RiGO801
Basics

high precision measurement systems

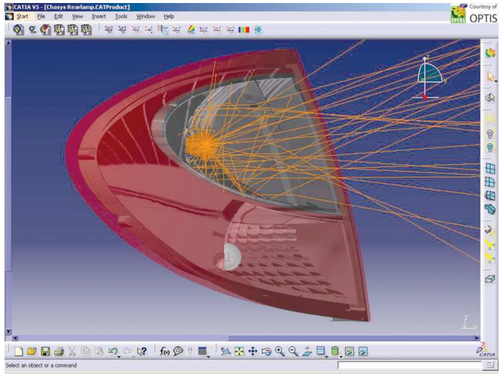
TechnoTeam.de

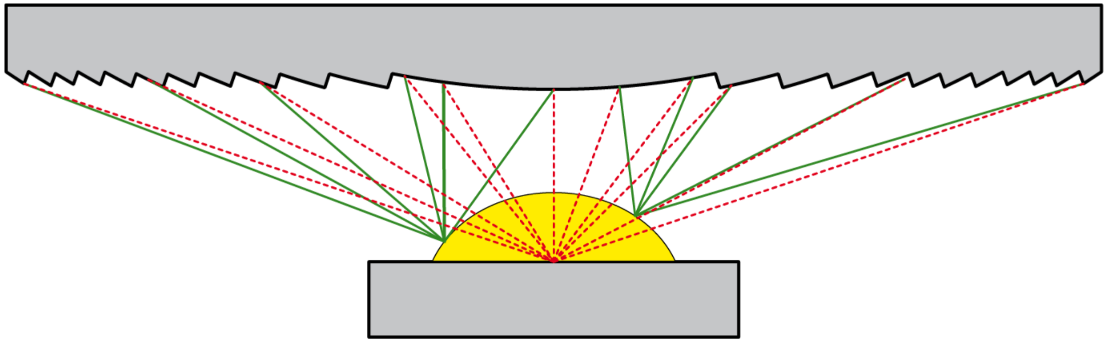
RiGO801 near-field goniophotometer

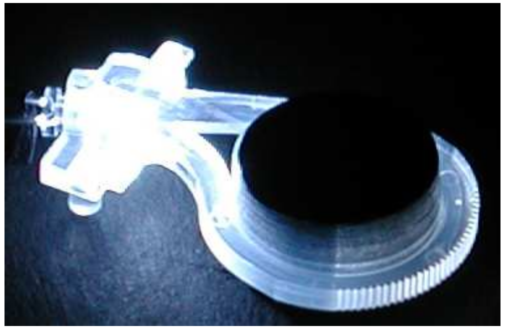
- Use of a CCD luminance camera to measure ray data (light field)
- Calculation of the far-field luminous intensity distribution (LID) from ray data
- Photometer sensor for precise measuring of the luminous flux but also the LID of small test objects (outside minimum photometric distance) can be measured

Aim of near-field data

- Near-field data ➔ Data for calculations close to the luminous object (LED or Lamp)
- Spatial resolved light output characteristic of LEDs or Lamps
- Data usable for optical simulation software
- Development of high quality optical systems







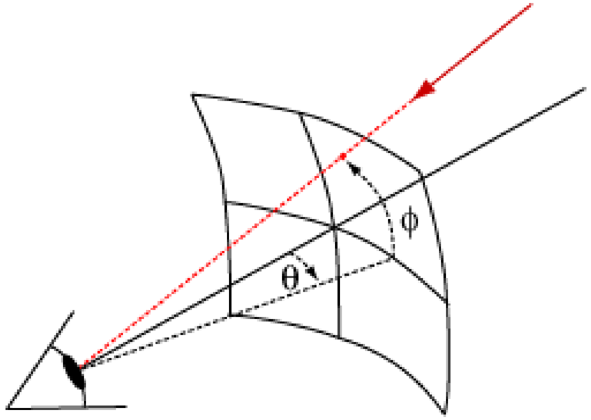
Basics of near field measurements

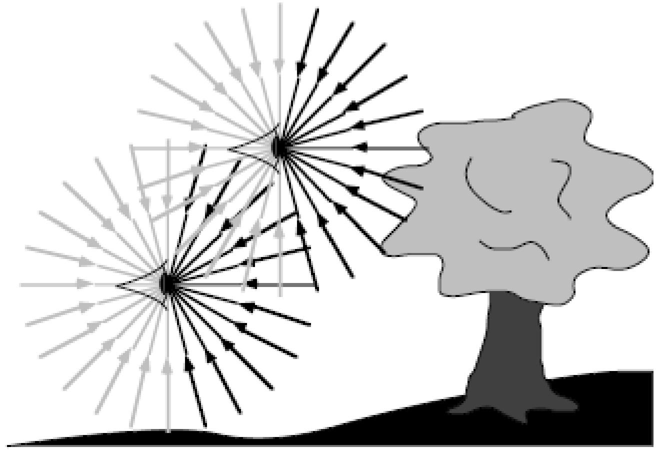
The 7D Plenoptic function

$$P = P(\theta, \phi, \lambda, t, V_x, V_Y, V_Z)$$

- Proposed by Adelson and Bergen [1]
- Commonly known for image based rendering techniques (IBR)
- Describes the information available to an observer at any point in space and time.

