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ATMOSPHERE READING LIGHT

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Abstract

LED Reading Light with a variable color temperature allows a convenient “Atmosphere” in the aircraft cabin. Depending on the situation the illumination can be tuned in color – from working to well-being.

1. PRESENT STATUS

Passenger Reading Lights with LED-technology are standard in a contemporary aircraft cabin. Typically they are based on a High Power LED, meaning they are only able to display one light color. This light appears as “cool white” due to the white PC-LED consisting of a blue Chip with phosphor conversation.

2. PROJECT TARGET

In future it will be possible to generate a “cool white” illumination for reading and working, but to change to a “warm white” color for dinning and relaxing.

Some investigations showed that food can look more delicious under a certain light color. This has also been a customer requirement especially in the F/C-area when serving high-grade dinner.
In contrast it has been demonstrated that people’s concentration increases in a bluish, cool white ambience.

With the “Atmosphere Reading Light” it is possible now to adjust any white color (technically: Color Temperature) between warm and cool light while also providing a “High Quality” of light.

FIGURE 1: Food and newspaper under different light sources (exhibition 2004)

2.1. Requirements

“Light Quality” of an aircraft Reading Light is specified by:

- a variable Color Temperature → here between 3.000K and 6.000K
- a pure white color appearance → meaning color coordinates exactly on the Blackbody Curve
- a good color mixing → resulting in no visible color differences within the illuminated area
- a high brightness with a homogeneously illuminated area → meaning (200 ± 30) lx
- a good color recognition → specified by CRI > 85

In addition AIRBUS required the following:

- a small size, especially to decrease the installation depth
- a large angle of light adjustment → ± 28° depending on the seat position
- a sharp borderline between the bright/dark area for no light interfering with the adjacent seat
- a modular design allowing different cabin applications with regard to color, size of illuminated area or installation height
- and a high lifetime reducing maintenance costs.

2.1.1. Basic Information

A “pure white” color means that the color coordinates (as shown in the Chromaticity Diagram below) follow exactly the Blackbody Curve defined by Max Planck displaying Thermal Radiation.

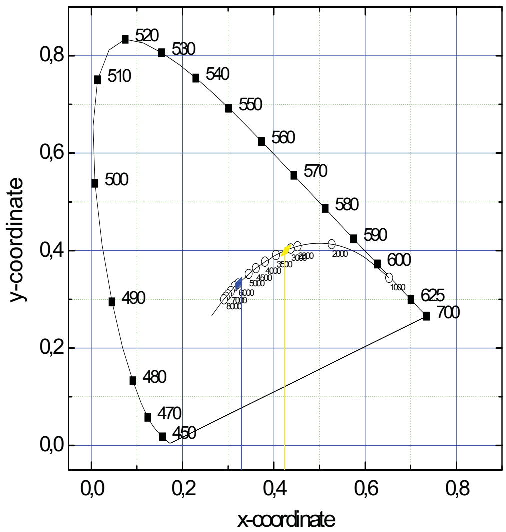


FIGURE 2: CIE 1931 Chromaticity Diagram

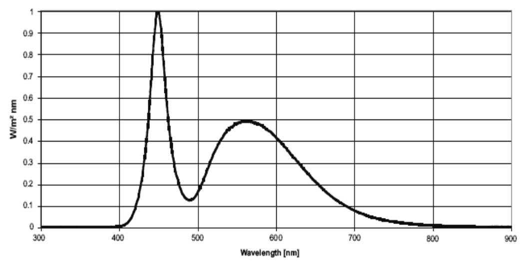
In order to meet this requirement it is essential to have at least 3 different LED-colors. The coordinates of these LEDs have to form a triangle, which encloses the corresponding section of the Blackbody Curve respectively the range of variable Color Temperature.

With only 2 LEDs the color could only be changed along the line between these two coordinates.

Today mainly RGB-LEDs are used to provide a so called "full color lamp" allowing different Color Temperatures.
Color Temperature describes the color appearance of a light source and the light emitted from it.

