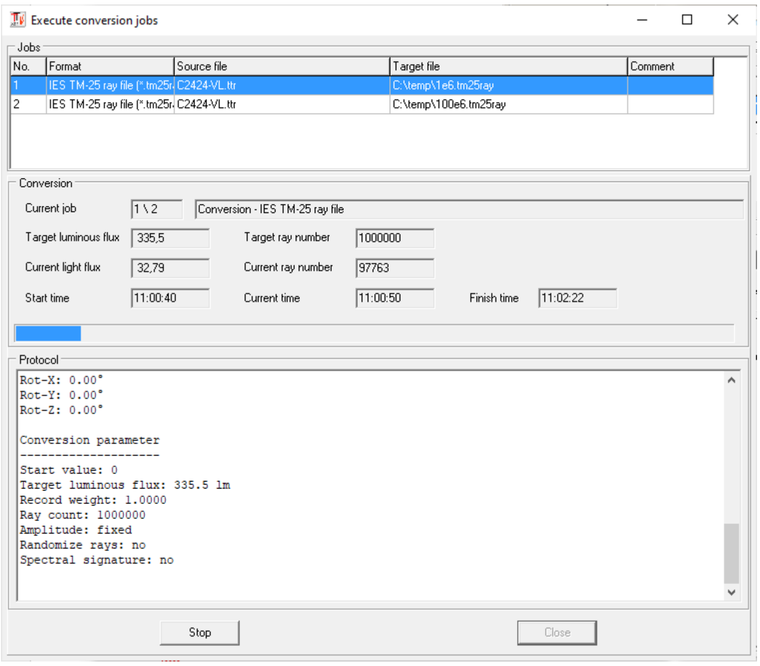


Figure 46: Batch processing – Execute jobs

Example log file:

```
Ray data conversion
======================================
Job file: C:\temp\unnamed.rcj
Job number: 1

Source file: C:\temp\C2424-VL.ttr
Target format: IES TM-25 ray file
(*.tm25ray)
Target file: C:\temp\1e6.tm25ray
Remark:
Luminous flux - source file: 335.4
Ray count - source file: 1352544910

Parameter - Target geometry
------------------------------
Type: Cuboid
Volume mode: 0
Depth: 2.200000e-03
Height: 1.000000e-04
Rot-X: 0.000000e+00
Rot-Y: 0.000000e+00
Rot-Z: 0.000000e+00
Tx: 0.000000e+00
Ty: 0.000000e+00
Tz: 0.000000e+00
Vx: 1.000000e+00
Vy: 0.000000e+00
Vz: 0.000000e+00
Width: 2.200000e-03
```

```
Transformation of ray data
------------------
Tx: 0.00 mm
Ty: 0.00 mm
Tz: 0.00 mm
Rot-X: 0.00°
Rot-Y: 0.00°
Rot-Z: 0.00°

Conversion parameter
--------------------
Start value: 0
Target luminous flux: 335.5 lm
Record weight: 1.0000
Ray count: 1000000
Amplitude: fixed
Randomize rays: no
Spectral signature: no

Conversion results
-------------------------
Start time: 11:00:40
End time: 11:02:23
Proportion - luminous flux: 99.38 %
Proportion - ray count: 99.38 %
```

6 Additional functions

The menu *[Tools]* lists various additional functions, which will be explained in the following sections.

6.1 LID export from TTL file

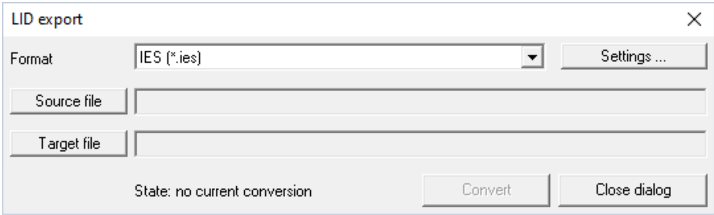


Figure 47: LID export

With this function, you can convert the LID from the TechnoTeam TTL format to various output formats. There are also simple calculation functions available, such as calculating the illuminance distribution on a plane (see 6.1.5). The *LID export* dialog (Figure 47) lists all available conversion functions in the *Format* selection. The *Settings...* button opens a dialog that provides information about the selected function and may include configuration options.

The following section explains the currently available conversion functions.

6.1.1 *LID ASCII (*.txt)*

The ASCII export format represents a universal text format. The output of the luminous intensity matrix (rows: Theta, columns: Phi, first row: Phi angle, first column: Theta angle) is generated only for the measured angular range.

The configuration parameters include the selection of the delimiter (tab or space) and the decimal separator.