→ Reconstruction of the scene from any point of view



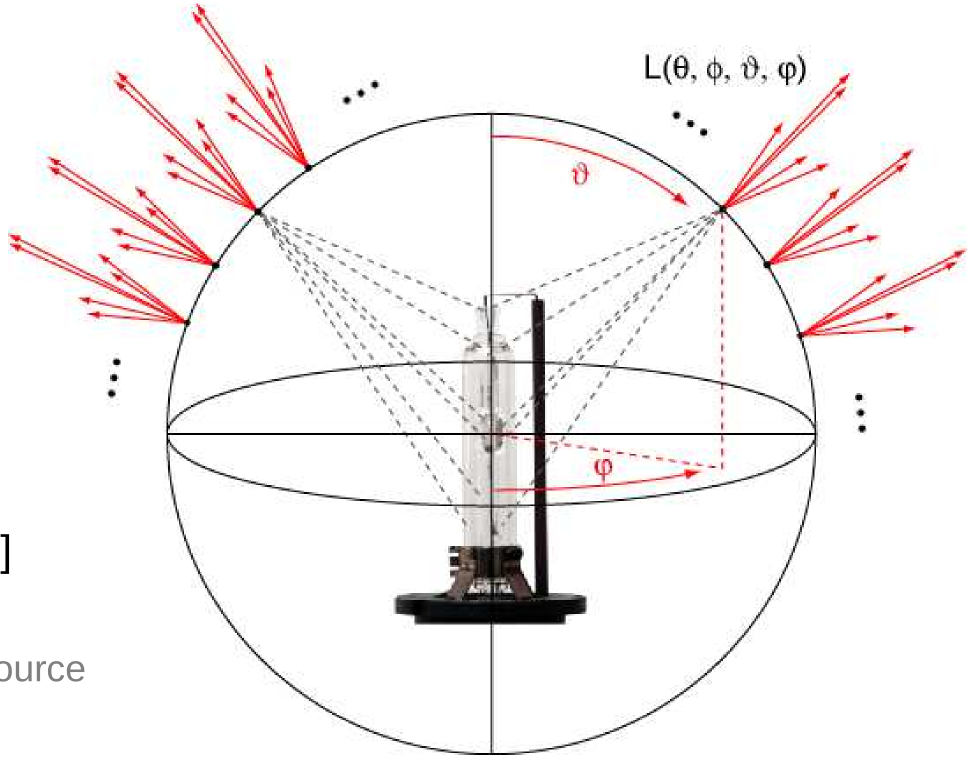


Basics of near field measurements

4D Light field or photic field

$$L(\theta, \phi, \vartheta, \varphi)$$

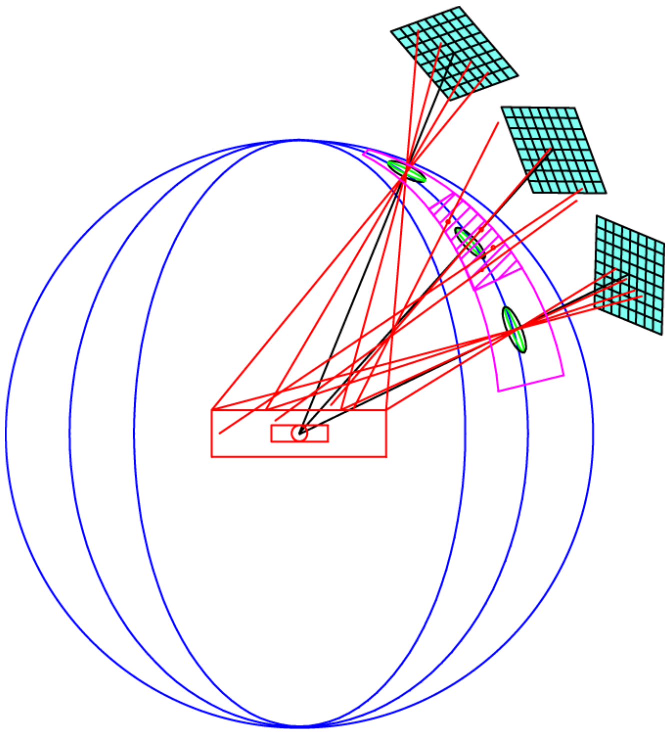
- Simplifications of plenoptic function
  - Time invariant
  - No wavelength information
  - Locations restricted to convex hull (describable with two variables)
- Term Photic field [2] or Light field [3]
- Term „Near-field“
  - Light distribution close to the light source
- Term „Ray data“
  - Light field sampled as vector data



Basics of near field measurements

Measurement of light fields / ray data

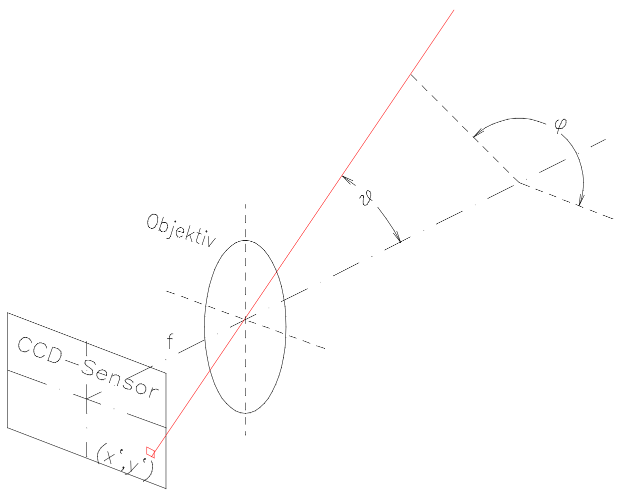
- Sampling of the light field at discrete positions by using a CCD camera
  - Discrete camera positions
  - Discrete pixel positions
- Sampling grid
  - Very difficult topic (high dimensional function) [4]
  - Resolution must be high enough for sufficient reconstruction of the function
  - Danger of aliasing effects
- Weight of the spectral distribution
  - $V(\lambda)$
  - Color channels
  - Special filters
- Storing of images or rays
  - Usually huge amount of data

