

Colour compensation for LED technology enables color constant RGB luminaires

Deviations in luminous flux and hue occur during LED production, but color compensation technology allows luminaire manufacturers to provide color-constant products for demanding applications, writes Thomas Schielke of ERCO Leuchten.

Lighting designers have always used colored light to add emphasis or provide atmospheric effects. This was done using colored lamps or luminaires with color filters, but thanks to electronically controlled RGB color mixing luminaires it is now possible to produce any color of light with LEDs. Using color compensation, the luminaire manufacturer is able to compensate for the deviations in luminous flux and hue due to the manufacturing tolerances of LEDs, and thus to satisfy the highest demands of designers for uniformity, e.g. for colored wallwashing (see figure 1).

Manufacturing deviations

High color saturation is one of the characteristic properties of LEDs. However, the actual color of the individual LEDs is determined by two factors that are subject to certain manufacturing fluctuations: the luminous flux and the dominant wavelength. In practice this means that the colors of light from two identical LED luminaires can in fact deviate from one other. Semiconductor manufacturers classify every LED according to these two criteria, sorting them into different categories called "bins".

Some luminaire manufacturers demand that their suppliers provide bins that are particularly stringently selected with respect to the dominant wavelength. There is a good reason for this: the greater the accuracy with which an individual light source emits a certain wavelength from the outset, the more exact the match between light colors of several luminaires. But even with the most stringent selection, deviations in both the luminous flux and the dominant wavelength between individual LEDs of one color still have to be accepted.

Perception of color differences

The problem of the manufacturing deviations of LEDs is aggravated when mixed colors of light are used. In RGB color mixing, the tolerances of two of three LEDs are compounded together. On the one hand, the dominant wavelength can deviate by 5 nm or more within one bin, depending on the manufacturer; on the other, fluctuations of 20 to 30% can arise for one luminous flux bin. This means that the mixed color of two LED luminaires can differ by more than 10 nm in a worst-case scenario.

The eye, however, can detect differences starting from 1–3 nm, depending on the wavelength and the background. Therefore, high-quality color mixing for architectural lighting with several luminaires cannot be implemented reliably on this basis. Achieving color constancy between several luminaires when washlighting a white wall – especially with an amber or cyan hue – is one of the most demanding

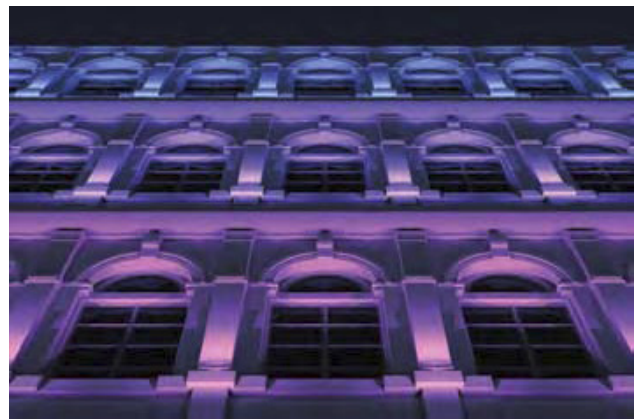


Fig. 1. Achieving colour constancy between several luminaires when wash-lighting a white wall – especially with an amber or cyan hue – is one of the most demanding challenges facing lighting engineers.

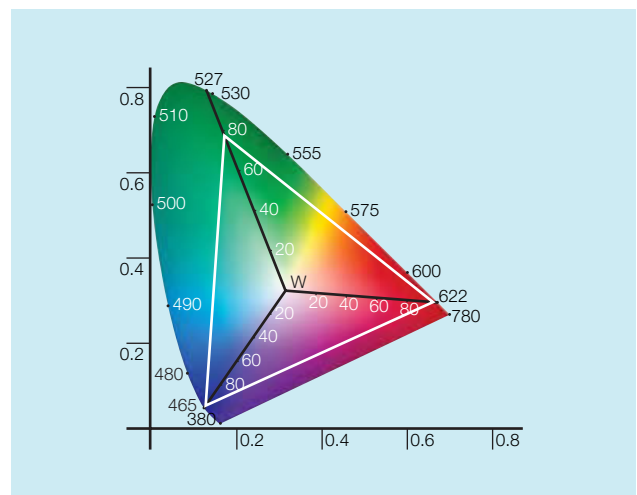


Fig. 2. Color mixing: CIE color diagram shows light colors with hue and saturation. Connecting the color loci of the red, green and blue light sources of RGB color-mixing luminaires gives a triangle that contains all the colors that can be produced. Colored LEDs have high saturation and therefore allow a large number of mixed colors to be produced. The line from the central white point to the RGB points serves as a scale for saturation. The numeric values on the outer edge of the curve indicate the wavelength.

