Evaluation of Advanced Automotive Interior Lighting using “Pixelated” RGB LEDs

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Visions for future automotive interior lighting base on large numbers of direct-lit (pixelated) RGB LEDs providing orchestrated effects and living room feeling for premium and autonomous cars. We evaluated and compared two smart RGB LED systems regarding optical parameters for automotive performance and other applications. Examples are spectra, uniformity, tolerances and system integration.

1 Introduction

Future cars with (semi-) autonomous driving will have interior lighting with theater-like effects [1]. Such systems have significant higher requirements as today’s edge-lit systems (Fig. 1 top, A). They consists of direct-lit (backlighted) light guides (Fig. 1 bottom, B) with RGB LEDs every ~30 mm (up to 1,000 per car in future). We compared two approaches and examined optical parameters and their tolerances by measurements and simulations.

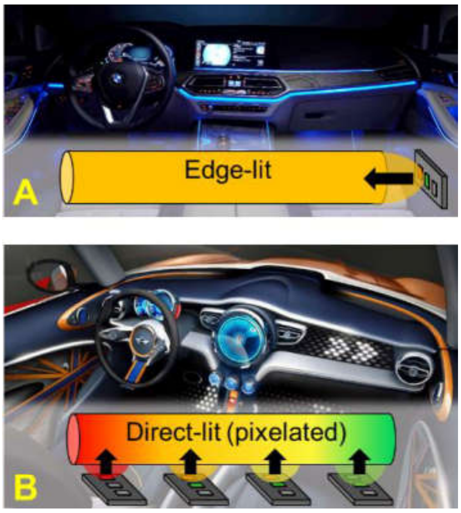

Fig. 1 *Today’s automotive interior lighting by edge light (A) and future advanced pixelated lighting (B, direct-lit).*

2 Smart RGB LED Systems

We evaluated two approaches (detailed information see [2]) for optical performance: A new professional solution for automotive interior lighting ("Integrated Smart Embedded LED") and the widely available low-cost RGB LED system (WS2812B, CE grade). At first glance, both approaches provide similar lighting effects however at different quality, performance, and cost.

The major difference (see Fig. 2) between WS2812B and ISELED is the wide range of additional features and automotive quality of the latter. Each ISELED in a daisy chain has its own address and is individually controlled via a microcontroller (µC) while the WS2812 system feeds through all data for the whole chain even if just one LED should change e.g. its grey level. For ISELEDs the calibration (intensity and white point) is performed during final packaging assembly and these data are stored in an OTP (one time programmable memory) in the ISELED chip. This eliminates the usual binning and bar-coding resulting in cost savings and high uniformity. A further key feature is the temperature compensation of the red LED. WS 2812 has none of these features which results in larger tolerances.

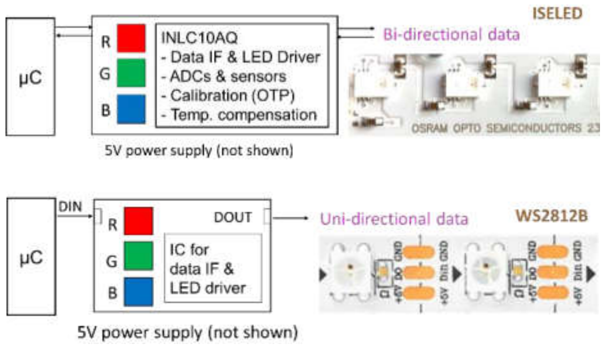

Fig. 2 *The two evaluated concepts [2] of RGB LEDs with integrated drivers and data interface: automotive optimized ISELED (top, [1]) and WS2812 (bottom) as example for consumer electronics and limited commercial use.*

Fig. 3 shows the hardware we built for optical measurements (spectra, intensity, color and uniformity at different temperatures) and systems evaluation (e.g. speed of animations, see Fig. 3 right).

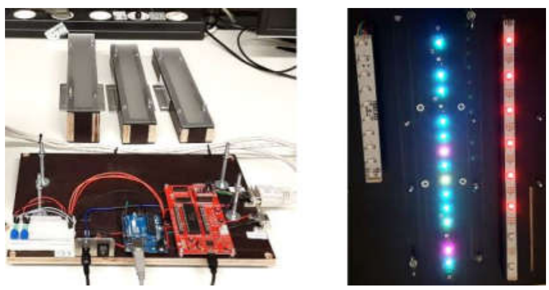

Fig. 3 *Prototype system for evaluation of the two concepts: Microcontrollers and housings with different diffusors (left) and screenshot of a movie of fast dynamic animations (right) such as chaser/running light.*

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3 Measurements and Tolerances

An example of our optical measurements is provided in Fig. 4 for WS2812 (ISELED see [3]). It is clearly visible that the eight neighboring LEDs have especially for green and red fluctuating intensities and peak wavelength. Via Color Matching Functions we calculated the color coordinates in CIE 1976 UCS for comparison and measured uniformity via a calibrated luminance and color imager.