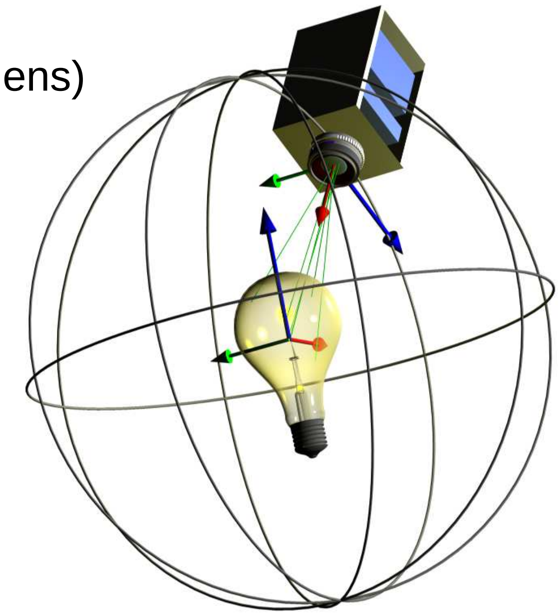


Measuring principle of RiGO 801 near-field goniophotometers

Measurment of ray data – image capturing

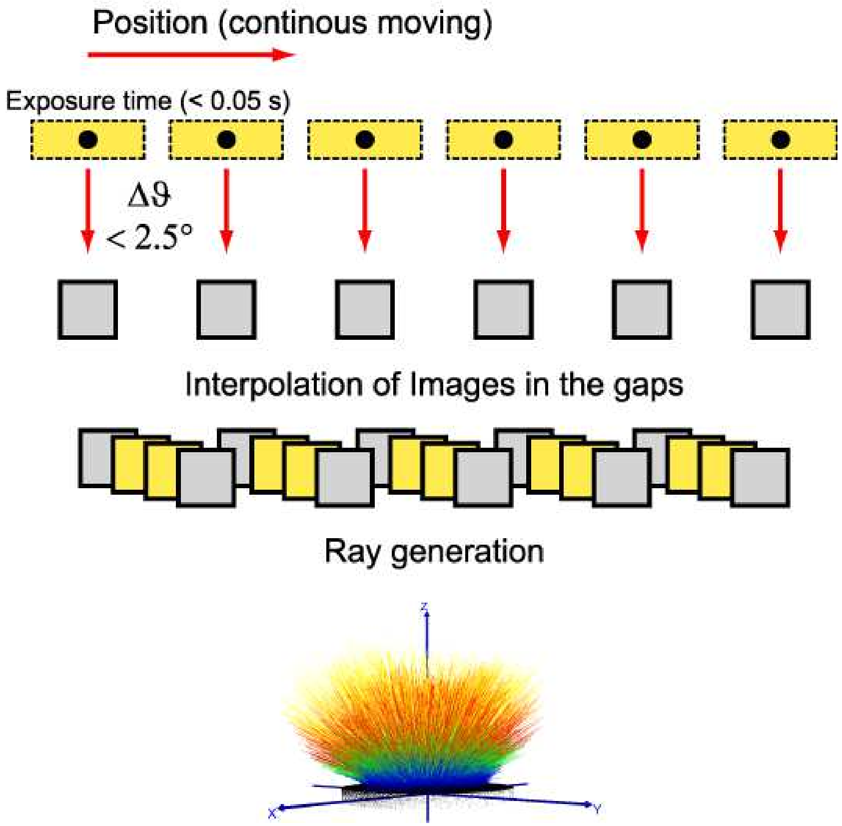
- A luminance measuring camera (LMK 98-4) is moved around the measuring object (spherical surface)
- Luminance images are captured continuously during movement
  - Very fast measurement with high angular resolution
- With the exact knowledge of the optical imaging system (lens) the “direction of light” from each pixel can be calculated





