LED Illumination: The Future of Image Appraisal

Michael Gall, JUST Normlicht GmbH Vetriebs + Produktion (Germany), and Eric Dalton, JUST Normlicht Inc (USA)

Abstract

LED Illumination captures more and more fields in our daily life and provides us with many advantages compared to conventional light fixtures based on fluorescent lamp technology. LEDs are less power consuming and are better for the environment than any other light source. However, until today the spectral properties have not been good enough to make LED Illumination usable for sophisticated industrial applications. JUST Normlicht has developed for the first time an LED light source that fulfils the high requirements for image appraisal in the Graphic Arts Industry.

Introduction

In the Graphic Arts Industry an exact color reproduction between a proof or an original sample such as textiles, plastic parts, lacquered parts, automotive interiors etc. and a print is essential to fulfill the growing requirements of quality control while reducing costs.

Beside the quality control with measuring devices the visual control of the achieved color match is an important requirement. For matching colors visually the biggest influence comes from the illumination. An incorrect illumination leads to the wrong results and therefore to complaints and increasing cost in the production process.

Metamerism

Colors, pigments and dyes can be visually identical, but are completely different in their chemical or spectral composition, like printing inks for the offset press, gravure press or digital printing presses based on inkjet technology or with toners. Furthermore lacquers for surface treatment or pigments or dyes for coloring plastics or textiles also differ in their chemical composition. In many cases it is required that all of these different materials appear to be the same color, for example the textile of the seats and the plastics of the dashboard in a car. If these different materials are judged under different lighting conditions, they will appear to be the same in one defined standard light source but can appear to be completely different under another light source. This effect is defined as metameric failure.

Monitor Proofing

Instead of using a printed paper as the proof for the printing process more often the proof is only displayed on a color monitor (SoftProof or Monitorproof) and these monitors are now able to achieve a very high level of color quality.

The LCD-displays that are used for monitor proofing today have reached such a high color rendering quality that for all visible differences in color the suspected cause is the color rendering properties of the illumination that is used for the visual color control.

This is especially noticed by manufacturers and users of remote proofing systems, where the parties involved, are based in different locations and are using monitor workstations for online print approval. (For example the print buyer in one city and the prepress studio in another city)

Fluorescent Lamps – the status quo

Most Color Matching Systems today, based on fluorescent tube technology are fulfilling the requirements of the valid ISO 3664, but in the future these requirements of the standard are probably no longer sufficient for the high quality requirements of softproofing technologies and it is questionable if much higher requirements in lighting quality can be achieved with fluorescent tube technology.

The fluorescent tube is a valid light source for a viewing booth but the spectral power distribution (SPD) has some peaks because of the different gases exploding in the light source, for example, mercury at 546 nm. These peaks make a direct spectral comparison between the SPD of a viewing booth and the reference light source D50 impossible and therefore tolerances for CRI and metamerism indexes are required.

For future applications these tolerances may be too big. Today’s standardized viewing booths may not be ideal in the future because the SPD of the viewing booth should be as close to the simulated reference light source as possible to avoid visual errors.

Another problem is the aging process of the fluorescent tubes. The phosphors used in a fluorescent tube are constantly degrading and therefore change in color temperature as they age. It is experienced that today’s light sources can be used for 2,500 hours before they have to be replaced.

The shift in color temperature is a permanent process; therefore today’s light sources can only be used for a much shorter time in future applications with tighter tolerances because the color temperature shift is clearly visible to the human eye.

Furthermore today the question about the “right” color temperature is asked more often. In many cases the alternative use of D65 as the standard is requested because this is the standard for visual color matching in many other related industrial sectors like the textile or automotive industry.

The SPD of a fluorescent tube is not adjustable. If the user needs to compare color under different light sources then they are forced to buy new viewing booths for visual comparison under each different light source.

LED Illumination - the challenge

Light sources based on LED-technology have been available for many years now. Their long durability and robustness are only 2 of many reasons that make them predestined for a nearly unlimited number of applications in our daily life. However, until today LEDs were not suitable for visual color matching applications. The spectrum of white LEDs is very fragmented. This is why the color rendering properties are not sufficient for the specific application of visual color matching. This fragmented spectrum causes the color rendering index (CRI) to be significantly below the required value of 90.

Today different approaches exist to simulate daylight based on R-G-B technology with red, green and blue LEDs, which in theory would be possible. Natural daylight consists of a very even and uniform spectral power distribution from 380 to 780 nm with additional UV content also included in daylight. Though colored LEDs do not cover a certain spectrum but produce light only as a peak in one determined wave length, by combining 3 different colored R-G-B LEDs it is possible to produce light in all different whites and colors. Since it is a very fragmented spectral power distribution, consisting of only 3 peak wavelengths (figure 1), the color rendering properties will be very weak and limited.

