MEASUREMENT AND SIMULATION OF POLYCHROMATIC RADIATION DATA

The functionality of LEDs for use in vehicles offers new possibilities and their efficiency will even rise. However, they need their own specific design methods as well as appropriate measurement and simulation technology. Monochromatic radiation data are not sufficient in this context. Opsira makes use of a camera system combined with a set of filters covering the whole range of emissions ejected by the emitter. This system features exact measurement and simulation of polychromatic radiation data. Thus, multi-coloured light sources can be moulded exactly.

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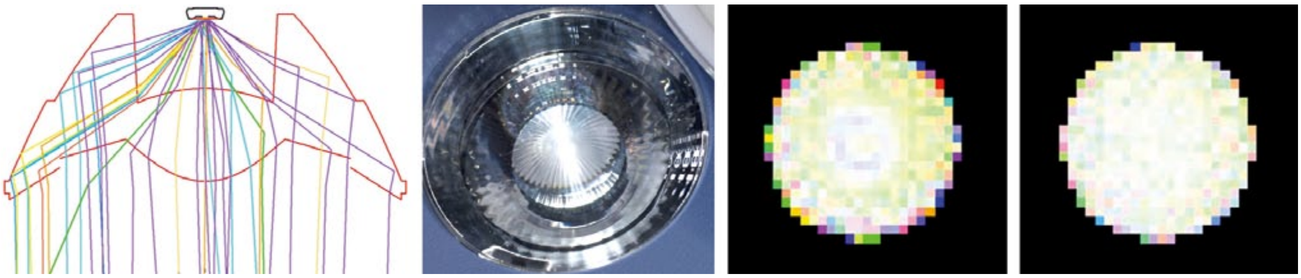
BACKGROUND

In the automotive sector, LEDs need to vanquish and surpass the standard xenon light has set in the premium car sector. This includes all functions of intelligent light systems, such as the country light with increased illumination of the left side of the road compared to the normal low beam, the highway light which lights the full width of the road at higher speeds, thus generating a greater range of sight, and the enhanced fog lamps bearing an improved illuminated side of the road. Furthermore, there is the active cornering light with headlamps following the steering movement, and finally the cornering light which additionally brightens the desired direction of travel. In addition, LEDs were successfully connected with the adaptive high beam assistant, which continuously and automatically dims up and down the headlamps and controls the headlight range of the low beam. Today, LEDs are used in almost all areas of automotive lighting. They also offer different colours of light: from ultraviolet to infrared almost everything is available and can thus serve driver assistance systems. Even the lack of space inside the car is met by the LED's small dimensions.

LED VERSUS XENON LIGHT

Another advantage of LED lights is the reduced glare compared to conventional lights because the light is coming from many widely distributed LEDs. The colour of light emitted by white LEDs has a colour temperature of 5500 K, which is similar to that of daylight. Thus, it provides an optimum of illumination of the road. The longevity of LEDs is another important aspect. At 10,000 h, it exceeds xenon lamps by more than a factor of five. In addition to that, high-performance LEDs achieve efficiencies of around 100, partially even 150 lm/W. In terms of their light output with automotive headlights, both xenon as well as LED headlights are still in the same range. The new full-LED headlights of Daimler provide, according to company information, about 17 lm/W, similar to the current xenon headlights. For 2013, LED lights which provide up to 36 lm/W are expected to come in the market. On top of that, the lighting design of the daytime running lights of the vehicles is unmistakably



❶ Example of an optics for colour mixing and homogenous illuminance; from left to right: rays within the optics; optics component; illuminance plot with poor colour mixing; illuminance with good colour mixing (pixel resolution of illuminance plots delivered by the detector)

typical of the particular brand due to the use of LED.