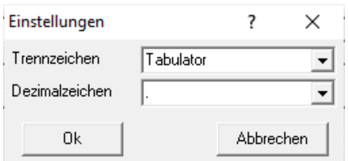


Figure 49: LID export – ASCII - Settings

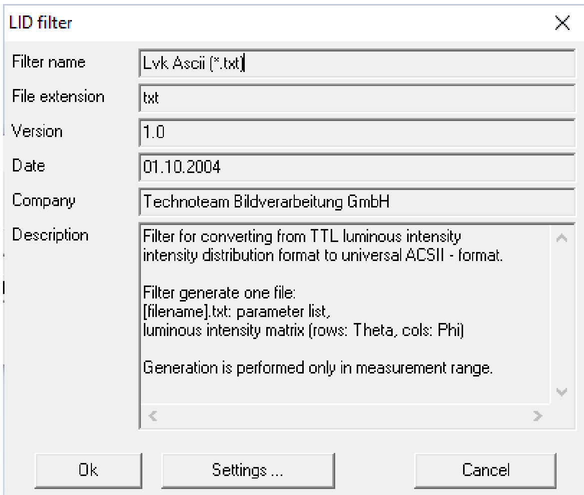


Figure 48: LID export – ASCII (*.txt)

6.1.2 *IES (*.ies)*

The IES format is synonymous with several backward-compatible formats for photometric data and related information, following the IES LM-63-02 standard. In this format, luminous intensities are provided in absolute cd values.

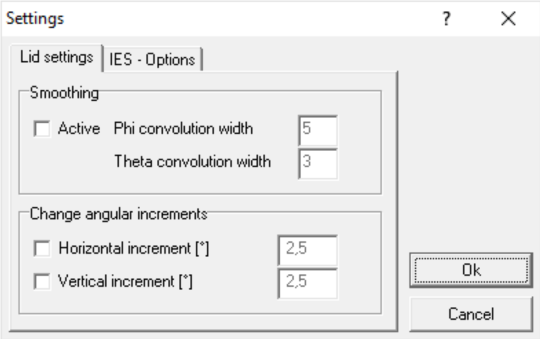


Figure 50: LID export – IES – Common options

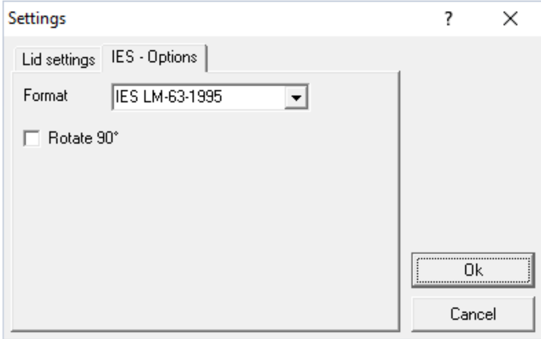


Figure 51: LID export – IES – Format options

In the *LID settings* tab, you can configure optional smoothing and adjust the measurement grid. The *IES options* encompass format-specific settings. The *Format* dropdown defines the version of the format standard. The *Rotate 90* option pertains to the differing alignment of a luminaire's longitudinal axis according to IES standards or CIE / EN standards. In accordance with IES, the longitudinal axis lies within the C0-C180 plane; otherwise, it lies within the C90-C270 plane. Enabling this option rotates the LID by -90°.

6.1.3 *EULUMDAT (*.ldt)*

EULUMDAT is a format for exchanging photometric data on luminous intensity distribution of light sources, originating from the year 1990. The common file extension is *.ldt. This format has become an industry standard for transmitting photometric data in Continental Europe.

Similar to the IES export format, the *LID Options* tab allows for smoothing and adjustment of the measurement grid.

6.1.4 *Luminous intensity distribution map (*.pf)*

The conversion function *Luminous intensity distribution map* generates an image projection of the absolute luminous intensity matrix in TechnoTeam PF file format. PF files (Picture Float) can be viewed using Techno Team's LMK Labsoft software or with the file viewer for TTR additional data (see section 4.3.4).

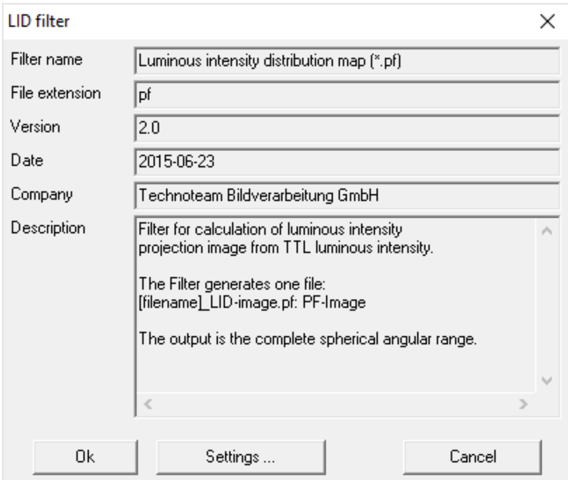


Figure 52: LID export – LID Map

The output is in the full sphere angular range. The image columns correspond to the C-planes (referred to as V), and the image rows correspond to the γ-planes (referred to as L) of the luminous intensity distribution. In addition to the luminous intensity image, a solid angle image is generated, which contains the solid angle for each luminous intensity. By multiplying both images, the luminous flux distribution can be obtained. This allows for the determination of luminous fluxes in spherical segments if needed.

