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LED Light-Spectrum-Modulator as a dynamic laboratory light source

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Halogen filament lamps are normally used for transmission or absorption measurements. They have a high intensity in the red spectral range which decreases continuously towards the blue range reaching down to a factor of 1/100. This requires a highly dynamic spectrometer, particularly when the sample shows very high absorption in the blue region. Another way is the use of optical filters to smoothen the reference spectrum and reduce infrared radiation.

The analytical considerations show that the problem can be reduced with LEDs. An LED Light-Spectrum-Modulator (LLSM) can produce almost arbitrary spectral distribution. It consists of 21 single-color LEDs with a peak wavelength λ_{peak} spacing of 20 nm and with width at half maximum $FWHM$ of 20 nm.

The Spektral distribution of an LED can be approximated with Gaussian function. Parameter A adjust the radiation intensity (see Fig. 1).

$$f(\lambda) = Ae^{-\frac{(\lambda-\lambda_{peak})^2}{2c^2}} \quad \text{with} \quad c = \frac{FWHM}{2\sqrt{2\cdot\ln(2)}}$$

For absorption or transmission measurements a continuous and almost equable spectrum (mode Q) can be generated (see Fig. 2 and Fig. 3).

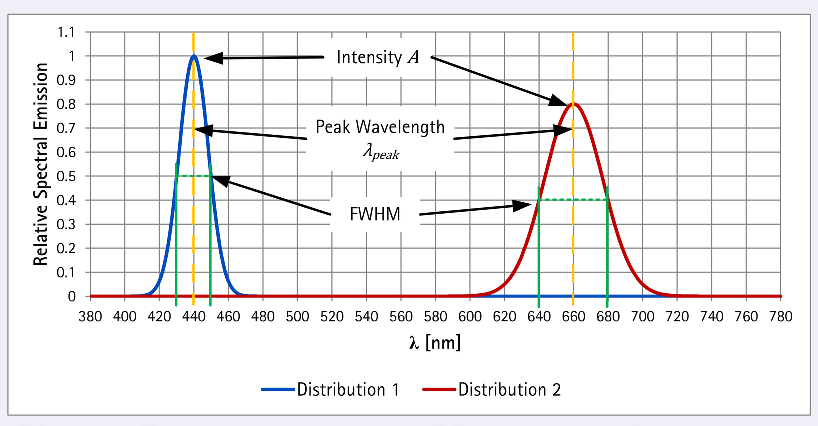

Fig. 1: Two computed LED spectra by Gaussian function. Left: A = 1, λ_{peak} = 440 nm, $FWHM$ = 20 nm. Right: A = 0.8, λ_{peak} = 660 nm, $FWHM$ = 40 nm