Given the variety of all options of LED use offered to the car manufacturer, the requirements for the lighting functions of head and tail lights are strictly regulated by law. The components are officially tested and approved. In this context, light intensity, light colour, the visibility angle, mounting dimensions, electrical circuit and function are crucial. As far as the interior lighting design is concerned, the OEM has more creative freedom, for the respective laws are not as constricted. Development efforts for high-end LED headlights are extensive for the following reasons: the complexity of light distribution and light functions in conjunction with sensors and driver assistance systems is difficult to identify and design, the cost of control systems and cooling of high power LEDs are substantial, and finally, the design demands have to be met.

REQUIREMENTS FOR WHITE LEDS

As long as monochromatic LEDs are used, there are few problems. Yet, most of the applications need white light and therefore, additive colour mixture. Differently coloured LEDs can be employed for this purpose, but instead, a luminescence dye is often used due to lower cost. Usually blue LEDs are chosen as their efficiency is higher. They are combined with luminescence dye, which converts the blue light into longer wavelengths, with which blue adds up to white. Additionally, not all LEDs of a batch have the same colour temperature because of production conditions. On that account, the manufacturers of lighting systems have to come up with a way to achieve a uniform colour temperature. Moreover, a specific colour temperature is required for the illuminant.

This makes it necessary to create a model of measurements of the LED’s radiation parameters, in order to optimise the lighting design for use through these records by means of simulation, ❶.

MEASUREMENT OF POLYCHROMATIC RAY DATA

Many LEDs show spectral distributions that vary with respect to the viewing angle and the location on the chip. By means of a goniometric system that combines a radiance measurement camera with a filter wheel and a spectroradiometer, this variation can be measured precisely. The result is a polychromatic ray set which serves as a basis for shaping the characteristics of advanced LED-based lighting fixtures, for example used for medical, architectural, and automotive applications.

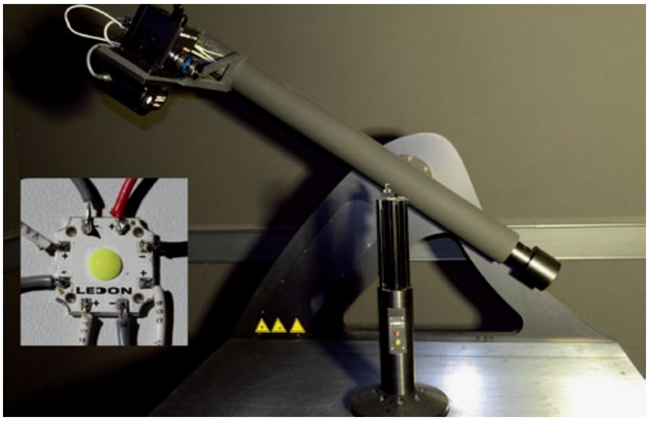
Via optics development and simulation tools, optical elements are modelled in such a way that the desired distribution of light intensity and colour is produced. Clients predominantly desire a homogeneous distribution of parameters. This requires the availability of detailed data on the light source, which again raises the need for improved modelling techniques for the work with multi-coloured light sources.

A ray set characterises the optical properties of a light source. Such a data set includes a set of vectors, to all of which a starting point on the light source, a direction and a wavelength are assigned. Different weights of these vectors characterise different levels of light emission.

APPROACH

To simulate a light source, the developers must know how much light from which part of the light source is emitted in which direction. Opsira uses a standard radiance camera, ❷ (left), combined with a filter wheel including up to ten filters for measurements. This camera is mounted on a goniometric setup and can be moved over the surface of an imaginary sphere around the light source to conduct angle-resolved radiance measurements, based on the observation direction, ❸. Different filters allow measurements in different spectral areas. One standard measurement is for example performed with a V(λ) filter that mimics the brightness sensitivity of the human eye. For accurate measurement of LEDs,

❷ Radiance camera (left) and spectroradiometer (right)