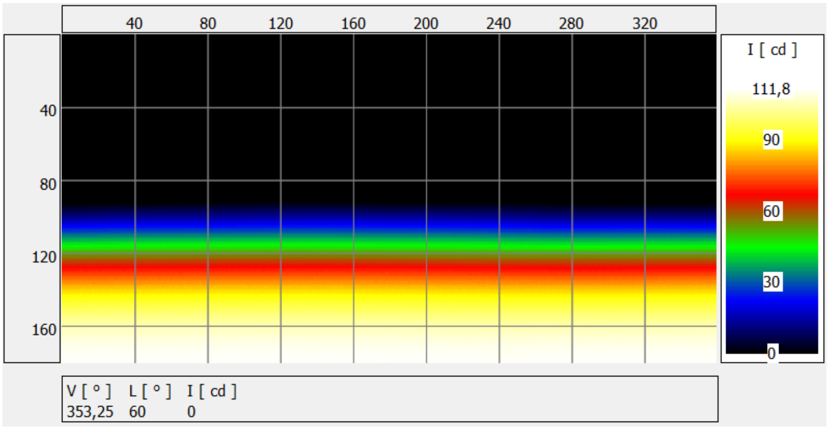


Figure 53: Example of an LID image (LED, Lambert emission)

The adjustment parameters include rotation parameters as well as the sequence of rotations for each axis and the determination of the photometric coordinate system (CIE (C, γ) or IES C(V, L), and CIE (A, α) or IES A (Y, X)).

One use case is, for example, the projection of the LID of a spotlight onto A-planes. In the following example, a reading lamp was measured in the C-plane coordinate system, oriented towards the pole. Rotating the LID around the Y-axis by -90° brings the orientation into the horizontal position. Finally, by selecting the A-planes option, you achieve the commonly used representation for spotlights.

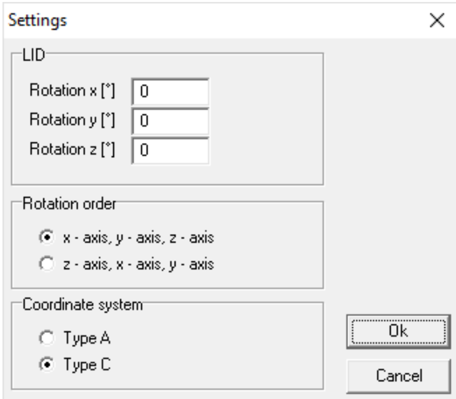


Figure 54: LID export – LID map - Settings

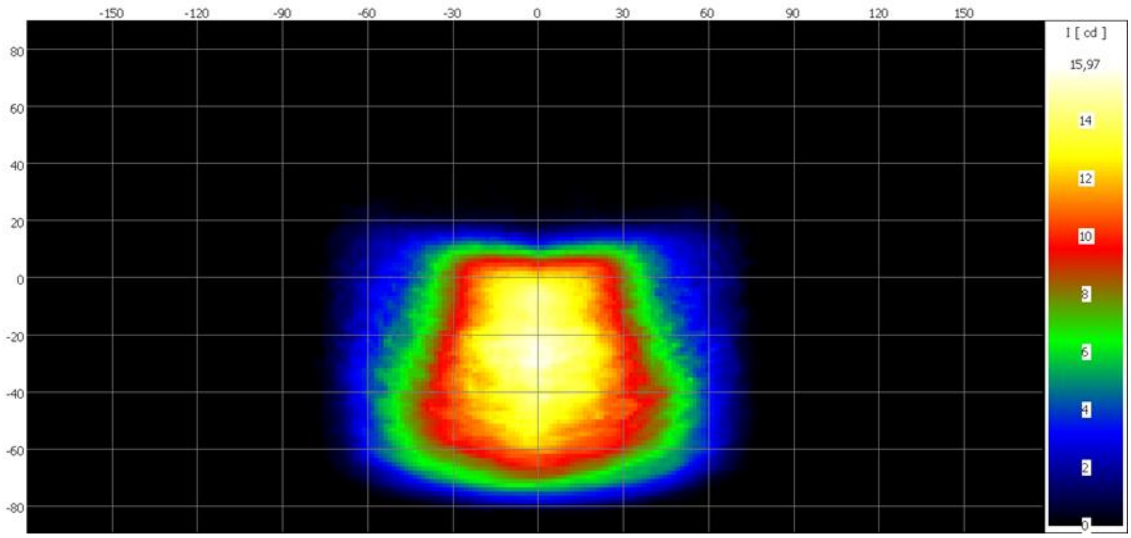


Figure 55: LID in Type-A coordinates as image

6.1.5 *Illuminance distribution on a plane (*.pf)*

This function calculates the illuminance distribution on a plane. The output format is a floating-point image in TechnoTeam .pf format (see also section 6.1.4). The positions and orientations of the luminous intensity distribution and the calculation plane in relation to the world coordinate system are freely definable.