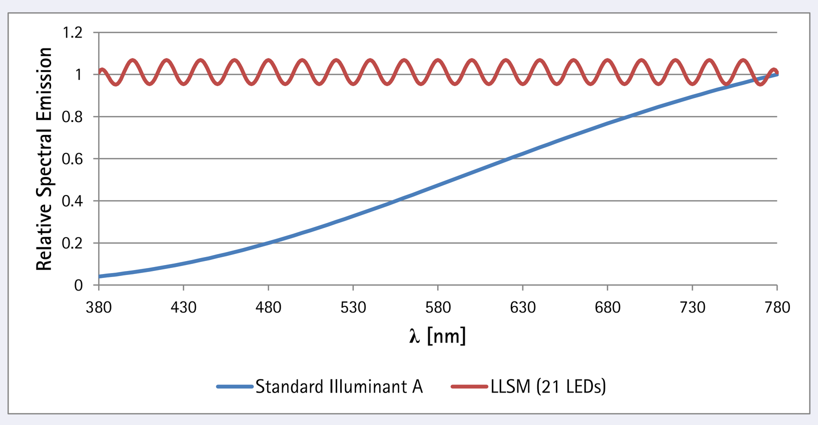

Fig. 2: Spectrum of halogen filament lamp and computed total spectrum of 21 LEDs

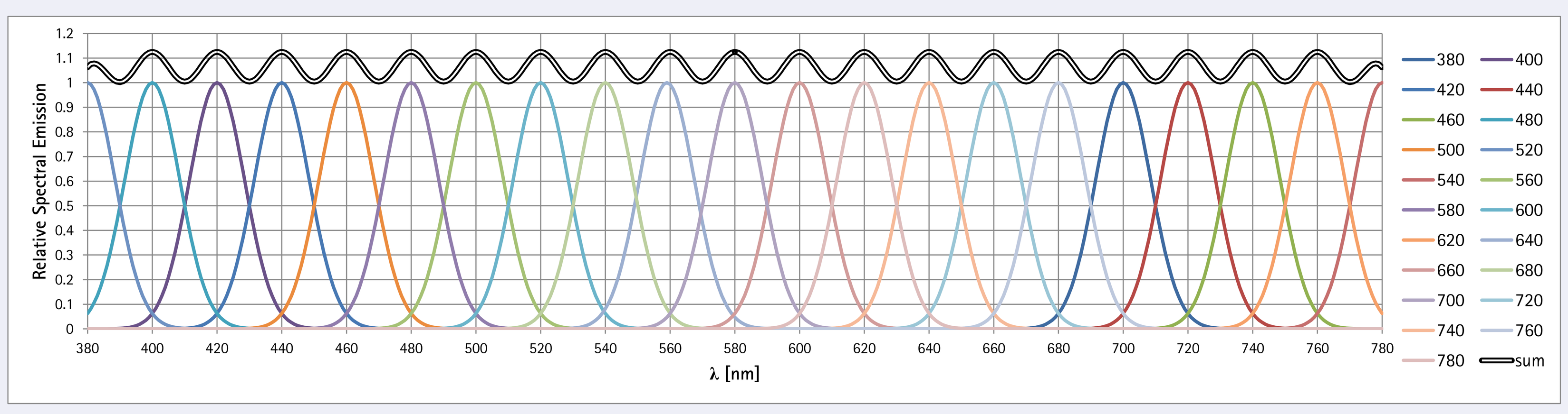

Fig. 3: Computed 21 LED-spectra and the sum spectral distribution of LLSM

Moreover, it is possible as a good approximation to modulate spectral distribution of standard light sources such as standard illuminant A or D65 (see Fig. 4 and Fig. 5) or each other kind of light source (see Fig. 6).

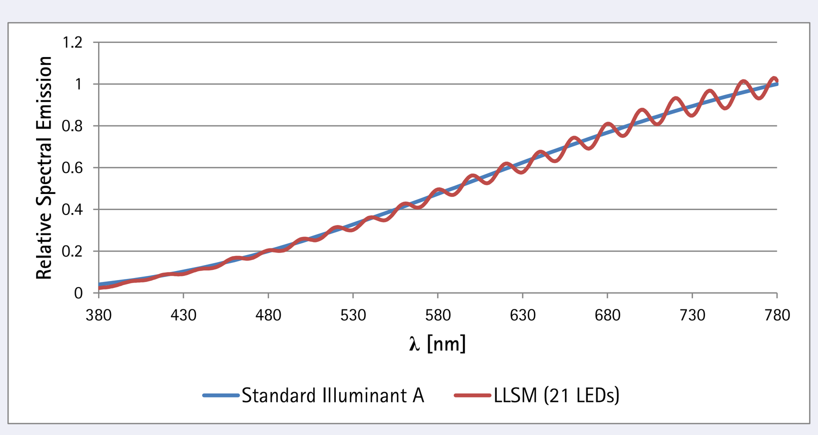

Fig. 4: Spectra of standard illuminant A (CIE) and computed total spectrum of 21 LEDs

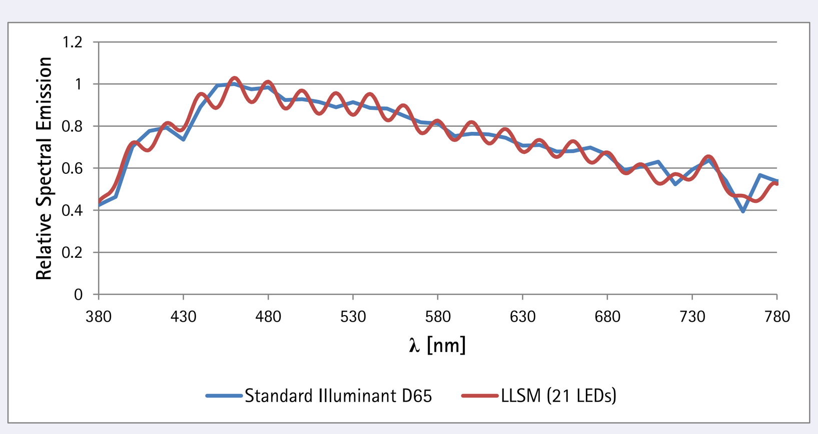

Fig. 5: Spectra of standard illuminant D65 (CIE) and computed total spectrum of 21 LEDs

Fig. 7 shows the transmission spectrum of an light filter with a light source standard illuminant A and the same filter with LLSM in mode Q (see Fig. 2) and in boost mode. In boost mode the intensity of selected LEDs can be increased. In case of Fig. 7 LED 1 to 6 have A factor equal to 10, LED 15 factor A =2 and LED 16 factor A =5. Other LEDs have A factor equal to 1.