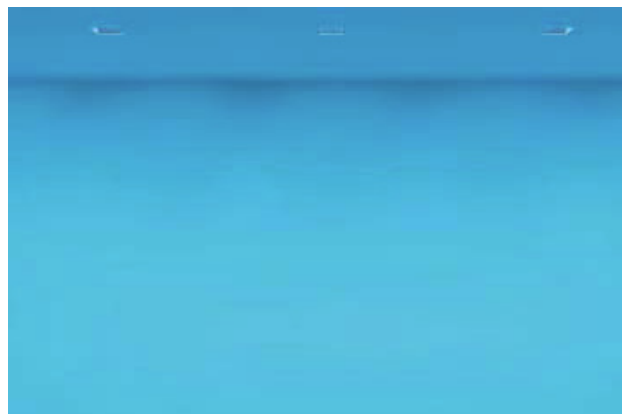
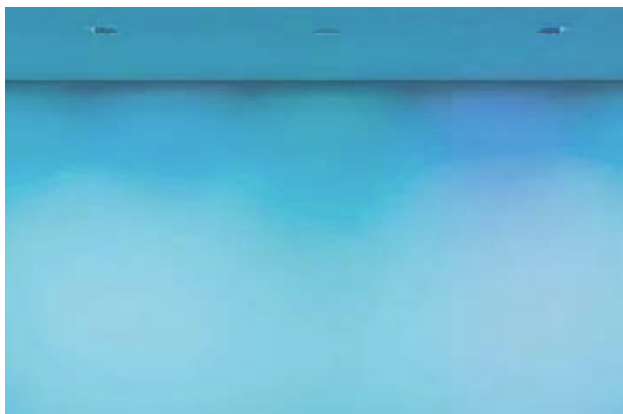


Fig. 3. Colored wall-washing (left) without color compensation, and (right) with color-compensated Quadra varychrome LED luminaire.

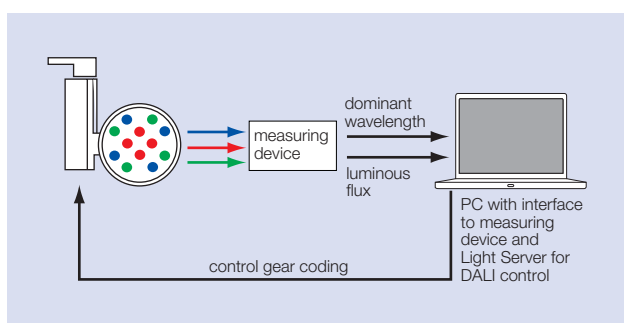


Fig. 4. Color compensation process diagram.

challenges that lighting engineers have to face. The eye has a very high sensitivity for these wavelengths and therefore detects even fine differences in color.

On the technical side, fluctuations in luminous flux are more serious than fluctuations in dominant wavelength for the perception of the color differences. Without color compensation technology, this could cause the light colors produced by RGB color mixing to deviate visibly from one luminaire to the next for the same DALI (Digital Addressable Lighting Interface) control values.

Conversely, lighting users require lighting products that will always reproduce exactly the same light color from a given DALI control value – even in difficult applications such as strip lighting or a row of LED luminaires acting as wallwashers (see figure 3). To ensure reliable color precision, ERCO has introduced color compensation technology, whereby LED luminaires with RGB color mixing capability (also known as varychrome luminaires) are individually measured and calibrated at the factory.

Color compensation process

Color compensation is performed in four steps: (i) the luminaires are operated for a certain time period; (ii) their actual values are recorded; (iii) compensation values are entered; and (iv) the compensation is checked. To achieve a reliable and constant value for the measurement, the luminaires are operated continuously for about two hours under reproducible temperature conditions until the luminaire reaches thermal saturation. Following this, a computer-aided measuring instrument records the luminous flux and the dominant wavelength for each of the luminaire's RGB channels.

In the third step, the measured values are compared with the set values. The software then calculates the compensation factors from these figures and permanently stores the result in the control gear (see figure 4). The set values are adjusted at certain production cycles to keep them up to date with technological progress. This will enable adjustment to suit the increasing luminous flux of future LEDs.