The functionality will be explained below using the example of calculating the illuminance distribution in the passenger compartment of a car. The goal is to calculate the illuminance distribution on a surface illuminated by a reading lamp. Even though the lamp has small dimensions, the photometric far-field distance is greater than the distance to the calculation surface. As a result, the calculated illuminance distribution is not accurate. The solution here is to calculate the near-field LID (see section 5.4) from the ray data at the distance of the surface. It should be noted that the illuminance distribution calculated using the near-field LID is strictly accurate only on a spherical surface, and there will be deviations on a flat surface in relation to the distance from the center. However, this can be neglected in this underlying configuration.

The calculation algorithm utilizes three coordinate systems. The fundamental one is the world coordinate system (X_W, Y_W, Z_W). Additionally, there is the luminaire's coordinate system (X_L, Y_L, Z_L) and the plane coordinate system (X_P, Y_P, Z_P), both of which are positioned with respect to the world coordinate system (see Figure 56).

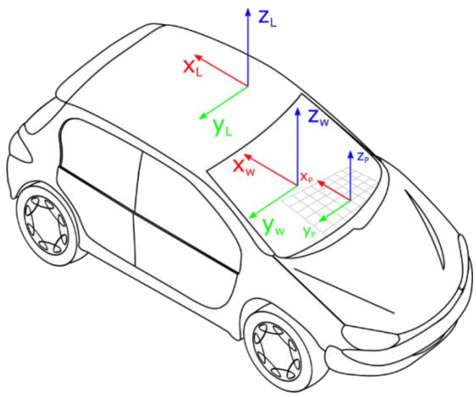


Figure 56: LID export – Illuminance distribution – Coordinate systems

In this example, the world coordinate system is assumed to be centered within the passenger compartment. The reading light (luminaire coordinate system) is positioned at X_W = -600 mm and Z_W = 800 mm. The orientation of the luminaire does not need to be changed since the measurement was already conducted in its installed orientation. The calculation plane for the illuminance distribution is placed at X_W = -600 mm, Y_W = 0 mm, and Z_W = 0 mm. For the size of the target plane, 1000 mm x 1600 mm is chosen with a resolution of 0.5 px/mm.

The input of parameters is done under *Settings* in the *Projection settings* tab. Depending on the preferred rotation sequence, you can choose between x-y-z and z-y-x rotation orders.

In the *Single value calculation* tab, you can specify a list of plane coordinates (Figure 58) for which the illuminance values will be written to a separate text file (.txt extension).

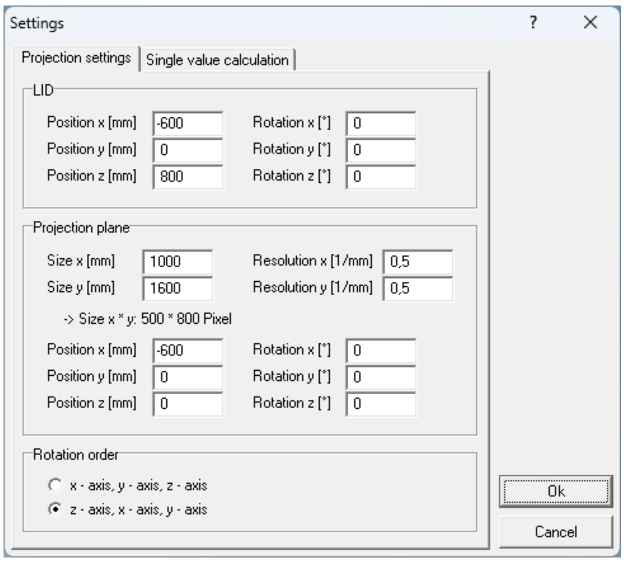


Figure 57: LID export – Illuminance distribution – Settings

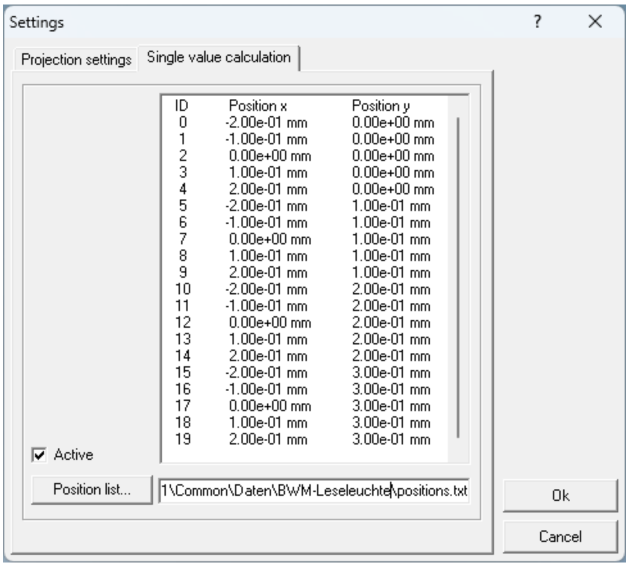


Figure 58: Position list for illuminance values

Position list format specification:

```
[Number]
[x y 0 0 0 0 1]
...
```

Positions are in Meters. File extension is .txt.