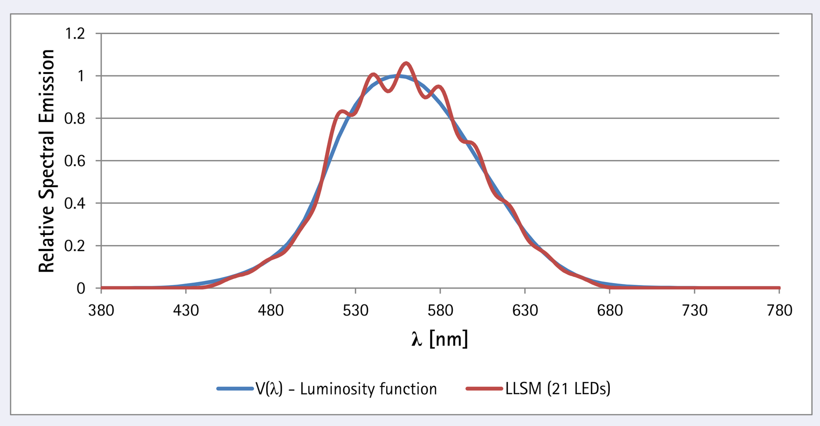

Fig. 6: V(λ)-Distribution (CIE) and computed total spectrum of 21 LEDs

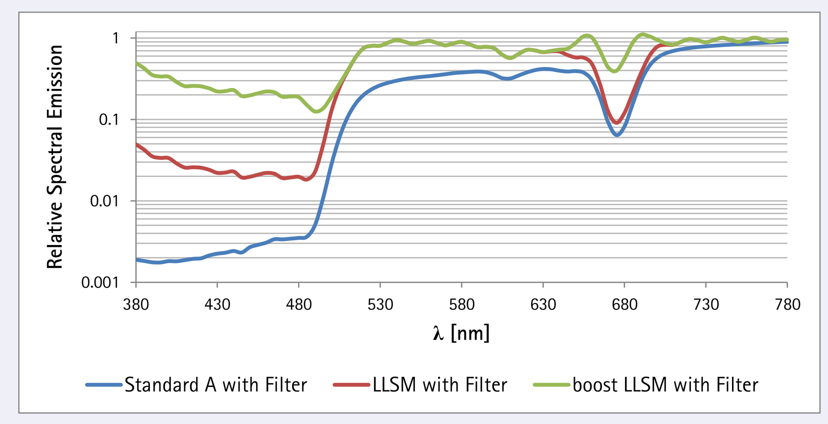

Fig. 7: Transmission spectrum of an light filter with a light source Standard A and with LLSM in mode Q and in boost mode

First prototype of LLSM (see Fig. 8a) was realized with 8 typical commercial color LEDs with peak wavelength at 440 nm (LD), 465 nm (LB), 505 nm (LV), 530 nm (LT), 580 nm (LY), 625 nm (LA), 640 nm (LR) and 665 nm (LH). Modelling results are shown in Fig. 8 b, c. Fig. 9 shows CIE color space with space area for first LLSM prototype and from 21 computed LED spectra.

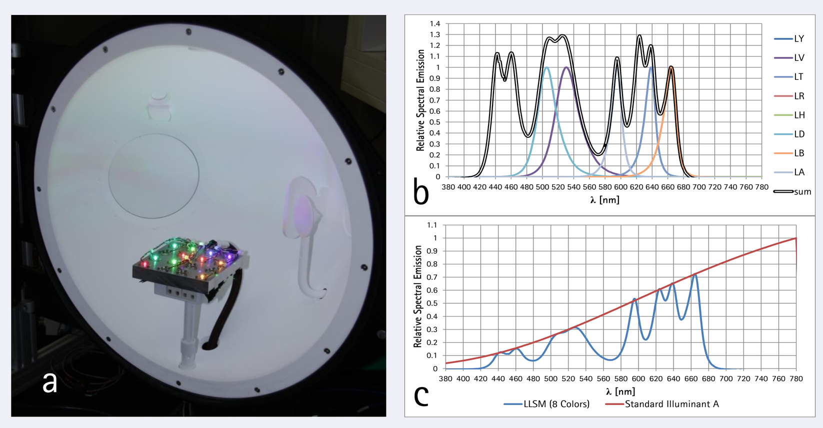

Fig. 8: a) Real LLSM prototype with 16 power LEDs in 8 typical commercial colors (b). c) Approximation to halogen filament lamp spectrum

