# LED-based Light Source for Producing Defined Light Characteristics

DIN standard illuminants or daylight simulation

Compact, robust and durable through LED-based colour mixing

Accurate and dependable through quasi-spectral monitoring and control

Versatile, scalable device concept


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The colour of an object is the result of the subjective sensation of an observer, which cannot be wholly represented by the object's physically measurable properties. An impression of colour requires the presence of an object, of light and of the act of observation. Only by specifying all of these elements a colour impression can be fully characterised. An array of standardised and device-specific colour spaces exists for the metric determination of colour, for example as defined in DIN standard 5033.

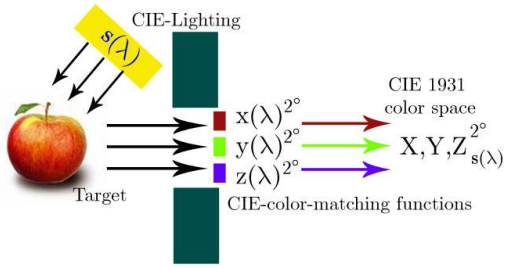


*Figure 1: Principle of the tristimulus method according to CIE 1931*

The use of colour measuring systems is indispensable in order to be able to compare and analyse colour values dependably over large periods of time.

## Light in colour measuring systems

Typical tristimulus measuring systems are oriented toward the three-channel colour vision found in the human eye. Sensors using this method attempt to realise the response curves of the eyes of a "standard observer" (CIE-1931), so that, from the point of view of that observer, colour information can be directly derived from these curves. Because many of these devices employ light sources whose spectra substantially deviate from the standardised sources typically used for colour comparison, each of these systems carries out its measurements within its own device-specific colour space. This means that a measurement is only meaningful in the sense of an objective colour measurement after being retroactively corrected according to the utilised colourimetric standard for comparison (observer, type of light etc.).

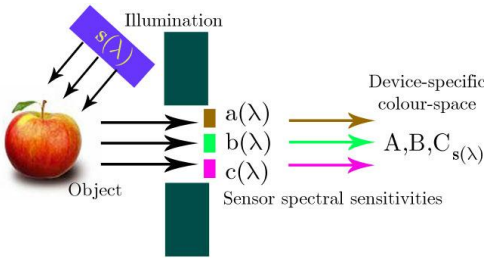


*Figure 2: Colour measurement in a device-specific colour space*

This correction, or "colourimetric calibration", is in most cases only approximately possible, which means that the measurement values calibrated after the fact often exhibit significant deviations from the actual chromaticity coordinates. The use of standard-conforming spectral light sources can reduce or eliminate this fundamental source of error.

## Light and its effect on humans

When colour is visually matched, the evaluation of the spectral stimulus is done directly using the human eye. Because only qualitative assessments can be made this way, the actual determination of the colour is completed through the comparison of the object with standardised colour tables. The use of a standard illuminant is indispensible in this process as well. Otherwise, metamerism effects, caused by the spectral deviations in the light source, can lead to false colour identification. Whether intentional or not, these conditions lead to a varying colour impression, for example when looking at clothing in daylight and under the artificial illumination of fluorescent lighting.

In addition to varying colour perception, lighting characterstics (a "lighting mood") constantly acting on a human observer can also have psychological effects. For example warm light with a large red component tends to make observers drowsy, whereas a large blue component tends to excite. Illumination simulating daylight has been used for a long time as part of phototherapy to raise the subjects'

sense of well-being and to inhibit depression.

## Light generation with LEDs

The development of semiconductor light sources, known as light-emitting diodes or LEDs, has progressed quickly since the 1960s and has now reached a state in which the principle has become interesting for illumination applications. Because a significant part of LED light is emitted within a narrow, material-dependent wavelength band, they have played an insignificant role for illumination purposes in the past. Only since additional converter materials (phosphors) can be implanted which can convert short-wave (blue) light into longer wavelengths has it been possible to generate wideband light using semiconductors. White light LEDs are an approximate realisation of the colourimetric chromaticity of daylight, but they are not suitable for colour measurement illumination or for colour matching because of the relative lack of agreement with standard illuminants.

## Functionality of the controlled LED-based light source

A colour measurement or colour matching can only lead to exact results in combination with a spectrally standardised illumination source. The principle of an LED-based light source allows the reproduction of a multitude of spectra. In order to generate a specific wideband illumination spectrum, several LEDs with different spectral characteristics are operated simultaneously.

The coordination of the total emitted spectrum is done using automated control with sensors. The light emitted from the LEDs is permanently monitored by a multichannel sensor. Using an intelligent calculation procedure, the values from the individual sensor channels can be combined to determine the underlying spectral distribution, independent of which selection of LEDs are actually generating the illumination. The determined spectrum is compared to the desired spectrum and the driver signals for the LEDs are adapted accordingly. Through this sensor-based control it becomes possible to compensate for all disturbances which are adversely affecting the emitted spectrum of the LEDs. Therefore, this controlled LED light source is the optimum light source for applications in which high demands are placed on reproducibility and long-term stability in addition to the required customised spectral adjustment.

## Advantages of the LED-based light source

The design of the LED-based, spectrally controlled light source is versatilely scalable. The arrangement of the light-generating LEDs is set up individually for each application through a newly developed selection process, so that the target spectra to be realised are optimally reproduced. Power LEDs can be used as well for applications with a high illumination demand.

The utilisation of LEDs as the primary light ermitter yields other excellent advantages as well:

- LEDs exhibit extremely long life as compared to typical light sources, which makes sustained use of the spectrally controlled light source possible.
- Light-emitting diodes are ready for operation immediately when switched off. Burdensome delays due to warming up or burning in are avoided.
- LEDs possess very small dimensions compared to other primary sources, which allows a very compact setup.

Through the implementation of several target spectra, metamerism indices can be automatically determined or the different perceptions of the colour of objects caused by changes in the illumination characteristics can be impressively demonstrated for example in a light booth – for product presentations, advertisements or colour matching.

## More Information

More information on the topic of **colour sensors** and about other interesting products from the Zentrums für Bild- und Signalverarbeitung e.V. can be found at:

www.zbs-ilmenau.de

or

www.zbs-ilmenau.de/farbe.html.