But for good color recognition it is not sufficient to use a "full color lamp" based on a RGB-lighting. Considering the electromagnetic spectrum a RGB-system only consists of three peaks.
The challenge was to create a light source which fills up the electromagnetic spectrum between the single LEDs.

a)



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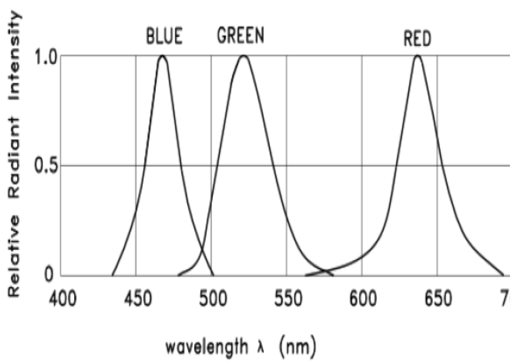

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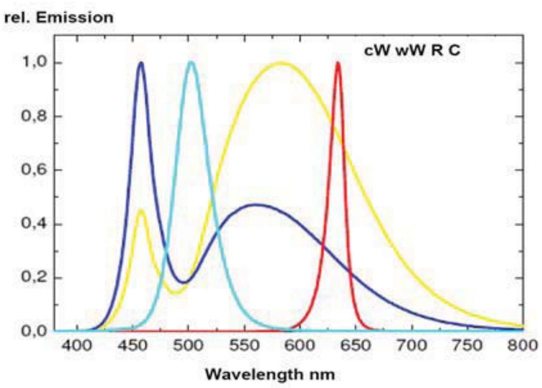


FIGURE 3: Electromagnetic Spectrum of:

a) white PC-LED
b) RGB-System
c) Atmosphere Reading Light with 4 LEDs (cW,wW,R,C)

Another criterion for rating color quality or color recognition is the "Color Rendering Index" CRI.
(Note: Presently a new standard for Color Appearance is under development for a better correlation to LED-technology.)
Color Rendering (expressed as a rating from 0 to 100 on the Color Rendering Index CRI) describes how a light source makes the color of an object appear to the human eye. The higher the CRI -value of a light source is, the better is the color rendering ability. For applications in the aircraft cabin a CRI > 85 is required.

For this evaluation a standardized target (Color Checker see Figure 4) represents some specific colors to be compared under different light sources.

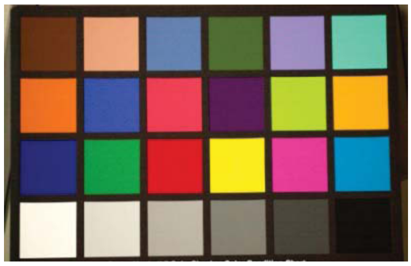


FIGURE 4: Color Checker for CRI-calculation

In summary Color Rendering describes how well the light renders the color of the object. Imagine two objects, one in red and one in blue, which are lighted by a cool light source with a low CRI. The red object appears muted while the blue object appears a rich blue. Now take out the lamp and put in a cool light source with a high CRI. The blue object still appears in a rich blue, but the red object appears more natural in its true red color.

3. DEVELOPMENT

In this project we started research mainly on two topics:

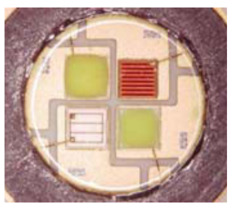
- development of a new light source
- development of specific optical elements.

3.1. Light Source

A LED (-PC white) can be designed to a high CRI for one specific Color Temperature.

In a previous diploma thesis we showed that a high CRI for a larger range of Color Temperature cannot be fulfilled by 3 LEDs of a different color. So a 4-chip LED had to be developed. The challenge was to find the best combination of 4 colors to fulfill all the requirements regarding "Light Quality".
The solution is a 4-chip LED consisting of cool white (cW), warm white (wW), red (R) and cyan (C) -see Figure 3c for electromagnetic spectrum.

FIGURE 5: 4-Chip LED



A 4-chip LED has a lot of advantages concerning the following optics. Mixing the color for example is much easier, when the light sources are close-packed.

First samples of this 4-chip LED have been tested to compare the simulated data with measured results.

The graph (see Figure 6) shows a good correlation between 4.000K and 6.000K with regard to color coordinates meeting the Blackbody Curve. In a next step the wW-LED will be modified to meet also the range down to 3.000K.

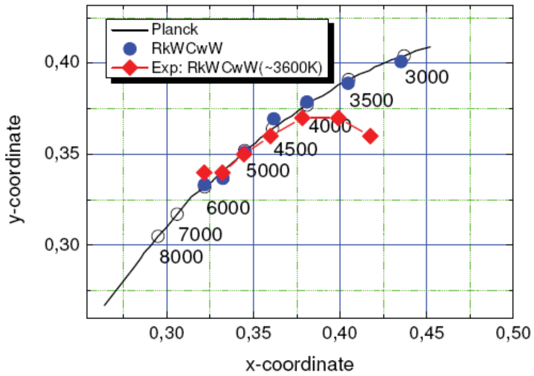


FIGURE 6: Results for Blackbody Curve

The requirement for color rendering with a CRI > 85 has been fulfilled very well. Figure 7 shows a measured CRI between 91 and 96 for the complete range of Color Temperatures.