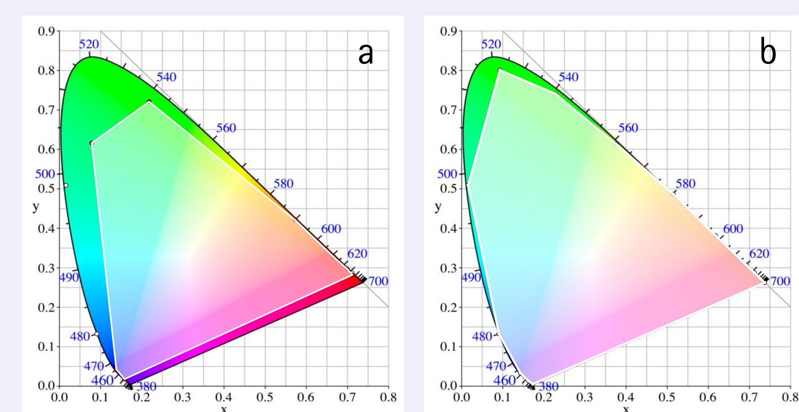

Fig. 9: CIE color space. Left: with space area from 16 power LEDs in 8 typical commercial colors. Right: space area with theoretical spectra of 21 LED

A particular challenge is considered of the light mixture. For experiment without the need for directional light, the light can be mixed in an integrating sphere. The principle setup and CAD model is shown in Fig. 10.

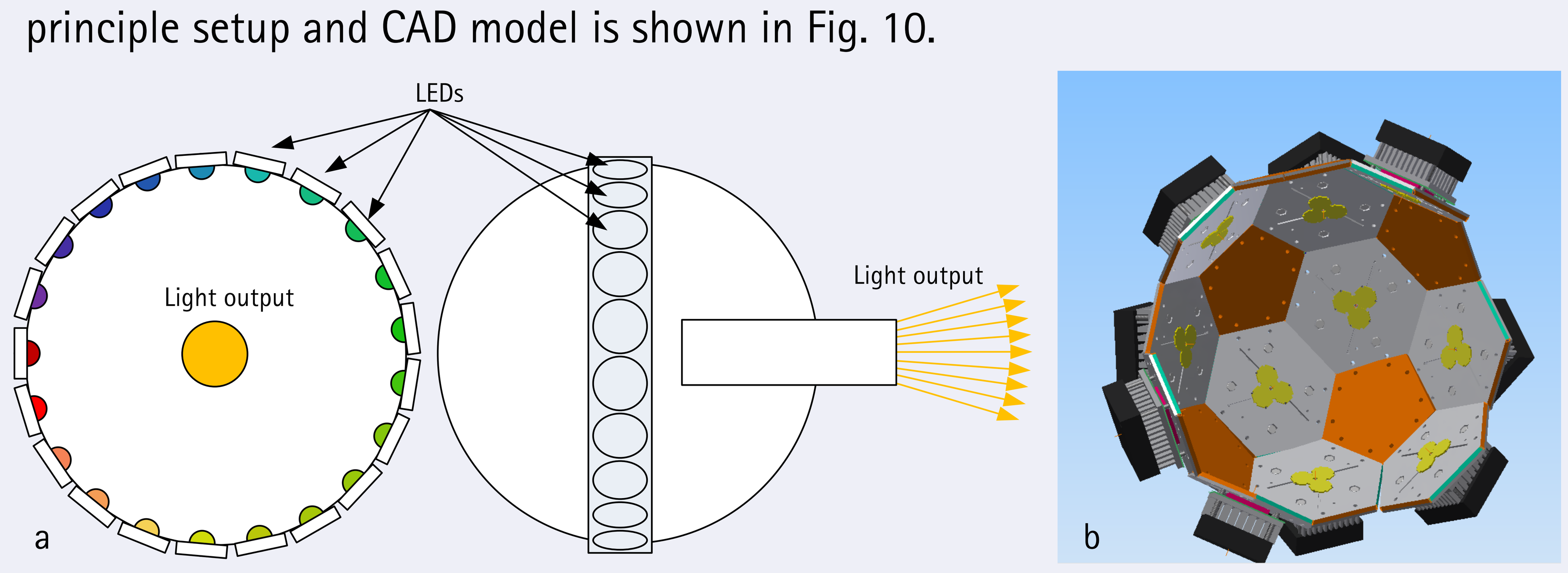

Fig. 10: a) Principle setup for mixing light in an integrating sphere. b) CAD model of an integrating sphere part with 11 LED modules. Each module is designed for 3 power LEDs with own thermal management.

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