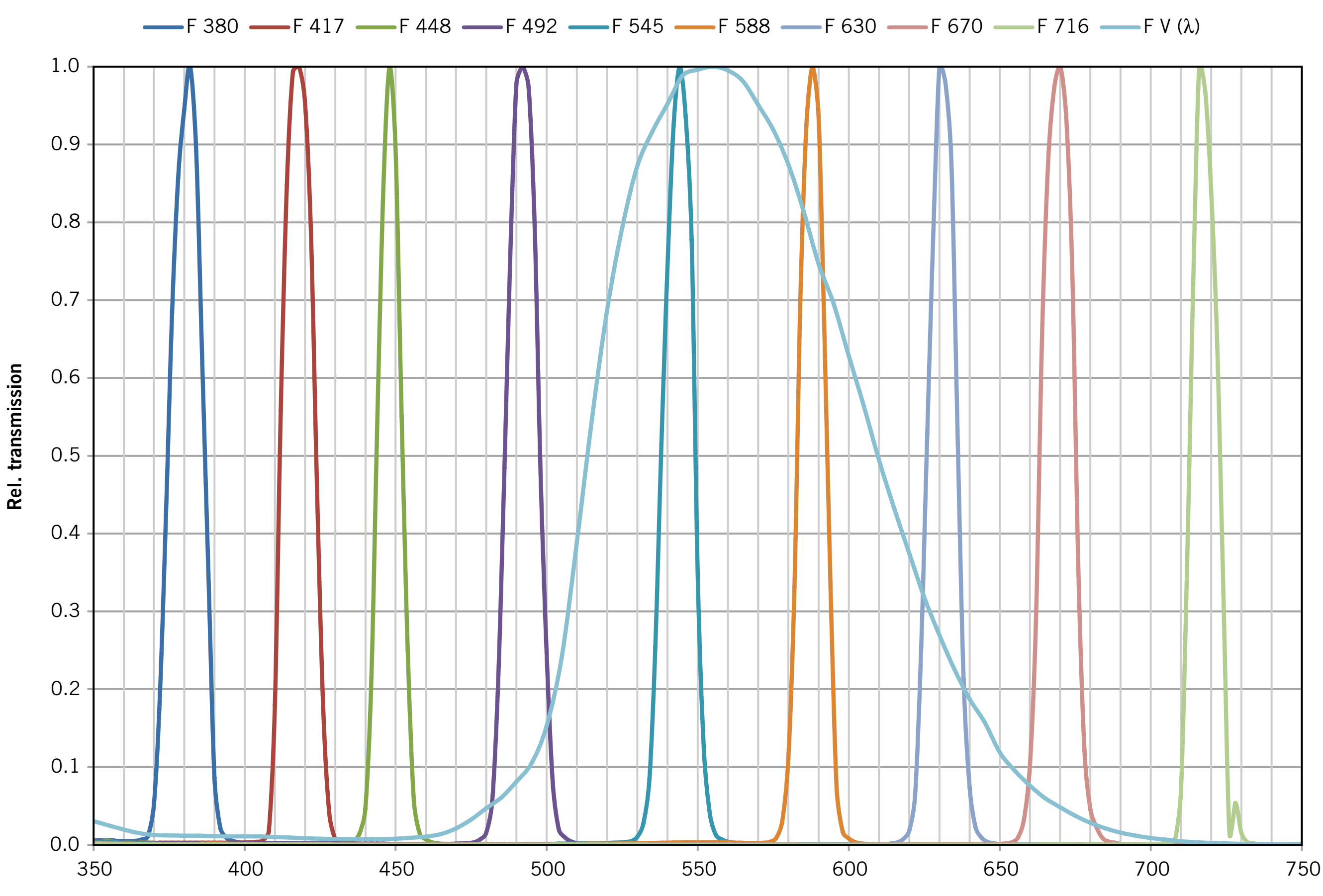
❸ The LED is mounted at the centre of a goniometric setup; the camera system and the spectroradiometer are mounted on a movable arm that rotates about an axis perpendicular to the back panel of the goniometer; the LED is placed at the centre of the setup (small image at left)

bandpass filters are used instead of the V(λ) filter, measuring the LED in narrow spectral ranges, ❹. For each filter, a separate ray set is generated. A spectroradiometer, ② (right), which moves along with the camera, additionally records the spectrum of the light source in every observation point. Radiance measurements are combined with the spectra into a polychromatic ray set, suitable for the colourimetric simulation of the light source. In addition, the spectroradiometer data can be integrated to yield the spectrally resolved total flux of the light source. The entirety of these ray sets is called polychromatic ray set.