Measuring principle of RiGO 801 near-field goniophotometers

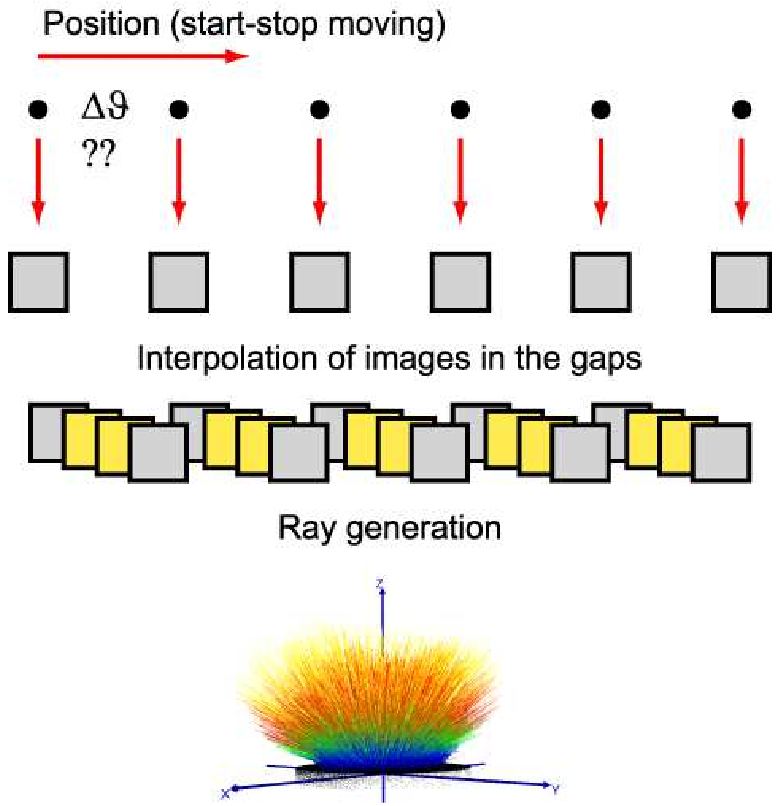
Image acquisition during continuous axis movement



- Images captured during movement
- Image positions are set to the center of the exposure time span
- Short exposure times (1 ms … 50 ms)
- Image information is smoothed within the corresponding angular range. Under the condition that the angular sampling grid is high enough to fulfill the Nyquist–Shannon sampling theorem this procedure is valid.
- Gaps between the images are closed by interpolation / randomization
- Very fast measurement with a high angular resolution

Measuring principle of RiGO 801 near-field goniophotometers

Comparison to start-stop image acquisition



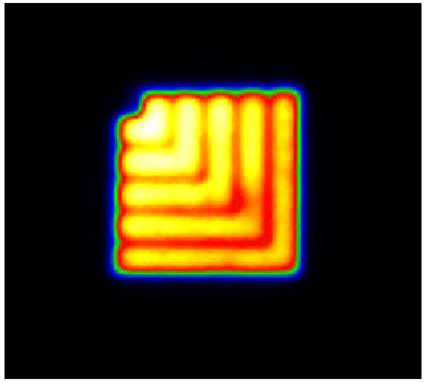
- Images captured while axis is stopped
- Due to very long resulting measuring times the angular resolutions are usually low
- Gaps between images also need to be closed by interpolating algorithms
- Faster angular depending scenery changes (depending on light source) require higher sampling grids. When using the start-top method it is difficult to fulfill the Nyquist–Shannon sampling theorem. The inerpolation within too large gaps is invalid.

Measuring principle of RiGO 801 near-field goniophotometers

Measurment of ray data – ray data from luminance images

- Multiplication of each luminance pixel with its corresponding solid angle
- Extraction of rays (compression to approx. 23000 per image)
- Ray bundle for each image

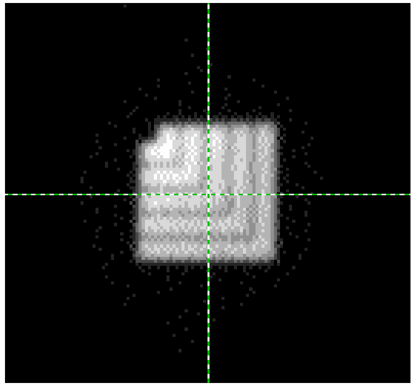
Luminance image



Luminance values to luminous flux portions

$$\Delta\Phi(i, j) = L_{i,j} \cdot c_{i,j} \cdot \Delta\Omega_{i,j}$$

Extracted rays



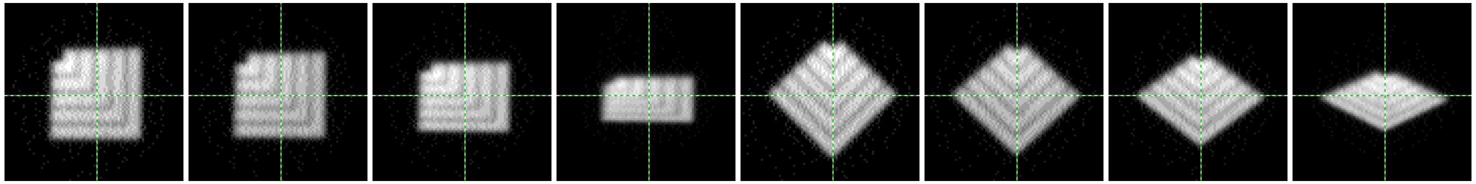
Ray bundles of all images transformed into goniometer coordinate system
→ **Complete ray data set**

$$\Phi(x, y, z, \vartheta, \varphi)$$

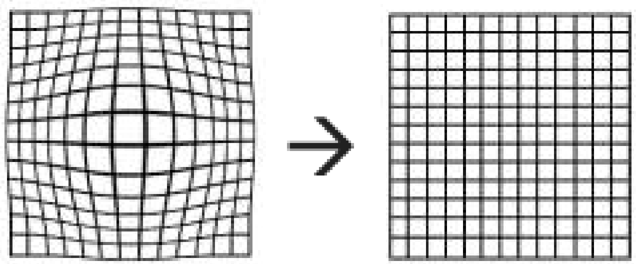
Measuring principle of RiGO 801 near-field goniophotometers

