Ray data of LEDs and arc lamps

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1 Introduction

The ray data measured by means of modern near-field goniophotometers open up new ways in the development of optical systems. For numerous applications, synthetic models of radiation characteristics are insufficient for realistic optical simulations. The near-field goniophotometers type RiGO801 developed by the TechnoTeam company measure the real 4D- luminance distribution of measuring objects and provide ray data for various simulation programs.

2 Measuring principle – Near-field goniophotometer

The complete description of the radiation conditions of an object requires to indicate the ray density distribution $L_e(x, y, z, \vartheta, \varphi, \lambda)$ in all surface points $(x, y, z) \in Surface$ of this object. These data can only be acquired using image-resolving measuring procedures. In the case of the RiGO801 near-field goniophotometers, a measuring camera is moved on a spherical surface around the measuring object by means of a goniometer mechanical system. In doing so, image data are recorded in a well-defined angular grid. Generally, the measuring camera is equipped with a specially adapted $V(\lambda)$ - filter for measuring luminances. Using other suitable filters, it is possible to realize, for example, standard spectral value functions so as to measure multichannel color information during several measuring series.

All luminance captures put together make up a four-dimensional data field $L(x', y', \vartheta_K, \varphi_K)$. Knowing the optical imaging by the camera lens, the image coordinates (x', y') together with the information about the camera positions (ϑ_K, φ_K) can be converted into spatial directions (cf. Fig. 1).

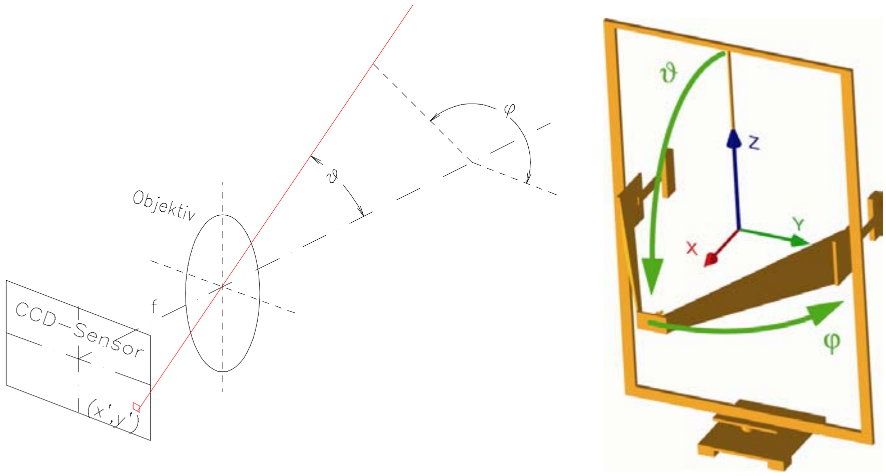

Fig. 1 : Ray calculation and goniometer coordinate system

The data field measured contains all photometric information of light radiation. Due to the very high number of luminance captures (e.g. 50,000 images), the data must be saved with as little redundancy as possible. For this, the luminance values of each pixel $L(x',y')$ are multiplied by the corresponding solid angles $\Delta\Omega(x',y')$ in the images, which results in luminous flux portions $\Delta\Phi(x',y')$. After a suitable division of luminous flux portions into certain groups and an adapted compression, a highly compressed ray data format results (e.g. about 350 MB for 10^9 rays).