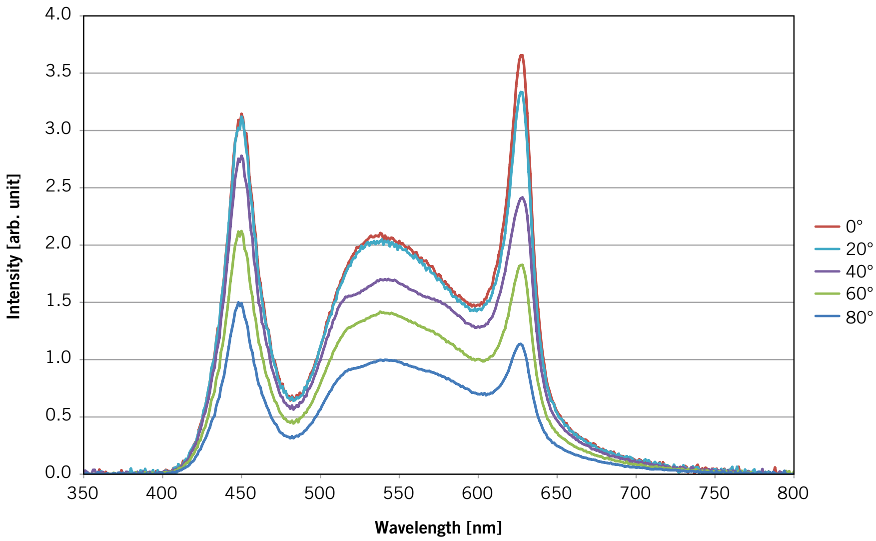
For measurements, a test LED was used which consists of four individual chips, sitting under a luminescence globe top. One of the four LED chips emits red light at a wavelength of about 630 nm, while the other three emit blue light at 450 nm. The luminescence dye converts part of the blue radiation into other wavelength ranges. As a result, the complete LED package emits a white light spectrum. The light colour can be adjusted by varying the proportions of red and blue LEDs.

MEASUREMENT RESULTS

The radiation intensity of the test LED decreases with the increase of the zenith angle, ❺. This results in a change of the ratio between the peak of the blue and red rays: at an observation angle of 0°, the red peak rises above the blue, while at larger observation angles (> 40°), the blue peak dominates the red one. This form of the spectrum clearly shows why a polychromatic ray set is important for accurate simulation of a multi-colour LED, ❻. With each change of the observation angle, the spectrum changes its shape significantly. Not only is the geometric information about the origin of the beam accurately reproduced this way,