Measurment of ray data – storage of ray data

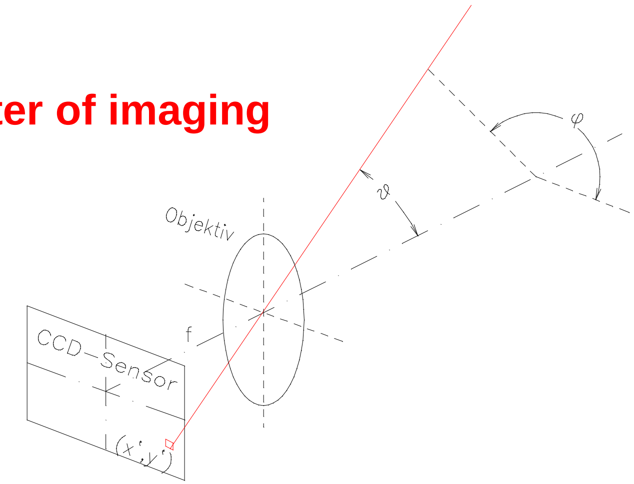
The "ray images" are compressed and stored sequential in a special file (TTR – TechnoTeamRay). The calibration data of the imaging system (lens) is also included.



Lens distortion data



Parameter of imaging system



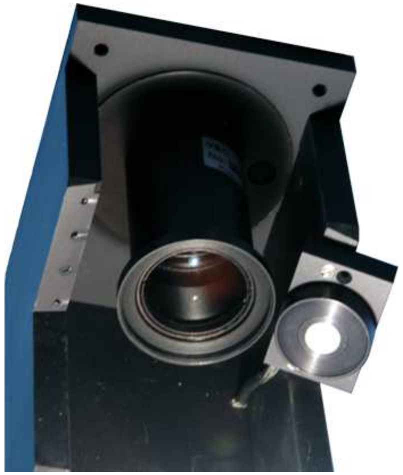
Measuring principle of RiGO 801 near-field goniophotometers

Illuminance meter for measuring luminous flux and also LID

- RiGO801 goniophotometers always use an additional illuminance sensor
- Robust method to measure the luminous flux by integration of illuminance values on a closed surface around the object

$$\Phi = \int E dA \quad [lm]$$

- Photometer based luminous intensity distribution (LID) measurements of small objects
- Simple calibration procedure by measuring a luminous flux standard lamp

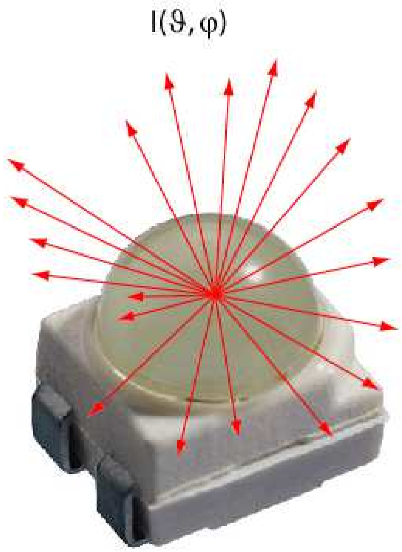


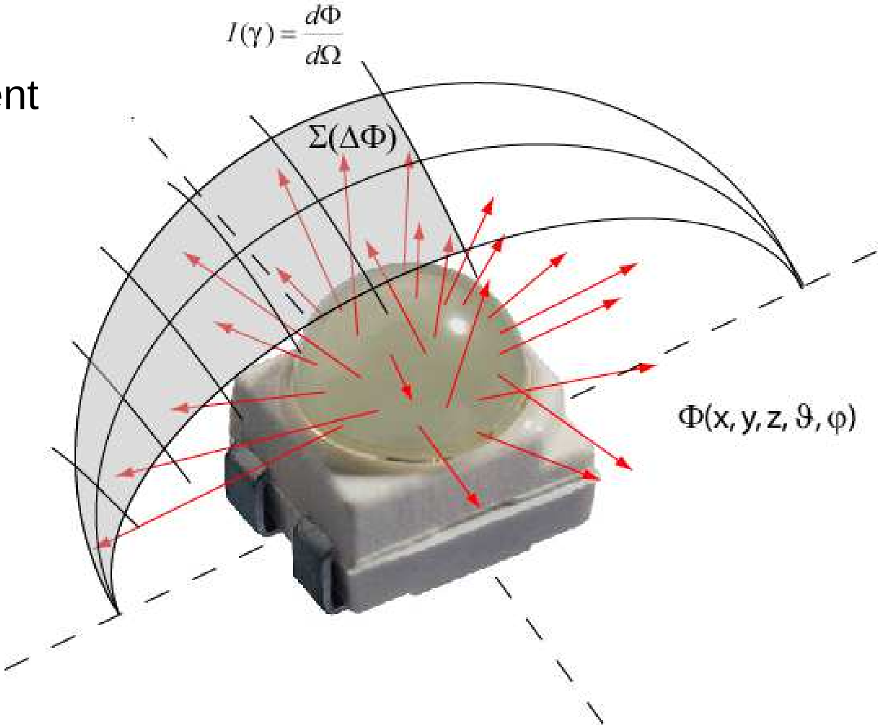
Calculation of LID from ray data

Far field as simplification of light field data

- Accumulation of ray data vectors into desired angular grid of the (luminous) intensity distribution
- LID calculation parallel to ray measurement