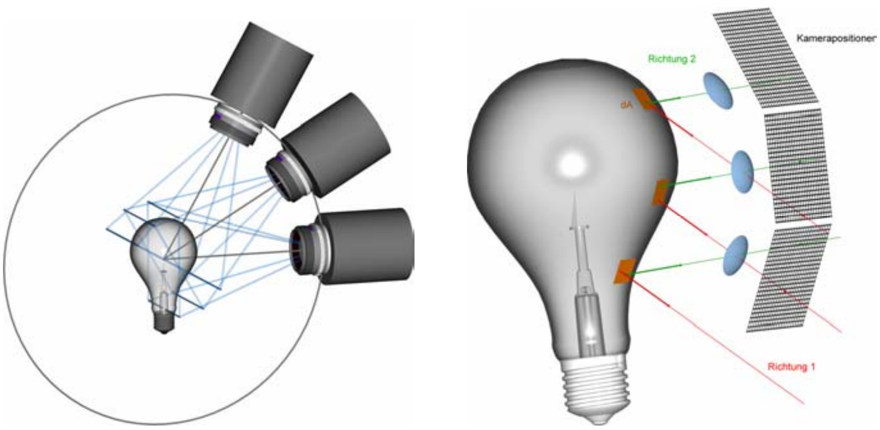

Fig. 2: Principle of the acquisition of the luminance image

Of course, derived measuring quantities such as the luminous flux Φ measured and the far-field luminance distribution $I(\vartheta,\varphi)$ can be calculated from the ray data. The output of the ray data into the desired ray data formats is effected by means of a conversion program which exports an optional number of rays from the internal TechnoTeam format into different standard formats. At present, the following export formats are available: ASAP, Speos, LightTools, Zemax and LucidShape.

As the measuring system is not able to register the actual geometry of the measuring object, the starting points of the rays lie on that spherical surface which is described by the entrance pupil of the lens. The conversion program transforms these starting coordinates to an optional enveloping geometry by calculating the intersection points of the rays with this geometry (cf. Fig. 3). Those rays which do not intersect the geometry are not exported into the target format.

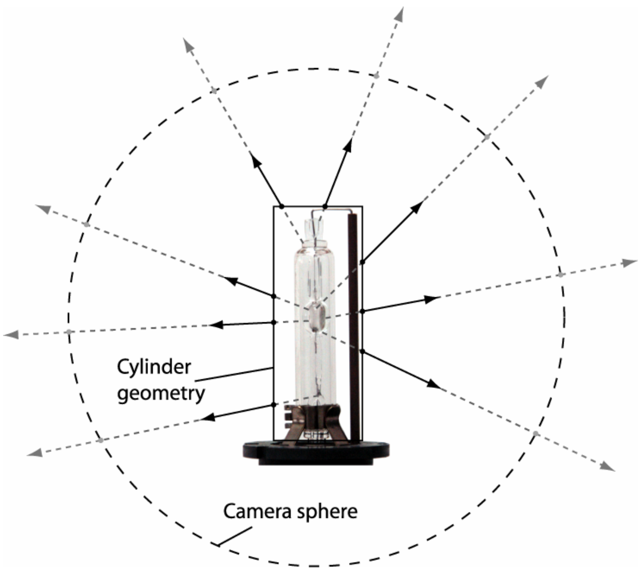

Fig. 3: Raytracing onto an enveloping geometry

The presently available enveloping geometries are a sphere, a cylinder and a cuboid. The geometry parameters are usually chosen such that an optimum convex enveloping geometry develops around the measuring object in order to make sure that this enveloping geometry does not intersect any possibly existing near objects during simulation.

2.1 Measuring systems

The RiGO801 series (cf. Fig. 4) covers a wide range of measuring object sizes, including LEDs, lamps and luminaires with a length of 2000 mm. For measuring small objects such as LEDs and small lamps (up to 50 x 50 x 50 mm³), a compact LED goniophotometer has been designed. A special goniophotometer for lamps and small luminaires (up to 300 x 300 x 300 mm³) is fully swiveling, which permits any static lamp orientations to be obtained. The design of the measuring set-up allows the size of large luminaire goniophotometers to be scaled. Thus, they can easily be adapted to the spectrum of the luminaire to be measured (up to 2000 x 2000 x 2000 mm³).

Fig. 4: LED goniophotometer, swivelling lamp goniophotometer, luminaire goniophotometer

Each of the single goniometer types covers a certain range of measuring object sizes. Also, only those objects can be measured which fit into the goniometer collision-free or also which can completely be covered by the imaging system. On the other hand, the objects on which ray data measurements are to be made should not be too small as otherwise the mechanical tolerances and the imaging properties will not allow a sufficiently exact measurement. Thus, it is not advisable, for example, to record ray data of small lamps in a large luminaire goniophotometer. However, the luminance distribution can now be made without any problems by means of the available photometer (far-field measurement) instead of using the image-resolving camera system.

3 Ray data of LEDs and arc lamps

In order to make sure that realistic simulation results can be obtained during the development process of optical assemblies, a high-quality description of the radiation characteristics of the light sources used is absolutely necessary. For describing light sources, models of different complexities are available. They include a simple direction distribution of a point light source just as complex physical models and models of real ray data measured. In many applications, the use of a physical model or of a model based on ray data measured is necessary as optical component parts are positioned in the immediate vicinity of the lamp geometry.