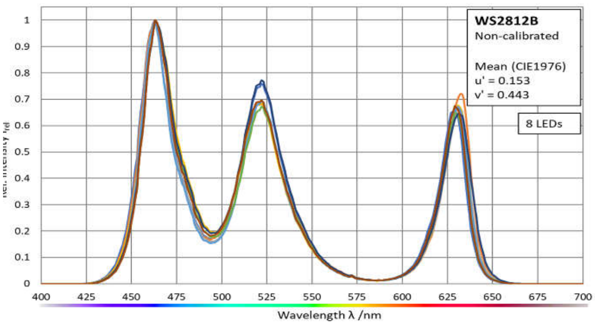

Fig. 4 *Example spectra of WS 28123B measured and visualized for 8 neighboring LEDs. ISELED spectral characteristics see [3].*

The results of our measurements and evaluations demonstrate that ISELED systems have significantly smaller deviations than the WS2812 especially for low and high temperatures. This could be however compensated for WS2812 via adaptation of grey levels acc. to temperature. The drawback is a reduced grey scale resolution which is noticeable e.g. at fading.

As the perceived quality is influenced by the temperature dependency of both intensity and spectra, this has to be taken into account for premium automotive interior lighting systems. Furthermore, all LEDs have production tolerances handled by binnings. To deal efficiently with these dependencies and tolerances we programmed a tool (MATLAB) for evaluating maximum individual LED tolerances for this multi-parameter system (RGB, intensity, color, temperature …) Fig. 5. Green stands for “within given tolerances” and red as “outside”.

Fig. 5 *Screenshot of tolerance evaluation tool for binning and temperature effects based on MATLAB.*

4 Animated Ceiling as Example Application

Beside pixelated light guides, hundreds of RGB LEDs can be used for large area animations via RGB LED matrix tiles. An example is ceilings visualizing blue sky and moving clouds. The pixel pitch is about 30 mm, which is sufficient as ceilings are mostly in the peripheral (low resolution) vision. Furthermore, such animations do not require extensive content creation and high data rates (computing power). Fig. 6 shows the block diagram of such a system we build as prototype. WiFi connects the matrix lighting to the control and sensor system (center) which provides as well the content. Users can connect to the system as well for individual settings and animations.

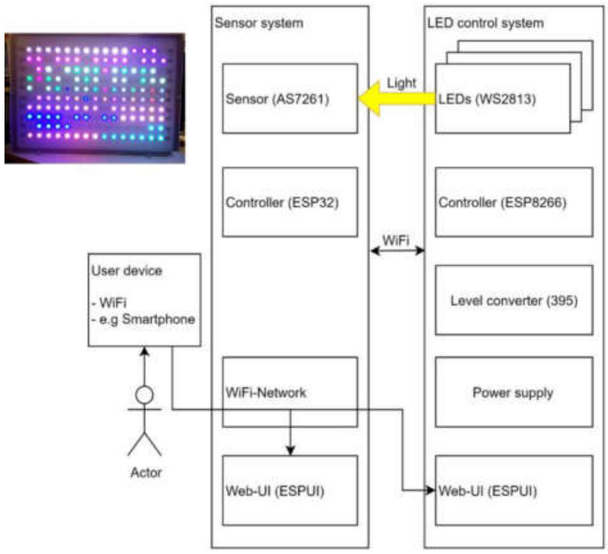

Fig. 6 *Block diagram of large area matrix RGB LED lighting with connectivity for remote control and animations (e.g. moving white clouds over blue sky) as well as illuminance and color supervision.*

5 Summary

We have successfully measured and evaluated several essential optical topics for advanced automotive interior lighting using RGB LEDs with integrated connectivity. Special attention was made to automotive requirements incl. simulation of tolerances. Our findings enable easier integration of premium lighting (direct-lit light guides and display-like areas) into cars and other applications more efficiently in terms of effort and cost.

References

[1] R. Isele, R. Neumann, K. Blankenbach: “Automotive Interior Lighting Evolves with LEDs,“ in SID Information Display, **33**(3):12-16 (2017), ISSN 0362-0972

[2] http://www.iseled.com; http://www.world-semi.com

[3] K. Blankenbach, F. Hertlein, S. Hoffmann: “Advances in automotive interior lighting concerning new LED approach and optical performance,” in JSI Display, **28**(8) 1-13 (2020). https://doi.org/10.1002/jsid.887