$$I(\gamma) = \frac{d\Phi}{d\Omega} \quad [\text{Candela } cd]$$

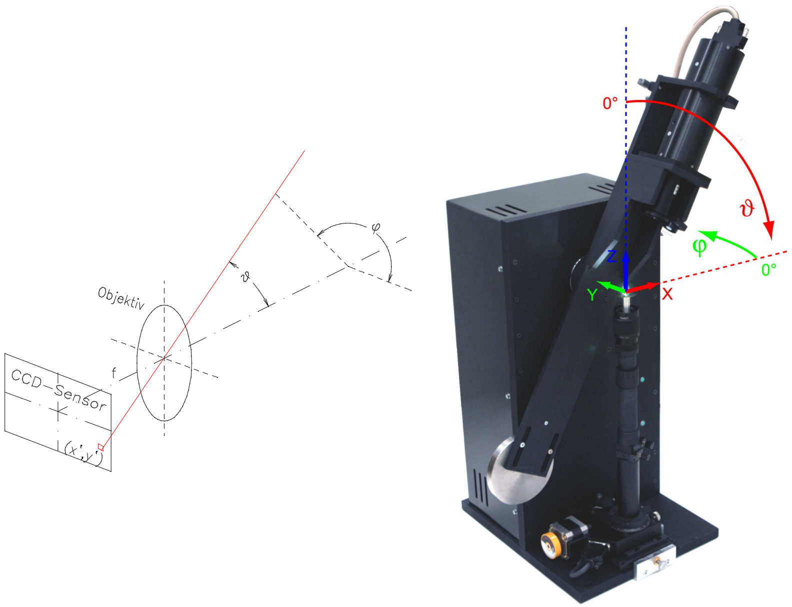




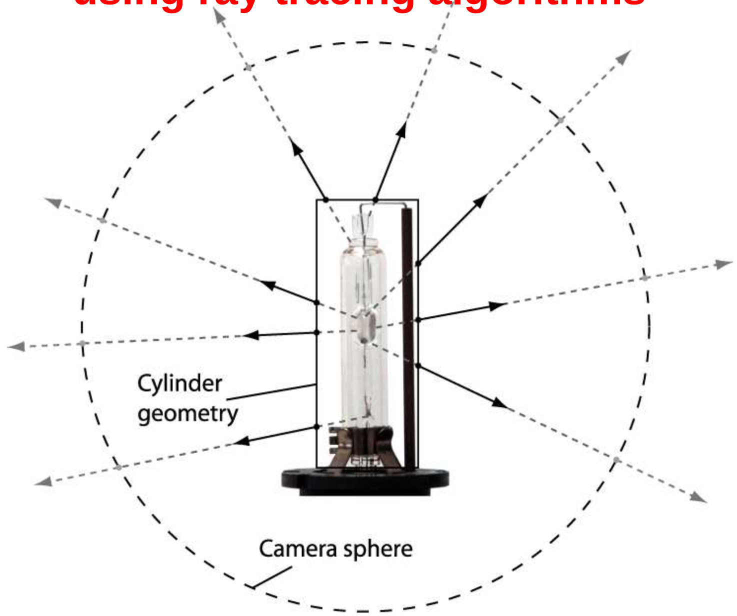
Conversion of rays to the target ray file format

Using the program Converter 801 the rays are transformed to a destination geometry and exported from the TTR file format to the destination file format

Transformation into the goniometer coordinate System using the distortion and imaging parameter of the lens

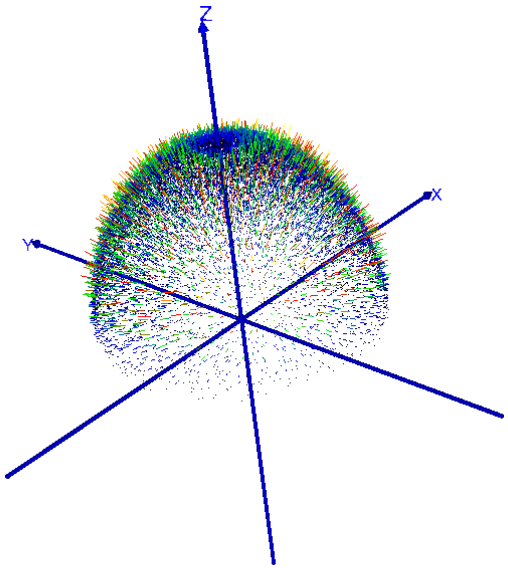


Moving the starting points of the rays back to a destination geometry using ray tracing algorithms