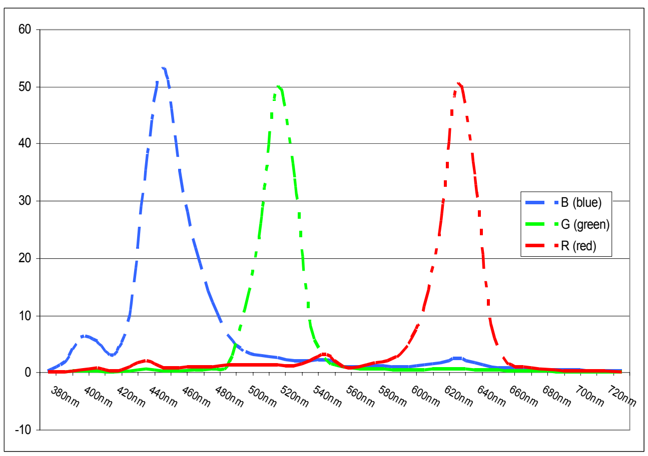

Figure 1: Fragmented SPD of typical RGB - LED

The Color Rendering Index according to CIE 13.3 of such an RGB – LED will never reach a value of 80 or above, which is required for all industrial quality control applications. By only increasing the number of different colored LEDs to fill in the gaps in the spectral power distribution you can only improve this problem, however, it is not a solution for a real smooth spectral power distribution with a high CRI and a very low metameric failure. This is one reason why all experiments to use LEDs for visual color appraisal according to standards like ISO 3664 or DIN 6173 have failed.

LED Illumination - the future

JUST Normlicht has now developed a multispectral LED light source that is able to replicate any light spectra in a very high quality, meaning a CRI between 90 and 100 and a Metamerism Index < 1. With this multispectral LED light source we are creating a color gamut larger than sRGB (figure 2) and we are now able to replicate not only standardized light sources like D50 or D65 for the graphic arts industry but also other light sources like A, C, D55, D75 and any other white or colored light. To avoid metameric failure caused by optical brightening agents, the UV-content in the light source is also included.

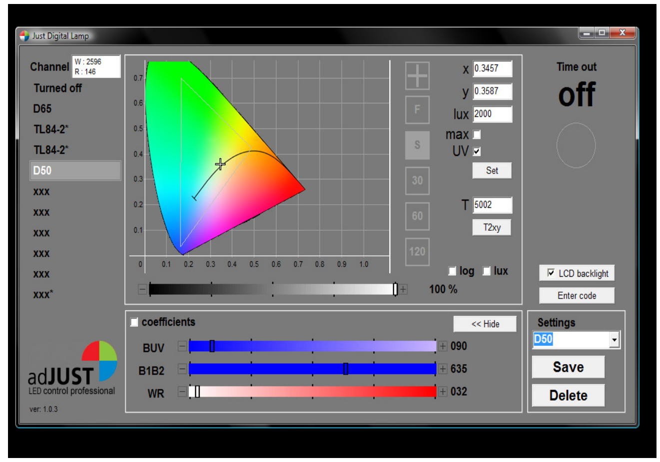

Figure 2: Color Space of JUST LED < sRGB

Current LED production limitations

While LEDs were initially not ideal for standardized lighting applications, it is interesting to know why many experiments using LED technology in the past have failed. Colored LED Chips - even out of one production lot - are very different in brightness and also in their peak wavelength. White LED-chips are primarily a blue LED with a peak wavelength of 460 nm. The blue LED is covered by a fluorescence colorant, emitting yellow light at a peak wavelength of 600 nm. Also here we realize high variety between each single chip. The LED industry tries to improve this problem by manually sorting the chips to certain quality specifications [binning] but the differences between the single chips is still too big for applications like ours.

The second problem is the self-heating during the working process and variable ambient heat, which causes extremely high shifts in the light spectra.

A third problem is the availability of defined LED chips is not guaranteed over a period of time. LED chips are mass produced mostly in manufacturing facilities in the Far East and the availability of LED chips is controlled by other market rules outside of what we can influence with our small niche market application.

Requirements for industrial applications

The expectations for our products are high. If we deliver an LED viewing booth today and we have to replace one LED light source after a period of time because of a malfunction, we have to guarantee that the replacement part will have the same spectral properties as the other LED light sources in this booth. Another expectation is if we sell an LED viewing booth today to a customer and another one a year later, the customer expects both units to be exactly the same.

For the user of our products we have to guarantee, that independent of all these issues, any LED light source has the exact same high quality spectral power properties for years. In the case of replacing a single LED light source in an LED light booth we cannot change the spectral properties of the whole unit. Only if this can be provided can LED technology be applicable for a sophisticated industrial application such as the Standardized Lighting Technology for color appraisal.

JUST Normlicht technology achievements

JUST Normlicht's LED technology has achieved the ability, for the first time, to control the properties of LEDs with consideration of all the issues described before. To control the LED properties to our requirements we have developed a complex multilevel calibration procedure that calibrates each single LED light source and stores the spectral properties in the unit's electronic controls. This process is unique and therefore has a patent filed for by JUST Normlicht.

The multilevel calibration is divided into the basic factory calibration and permanent online-calibration during operation without using an external metrological device. The LED Viewing Booth is effectively self-controlling its operating conditions and is adjusting the light result with a very high frequency (> 100Hz) permanently and invisibly to the human eye.