Example:

```
20
-0.200 0 0 0 0 0 1
-0.100 0 0 0 0 0 1
0 0 0 0 0 0 1
0.100 0 0 0 0 0 1
...
```

For evaluating the illuminance image (TechnoTeam .pf format), the LMK LabSoft software is required. Here, an isolux representation can be realized. A basic image display is also available within the *Konverter801* program when processing additional data (see section 4.3.4).

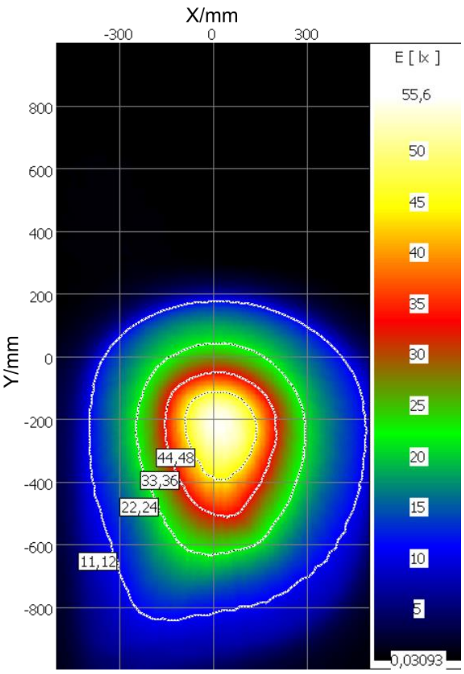


Figure 59: Illuminance distribution with isolux - lines.

6.2 Merging of ray files

For specific applications, merging multiple TTR measurement files into a single target ray file can be useful. For instance, it allows generating an averaged ray file for measurements of an LED type with production-related variations in emission characteristics. Another application is creating a spectral ray file from multiple measurements in different spectral ranges. A third application is combining measurements of the same measurement object taken with disjoint driving ranges.

The menu option *[Transform | Merge ray data...]* allows combining multiple TTR ray data sets into a single dataset. The procedure for this operation is similar to the batch processing of ray conversions described in Section 5.5.

First, a conversion project with at least two tasks must be created (see Figure 60). For each TTR source file, the conversion parameters, including *Target geometry* and *Target coordinate system*, must be set similarly to batch processing (see section 5.5). Ideally, these parameters are already included as defaults in the TTR file.

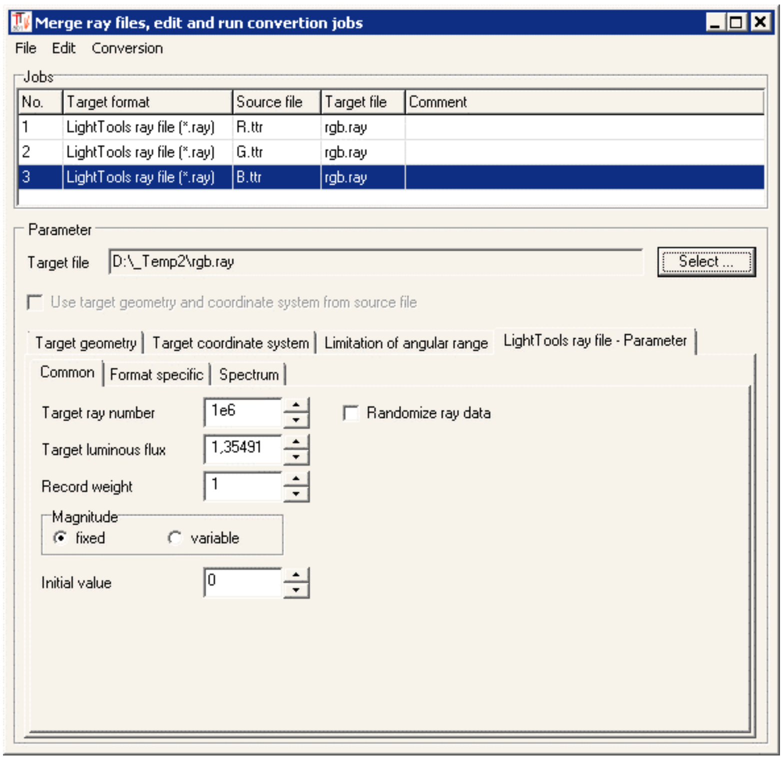


Figure 60: Merge ray files – Create conversion list

If necessary, when combining TTR measurement files, an angle range can also be specified for each TTR file. When activated, all rays in the relevant TTR measurement file that lie outside the specified angular range are ignored. Valid phi values are between 0° and 360°, valid theta values are between 0° and 180°. If a phi range is to be specified that covers the 360°/0° limit, the value of the end of the angular range must be selected to be greater than 360°.