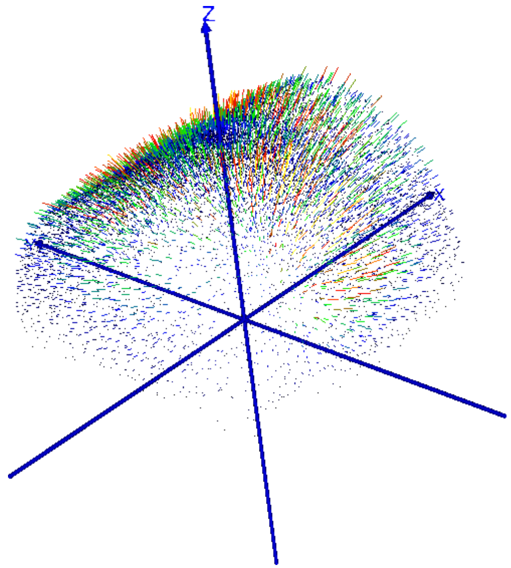


Available destination geometries for ray export

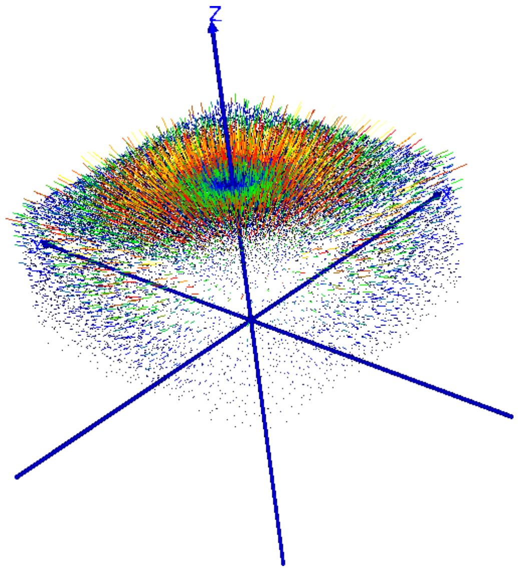
Sphere (Surface)



Cylinder (Surface)

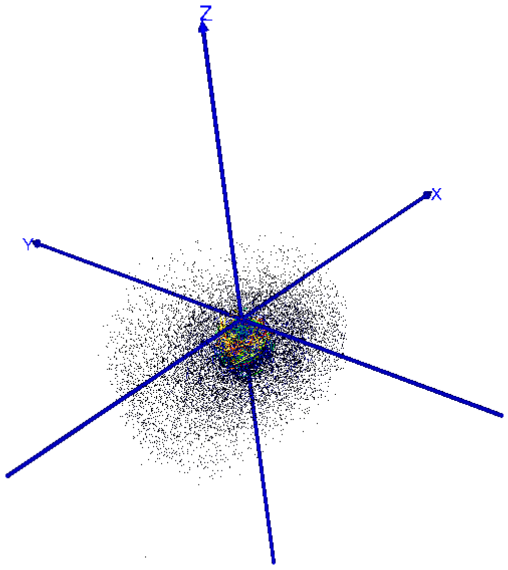


Cuboid (Surface)

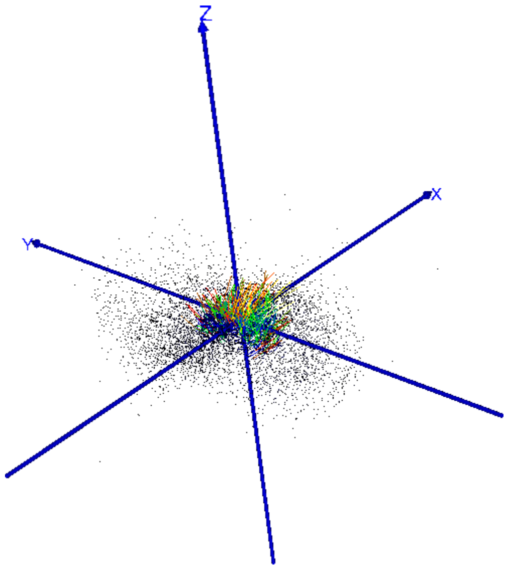


Available destination geometries for ray export

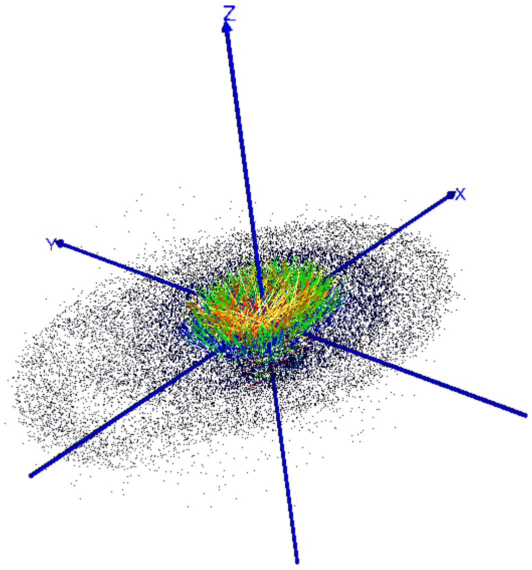
Sphere (Volume)



Cylinder (Volume)



Cuboid (Volume)



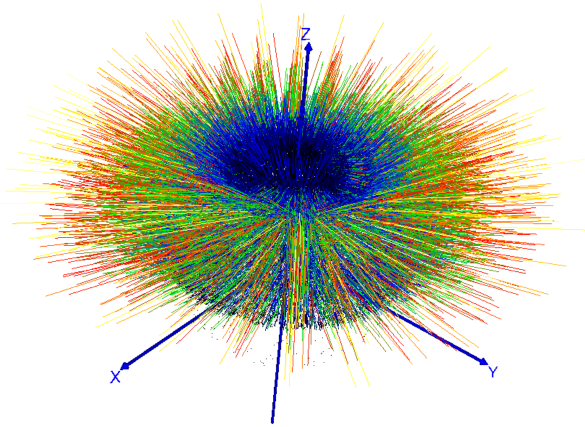
RiGO801 – Technical data

RiGO801 near-field goniophotometers – shared technical data

CCD camera	CCD – digital camera (Kappa DX4), LMK98-4, 12 bits, V(λ) – full filter-adapted
Image resolution	512 x 512 pixels (Binning 2x2), 13 bit by digital binning
Measuring resolution	0.1° x 0.1° … 2.5° x 2.5°
Illuminance sensor:	18 bit digitalization, 8 measuring ranges, V(λ)-calibrated (f1' < 1.5%), cosine – adaptation