The JUST LED technology is not only exceeding the conventional Standardized Lighting Technology in light quality, but is now for the first time able to replicate a tremendous color space with the highest quality.

A second advantage of the JUST LED technology is a lifetime of at least 10 times longer than that of the traditional fluorescent lamp technique. This means not only stable, unchanging quality of light over a very long time period but also a high savings for replacement lamps over the life of a JUST LED Viewing Booth.

Another advantage to keep in mind is the environmental benefit of the LED technology. By not using mercury and only a very little amount of phosphors, which are both major components of fluorescent lamps, the LED Technology reduces the amount of hazardous waste being disposed of in our landfills across the globe.

Benefits of JUST LED Technology

- near-perfect replication light sources like D50, D65, D75, A, TL 84
- simulation of optical brightener agents by providing the required UV content
- free selection of light spectra out of color space bigger than sRGB
- stable conditions by a unique calibration method
- more than 10 times longer lifetime compare to fluorescence lamps
- no mercury

SPD Samples of different Simulations:

Included below is the spectral curve of the JUST LED Color Viewing Light as it compares to various standardized light sources.

D50 simulation

In figure 3 you can see the spectral curve of the JUST LED as it compares to D50. This spectral curve has also been measured with and without UV and you will notice how the curve is almost identical when the UV is cut from the spectrum.

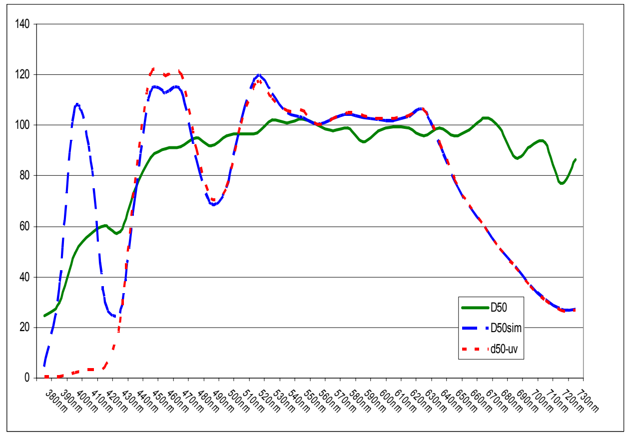

Figure 3: Simulation of D50 and D50 (UVcut) vs. D50

In figure 4 you can see how well the JUST LED is able to reproduce A (Incandescent) lighting condition.

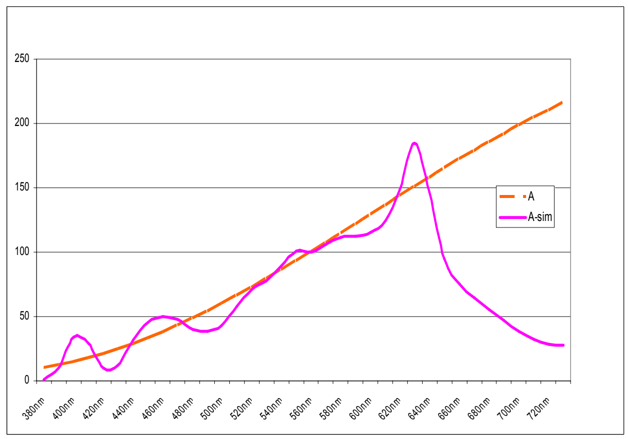

Figure 4: Simulation of Light source A

In figure 5 the JUST LED is simulating the spectral curve of a standard fluorescent tube, F11 which is more commonly know as TL-84 throughout Western Europe.

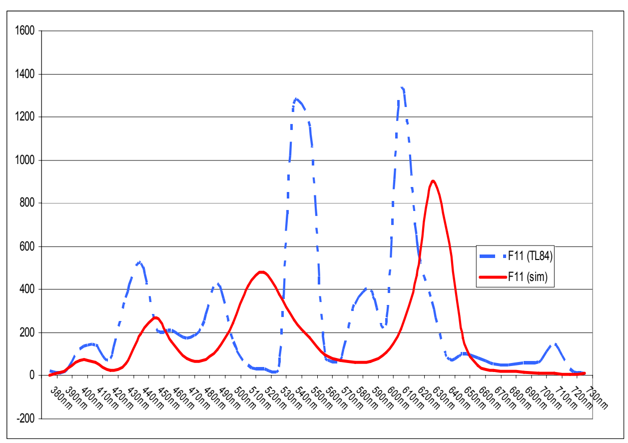

Figure 5: Simulation of F11 (TL84)

Author Biographies

Michael Gall has been the Managing Director with JUST Normlicht GmbH Vetriebs + Produktion since 1995. Now as the CEO and sole shareholder of the company Michael has been working closely with industry organizations throughout the world on improving the standards for visually assessing color in the Graphic Arts Industries.

Eric Dalton has worked with JUST Normlicht Inc since 2002 and has quickly rose from Inside Sales Manager to Vice President. He is currently active in many Graphic Arts Industry organizations including Printing Industries of America, IPA, NPES, CGATS, and IDEAlliance. Currently Eric is an active participant on ISO TC-42 and TC-130 committees as well.