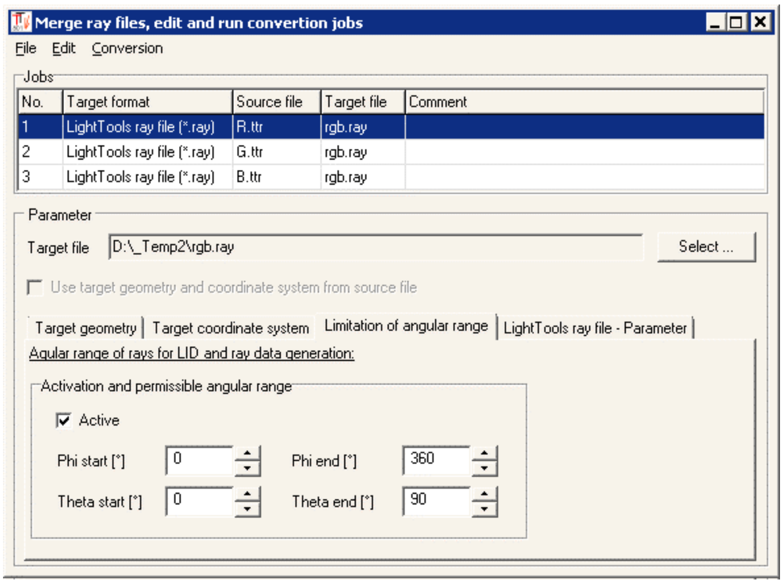


Figure 61: Merge ray files – Limitation of angular range

In contrast to batch processing, there is only a single target file in this case. For this file, you specify the desired format along with the common conversion parameters: *Target luminous flux*, *Target ray number* and *Randomize ray data* (refer to section 5.3.2).

For each source dataset, you can provide a dataset weighting w_i in the parameter dialog. This allows you to adjust the ray counts and luminous fluxes of individual conversions, thus altering the significance or impact of a source dataset. The ray counts of individual conversions $n_{dst,i}$ are determined from the target ray count n_{dst} and the source ray counts $n_{src,i}$, as well as the dataset weights w_i, using the following formula:

$$n_{dst,i} = \frac{w_i}{\sum w_i} \cdot n_{dst} \cdot \frac{n_{src,i}}{\sum n_{src,i}}.$$

The luminous fluxes of the temporary ray sets $\Phi_{dst,i}$ are calculated from the target luminous flux Φ_{dst} and the source luminous fluxes $\Phi_{src,i}$, as well as the dataset weights w_i, using the following formula:

$$\Phi_{dst,i} = \frac{w_i}{\sum w_i} \cdot \Phi_{dst} \cdot \frac{\Phi_{src,i}}{\sum \Phi_{src,i}}.$$

Executing a project for combining TTR ray datasets is exactly the same as executing batch processing projects (refer to section 5.5.2). A conversion project for batch processing is saved in the same way as batch processing projects, as an ASCII file (*.mcj - Merge-Converter-Job) in INI-file format.

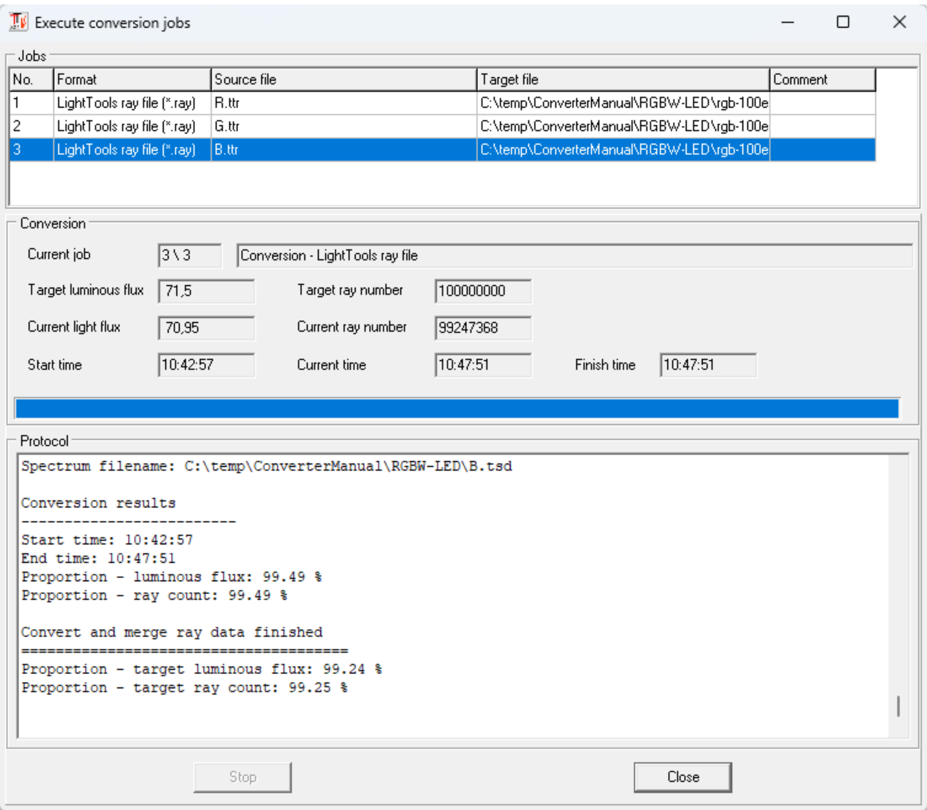


Figure 62: Merge ray files – Finish of the progress

Figure 62 displays the conversion dialog at the end of the process. The protocol file (target filename with the extension _log.txt) of the conversion is shown under *Protocol*. The significant protocol data primarily includes:

- Single conversions

- Target luminous flux: This should be checked to ensure that the utilized luminous flux is correct. When using spectral data, this luminous flux is determined from the given total luminous flux and the spectral distribution.
- Ray count: This is the number of rays used from each respective source file. When merging rays, source data with lower weights will have fewer rays represented in the target file. If this count is too low relative to the total ray count, it can negatively affect the quality of the simulation. In such cases, using separate ray files in the simulation might be more favorable.
- Portion - luminous flux and ray count: These portions refer to the rays captured by the target geometry. As with regular ray conversion, these portions should ideally be close to 100%, otherwise important areas might be excluded.

- Total Result, Portion - target luminous flux, and target ray count: The criteria for evaluating these values are the same as those for individual conversions.

6.2.1 *Example: RGB-LED*

As an example, the generation of a spectral ray file from measurements of an RGB LED is demonstrated here. The red, green, and blue LEDs were measured separately, each operated with the same current. The spectrum for each LED is also available as a .tsd file. The data processing is carried out through the following steps:

1. Determine the suitable target geometry and insert the parameters into the TTR files (see 4.3.1).
2. Assign the spectral distributions to the TTR files (see 4.3.3).
3. Create a project for merging the ray data. For the target light intensity, provide the sum of the measured luminous fluxes (R = 17 lm, G = 45.7 lm, B = 8.8 lm, Total = 71.5 lm). The weighting factors remain unchanged, as the weighting of the partial luminous fluxes is already derived from the spectral data (refer to conversion protocol). The number of rays is 100e6.
4. Execute the conversions

A LightTools file was generated as the target file with a specified goal of 100e6 rays. The achieved results were 99.21% of the total luminous flux and 99.23% of the target ray count.

The utilized RGB LED is equipped with a lens, and its emission directions are significantly asymmetric. Consequently, the use case for this LED type is likely specialized, and a straightforward simulation result of color mixing for the channels cannot be presented at this point. To achieve that, the channel weighting would need to be suitably adjusted. Figure 63 illustrates the simulation outcome on the x/y plane as a color image.

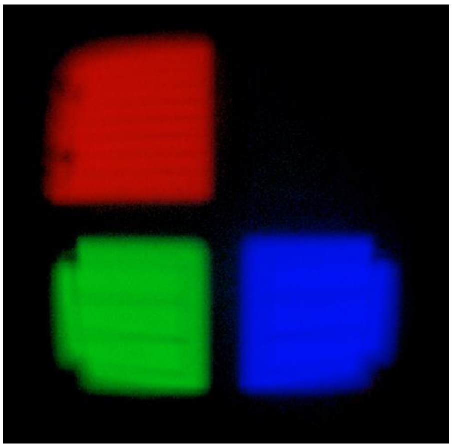


Figure 63: Simulation result - RGB-LED

6.3 Randomize rays

The random swapping of ray order within a ray file (see Section 5.3.2) is also available as a distinct function. The menu option *[Tools | Exchange rays randomly...]* opens the corresponding dialog, where you select the source and target files, and then initiate the process with the *Start* button.

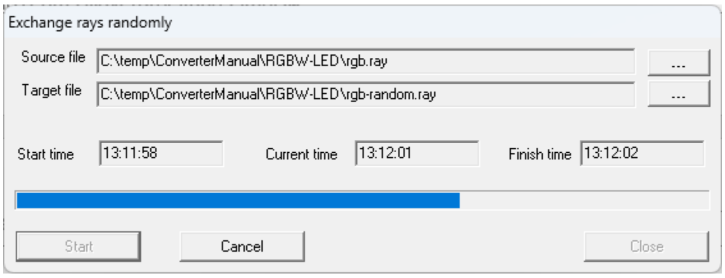


Figure 64: Additional functions – Randomize rays

6.4 Inserting spectrum into TTR file

By selecting the menu option *[Tools | Add spectrum to TTL/TTR file...]*, you can insert a single spectrum into the currently loaded TTR file. This functionality is equivalent to specifying a spectrum in the editing mode (see Section 4.3.3).

6.5 Smoothing LID

The menu item *[Tools | Smooth LID...]* allows for the retroactive calculation and smoothing of an LID from a TTR file, resulting in a smoothed TTL file.

The smoothing is performed with a geodetically constant filter width, meaning that the filter width is adjusted for each latitude (Phi direction) so that the distance along the longitude (Theta direction) across the surface of the LID sphere remains constant. The specified filter widths apply to the equator of the LID sphere (Theta = 90°). Both a Gaussian filter curve and a box filter can be selected for this process.