RiGO801 – Technical data

RiGO801 near-field goniophotometer for measuring LEDs and small lamps



RiGO801 – Technical data

RiGO801 near-field goniophotometer for measuring LEDs and small lamps

Size of measuring object:	<= 60 x 60 x 60 mm³
Space required:	LxWxH = approx. 700 x 300 x 800 mm³
Movement:	The measuring camera and the illuminance meter are moved on a circular path around the lamp (horizontal ϑ-axis). The lamp/LED itself is turned around a vertical φ-axis.
Travel path:	φ = 0° ... 360°, ϑ = -145° ... 145°
Measuring width:	100 mm
Fields of view	a) 10x10 mm², b) 50x50 mm²
Positioning accuracy:	φ < 0.02°, ϑ < 0.05°
Repetitive accuracy:	φ < 0.01°, ϑ < 0.02°

RiGO801 – Technical data

RiGO801 near-field goniophotometer for measuring lamps and small luminaires

- Measuring object not moved
- Horizontal and vertical alignment due to swivel-mounted goniometer
- Two sided lamp holder possible

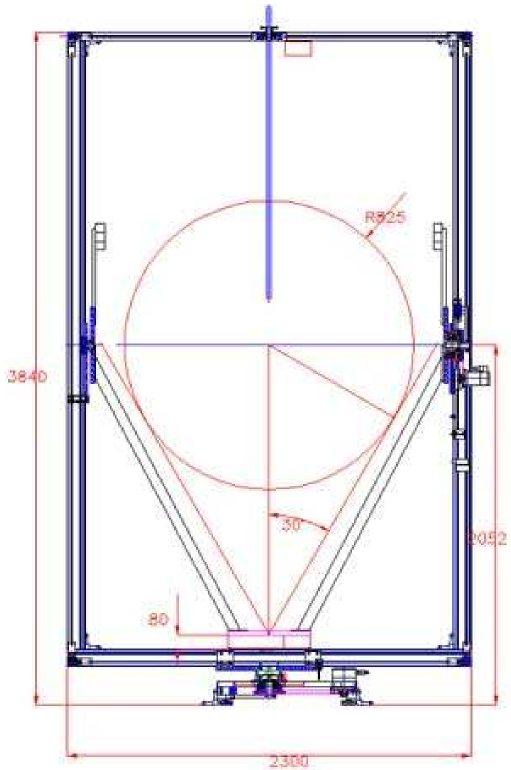
RiGO801 – Technical data

RiGO801 near-field goniophotometer for measuring lamps and small luminaires

Size of measuring object:	<= 300 x 300 x 300 mm³
Space required:	LxWxH = 1900 x 1500 x 2100 mm³
Movement:	The measuring camera and the illuminance meter are moved on a sphere around the lamp (two independent axes arranged vertically to each other (δ, φ)).
Measuring position:	Normal position, no movement of the measuring object. The whole goniometer can be swivelled, which permits different measuring positions to be realized.
Travel path:	φ = 0° ... 360°, ϑ = 15° ... 345°
Measuring width:	270 mm
Fields of view	20x20 mm² … 300x300 mm²
Positioning accuracy:	φ < 0.05°, ϑ < 0.05°
Repetitive accuracy:	φ < 0.02°, ϑ < 0.02°

RiGO801 – Technical data

RiGO801 near-field goniophotometer for measuring large luminaires



(Maße als Beispiel einer konkreten Konstruktion)

RiGO801 – Technical data

RiGO801 near-field goniophotometer for measuring luminaires

Size of measuring object:	<= 1500 mm … 2000 mm
Space required:	LxWxH = ≤ 2600 x 2600 x 3100 mm³ …3300 x 3300 x 3900 mm³
Movement:	The measuring camera and the illuminance meter are moved on a sphere around the lamp (two independent axes arranged vertically to each other (δ, φ)); mounted to a fixed upper point.
Travel path:	φ = 0° ... 360°, ϑ = 4.6° ... 352.5° … ϑ = 5° ... 355°
Measuring width:	270 mm
Fields of view	Type dependent, different optical lenses
Positioning accuracy:	φ < 0.05°, ϑ < 0.05°
Repetitive accuracy:	φ < 0.02°, ϑ < 0.02°

Bibliography

[1] E. H. Adelson and J. R. Bergen, The plenoptic function and the elements of early vision, M. Landy and J. A. Movshon (Edt), Computational Models of Visual Processing, The MIT Press, Cambridge, MA (1991), 3–20.

[2] P. Moon and D.E. Spencer, *The Photic Field*, MIT Press, 1981.

[3] M. Levoy and P. Hanrahan, ‘‘Light Field Rendering,’’ *Proc. ACM Siggraph*, ACM Press, 1996, pp. 31-42.

[4] Cha Zhang, „On sampling of image-based rendering data“, Dept. of Electrical and Computer Engineering, Carnegie Mellon University, Pittsburgh, PA 15213, 2004

[5] Poschmann, R.; Riemann, M.; Schmidt, F.: Verfahren und Anordnung zur Messung der Lichtstärkeverteilung von Leuchten und Lampen; Patent DE 41 10 574 v. 30.03.1991