❹ Transmission curves of the bandpass filters and of the V(λ) filter



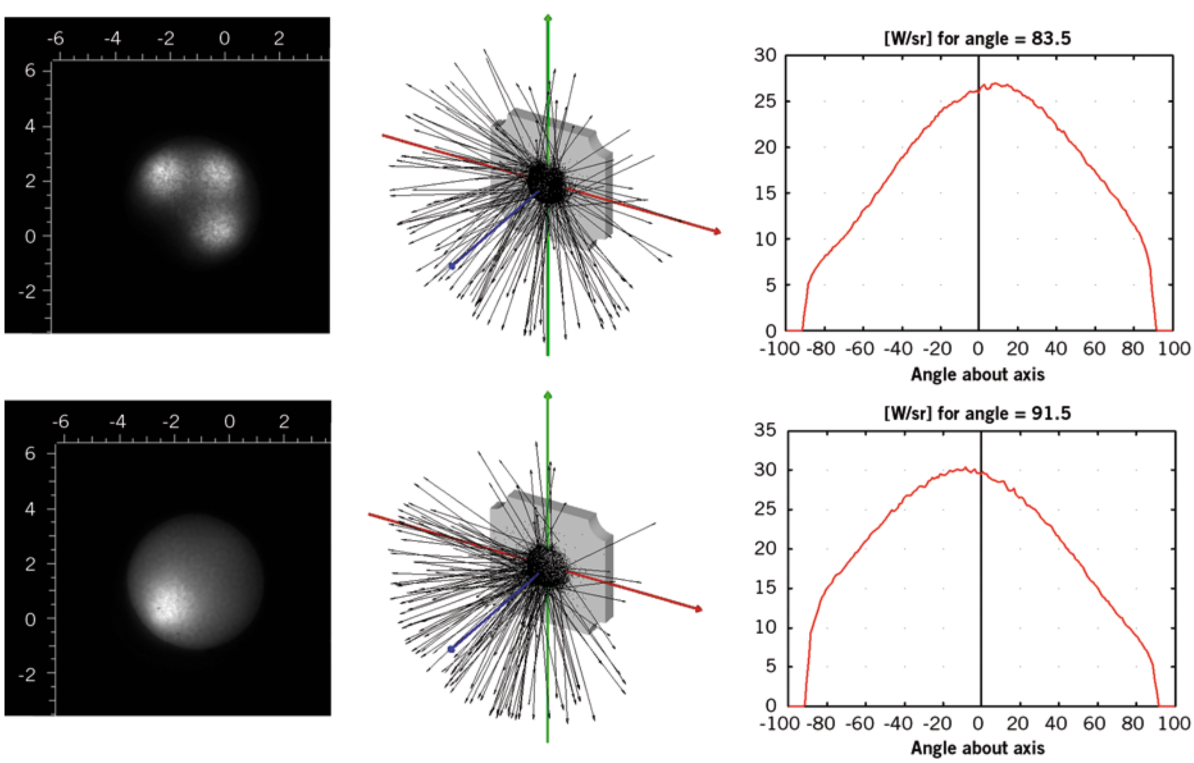
❺ Spectrum of the LED for observation angles between 0° and 80°; the radiant flux decreases with increasing angle and the read peak becomes smaller in relation to the blue peak

but also the individual weighting of the different wavelength bands is included.

CONCLUSION

Current technology increasingly uses LED packages that consist of multiple LED chips of different colours. Moreover, LED packages are used in which the emitted radiation is shifted to other wavelength bands by means of additional luminescence dies. These LED packages allow for a certain variation of the combined radiation according to the desired colour characteristics of the application. To simulate these LED arrays for the design of applications, accurate ray data of the source are vital. Standard monochromatic radiation data are insufficient for this task, but by using polychromatic ray sets, polychromatic sources can be modelled with exact refinement. Thus, a polychromatic ray set can be generated by a camera system combined with a filter set that covers the whole range of emissions of the source. Depending on the characteristics of the source's spectrum, the resolution of the spectral bands of the filters can be increased by incorporating additional spectroradiometer data.

This modelling based on the measurements and the simulation of the lighting for vehicles is the indispensable basis for the design of the lighting fixture of future vehicles and thus can support the trend to gradually replace incandescent and xenon lamps even in middle-class vehicles by LEDs. Furthermore, manufacturers of LED lights are working on ways of eliminating the mechanical parts and simplifying the cooling. Thus, the use of LED technology for increasingly complex lighting functions will become easier and more affordable.



❻ Parts of the polychromatic ray set: measurements corresponding to filter 3 (488 nm, upper half) and filter 7 (630 nm, lower half); left: radiance images; middle: subset of rays and model of chip; right: cross section of radiant intensity distribution; clearly visible are the three blue LEDs and the single red LED, the differences in ray distributions, and the different shapes of the intensity distributions