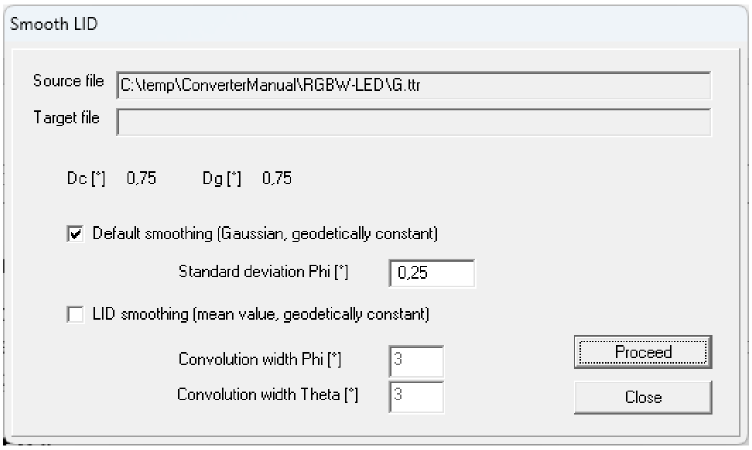


Figure 65: Additional functions – Smooth LID

6.6 Calculate center of gravity of rays

The menu item *[Tools | Calculate the center of gravity of rays...]* allows for the calculation of the center of gravity of rays within a ray data file. The ray center of gravity is defined as the location where the sum of the squared distances to the ray vectors is minimized. During the calculation, the luminous fluxes of the rays are taken into account for weighting. The ray center of gravity is equivalent to the photometric center, which is relevant for positioning luminaires in far-field measurements. An application of this cal-

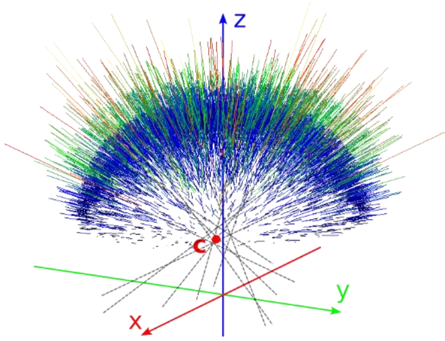


Figure 66: Center of gravity of rays

culation in the automotive sector is the measurement of the light center length according to IEC 60809:2021 (see TechnoTeam Application Note AN RIGO 001, https://www.technoteam.de/main/learn_more/application_notes/light_center_length_from_ray_data/index_eng.html).

The calculation of the ray center of gravity is performed from a TTR file. The rays are calculated based on the specified target geometry and ray count, similar to the regular conversion process. The choice of accurate target geometry is crucial here as rays located further away (e.g., reflections) might be excluded. These rays, due to their larger distance, could potentially distort the result.

A measure of the quality of the beam center of gravity is the square root of the mean squared distance of the rays to the center (RMS distance). This can be considered as the "spread" of the distance. If the RMS distance should also be displayed during the center of gravity calculation, you can activate the corresponding checkbox.

The results of the calculation are displayed in the text field in the Calculation section. Just like in the normal ray conversion process, it is important to verify the number of rays used (intersection with the target geometry). The order of the center of gravity coordinates is x-y-z.

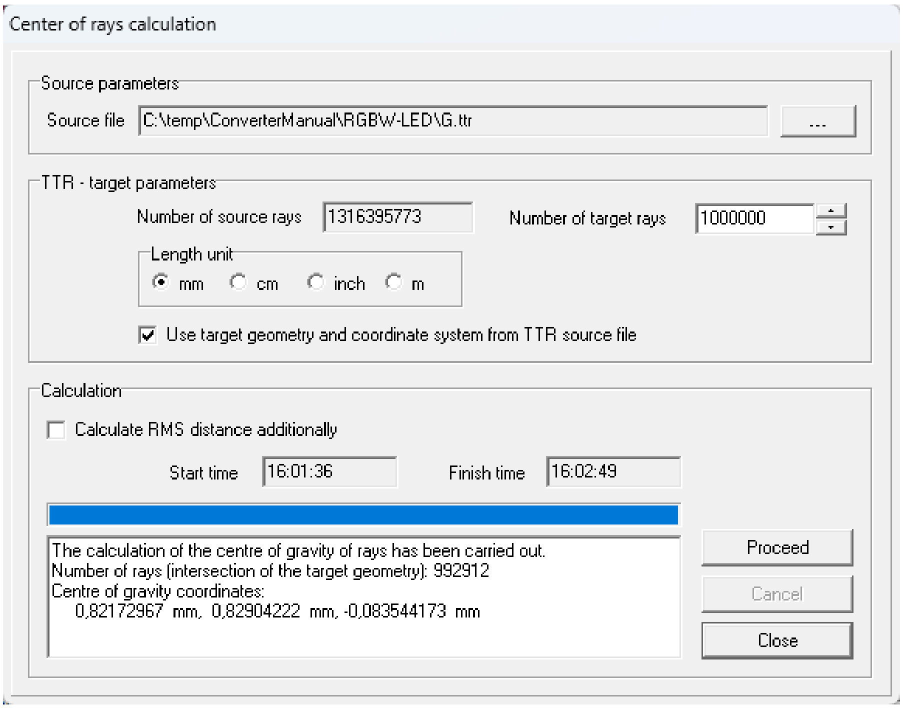


Figure 67: Calculation of center of rays