The resulting product versions are identified on the label of the luminaire to ensure that it can be reordered or reproduced as and when required. Color compensation technology comes into play on luminaires featuring their own control gear where the compensation factors can be stored individually. Color compensation, control gear and LED module are seen here as a single unit and can be replaced as a single unit in a luminaire as and when necessary. Color compensation is used, for instance, for spotlights or wallwashers in the indoor area or for outdoor luminaires such as projectors, in-ground luminaires or facade luminaires.

Encoded DALI control gear

The Light System DALI uses encoded DALI control gear, which enables the central DALI controller to identify automatically the luminaires and their properties and enable user-friendly functions. Various data (including the article number, a unique luminaire ID and an index for identifying the lamp type and lamp color) is saved in the 16-byte memory of the DALI control gear to provide unique identification within the system.

The advantage of the encoded DALI control gear is particularly apparent when implementing colored lighting installations with luminaires featuring RGB color mixing technology. These luminaires have three addresses with which the light colors red, green and blue are already assigned to the respective control gear. Compared with conventional DALI systems, this does away with the time-consuming task, performed on-site, of assigning the addresses to the luminaires with their respective color channels and control gear. A light color can now be selected and assigned to several luminaires via the software. The LED compensation factors stored in the control gear are used to compensate for the deviations in the LEDs, due to their manufacturing process, so that the user always receives a uniform color of light.

Output comparison of RGB luminaires

The prerequisite for color mixing luminaires is to have lighting tools with individually dimmable light sources in the primary colors of red, green and blue as components of additive color mixing. Colored fluorescent lamps, as well as LEDs in particular, are suitable for this task. The saturation of

the individual primary colors will determine the usable color space.

Due to their operating principle, LEDs have one advantage over color mixing luminaires with fluorescent lamps: their very high color saturation produces a large color space, which also includes highly saturated mixed colors. A quantitative output comparison of LED color mixing luminaires should therefore not be based on the maximum luminous flux for white mixed light, but on the entire spectrum and the saturation. Color compensation allows the luminaire manufacturer to ensure that the user obtains the same hue on several adjacent luminaires; however, the trade off for this is that, in practice, the luminous flux can be slightly below the LED module's maximum possible level.

Summary

Color compensation technology for color mixing luminaires with LEDs makes it possible to compensate for the luminaire's manufacturing tolerances and to achieve optimum lighting quality for the user. Even when LED bins of the highest grade are sourced, the variation of both the maximum luminous flux and the dominant wavelength still represents a real problem for discerning architectural lighting solutions. Compensation factors stored in each luminaire's own control gear ensure a uniform color of light for luminaires of the same type during operation. In addition, the version control also takes the technical progress of the increasing luminous flux into account and improves the reordering process for subsequent deliveries.

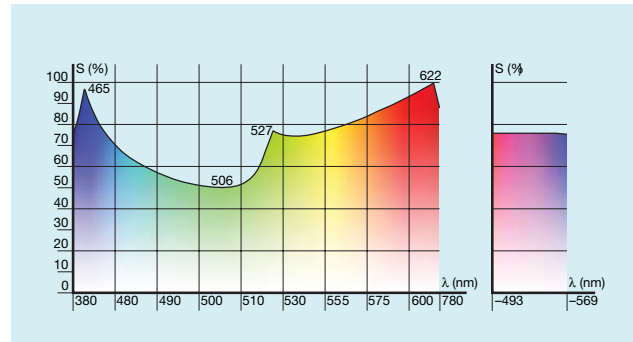


Fig.5. Because ERCO uses LEDs with a very high color saturation in the varychrome luminaires, a particularly wide range of colors can be obtained. The saturation diagram shows the mixed colors as wavelength with the respective saturation given as a percentage.

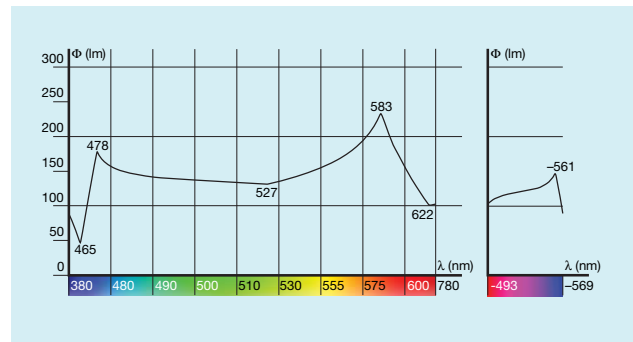


Fig.6. ERCO's varychrome LED luminaires have been optimized so that they produce high luminous flux levels even with extremely saturated light colors. The luminous flux diagram indicates the luminous flux of the LED module with respect to the wavelength.