In many cases, setting up a physical model is very complex, requiring an exact definition of the geometries as well as of the optical and thermal properties of all optically relevant elements. Particularly in the case of modern LED technologies and arc lamps, the time and amount of work involved in establishing realistic models is enormously high. As an example, Fig. 3 shows optical distortions on a D2 lamp which are very difficult to model.

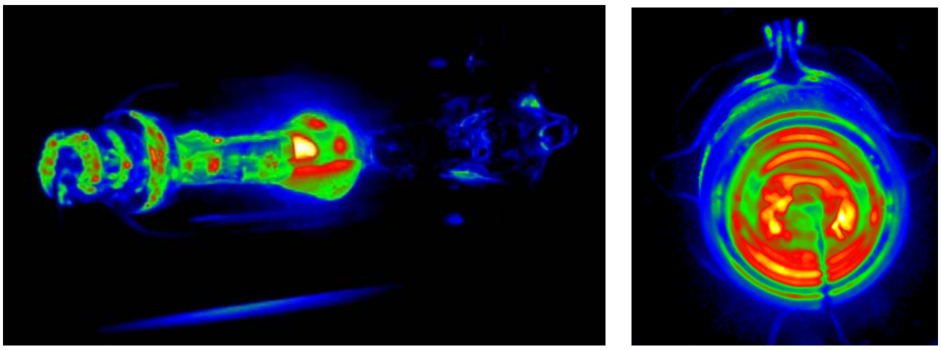

Fig. 5: Examples of great distortions on glass elements of a D2 lamp

Ray data measured describe the real light source, thus making a complex physical model unnecessary. When combining the data measured with geometrical information about the geometry of the light source, the influence of the light source on the optical path (e.g. shading) can be taken into consideration.

The real ray data models also consider the effects of production tolerances, which are disturbing particularly in the case of LEDs. Here, it is possible to measure several samples of a light source so as to obtain the variability of the real parameters.

Another important aspect is the determination of the spectral properties of light sources. From a metrological point of view, a complete spatially resolved measurement of the spectral distribution is not practicable. However, the RiGO801 near-field goniophotometers offer the possibility to realize, by means of filters, spectral valuation functions and to obtain multichannel spectral valuations, for example in several measuring series. Furthermore, the direction-resolved measurement of spectra by means of a spectrometer is possible (option), which is moved together with the camera on a spherical surface by the mechanical system of the goniometer.

3.1 Applications

For the light-engineering simulation of an LED bicycle headlamp (reflector and cap), the ray data record measured of an LED (side emitting) was used.

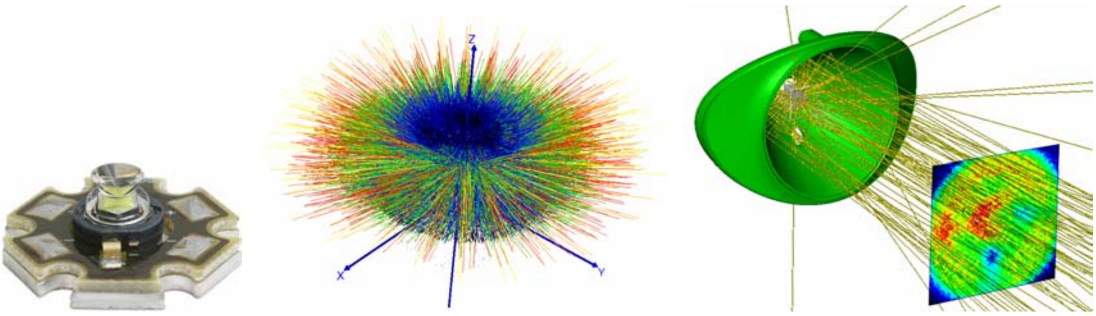

Fig 6: Development of an LED bicycle headlamp

The use of ray data records measured allowed the quick realization of the system in only two iterations.

Applications where optical component parts are positioned within the extreme near-field range can hardly be simulated without real ray data. An example of this is the light injection in optical fibers by means of LEDs. An operating element in the passenger compartment of a car is shown below.

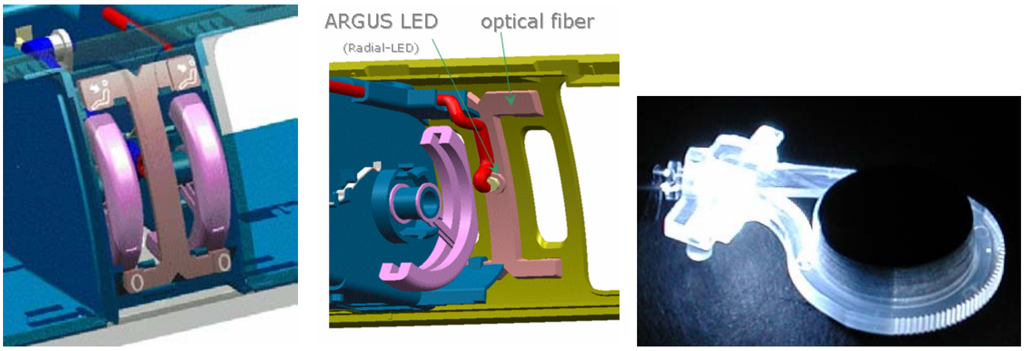

Fig 7: Light injection in optical fibers

Also for the development of new types of lamps (e.g. Hg-free arc lamps), high-resolution luminance images are often indispensable. The near-field goniophotometer makes it possible not only to obtain complete ray data, but also to realize single, high-resolution luminance captures and measuring series using the LMK2000 luminance measuring software.

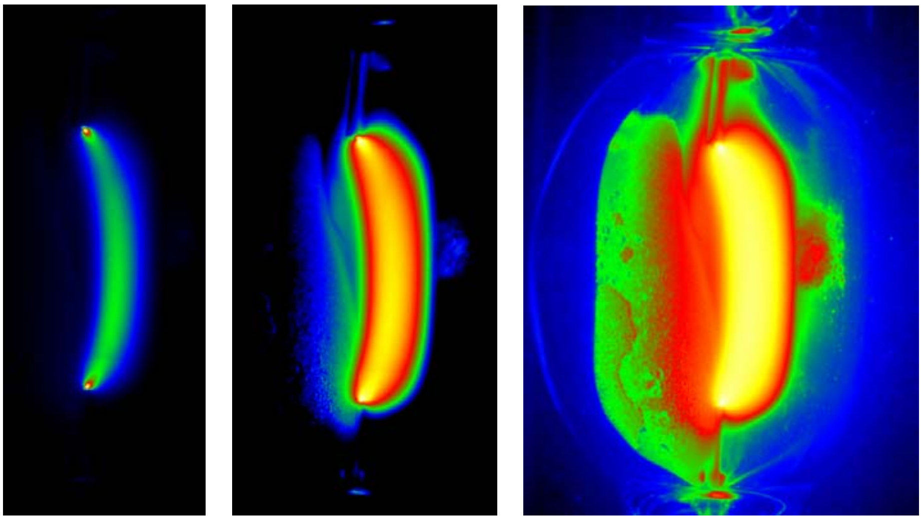

Fig. 8: Arc of a D2 lamp with linear 3-and 4-fold logarithmic scaling

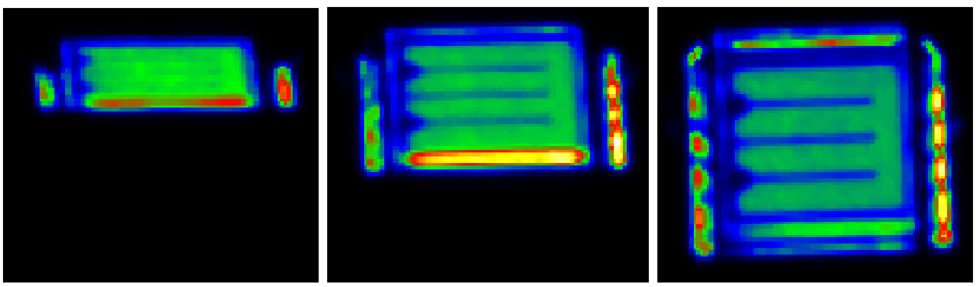

Fig 9: Luminance images of an LED chip

4 Literature

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