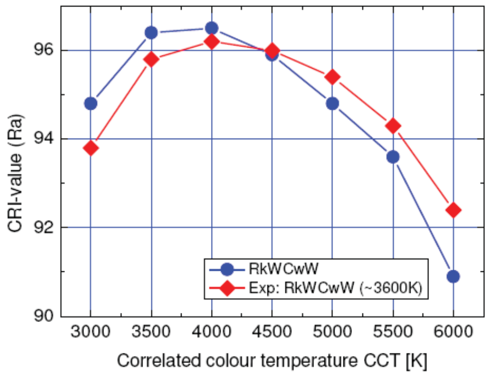


FIGURE 7: Results for Color Rendering Index

3.2. Electronics

At 3.000K the light output is mainly generated by the wW-LED, while at 6.000K the cW-LED plays the leading part.

The power consumption is 2.7W and fulfils the requirement for LED Reading Lights since it is ≤3W. It stays nearly constant over the whole range of the adjustable Color Temperature.

Unfortunately all four chips show a different characteristic with regard to temperature and aging. To guarantee the high quality of color over lifetime it is essential to integrate a color sensor into the Reading Light. An active color management compares the present light color with the presetting.

The second problem is that the chips of the adjacent Reading Lights (may) vary in color and brightness due to a different LED manufacturing lot. Therefore every single unit needs a calibration to save the correction data into a controller memory. Only this procedure allows an independent change of Reading Lights in the aircraft cabin without any visible differences in color and brightness.

3.3. Optical Lenses

Overall the optical system is affected by the size of the light, especially the depth. Some optical lenses have been designed to meet the requirements of an Atmosphere Reading Light. The main task of this lens is to assure:

- color mixing for a uniform illuminated area
- brightness and homogeneity of the illuminated area.

The creation of white light by mixing different LED-colors can be achieved by fiber optics (or a special light guide) or a micro optical element. Due to the limited size of the Reading Light some micro optics have been designed. In general the micro optic consists of more than thousand micro lenses instead of one single lens (see figure 8). This high quantity of lenses multiplies the image of the LED-source resulting in an excellent color mixing.

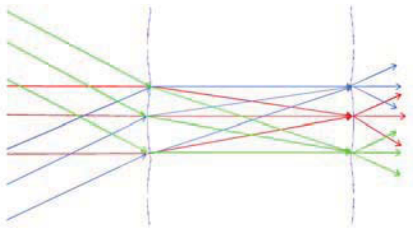


FIGURE 8: Design of micro optic

Additionally the micro lenses are responsible for a uniform brightness of the illuminated area.

The radius of each single micro lens defines the angle of radiation. The installation height in an aircraft cabin varies due to different seat locations, while the diameter of the illuminated area is not changing. Consequently we have to use different micro optics in front of the Reading Light depending on seat location.

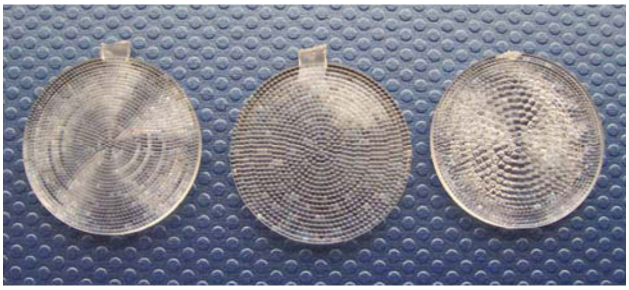


FIGURE 9: Micro optic for different applications

As a major advantage this design allows a high flexibility by just changing the front lens (see Figure 9) in order to increase the illuminated area or for a different brightness requirement.

Further the design equally works for different LED-sources. Without changing the optical and mechanical design it is possible to realize a Spot Light for instance just by replacing the LED(s).

4. ACHIEVEMENT

A LED-light showing a high Color Rendering while also allowing a change in Color Temperature requires a combination of different LED-colors. Some efforts have to be made to control the chips guaranteeing a high lifetime.

With the Atmosphere Reading Light it gets possible now to integrate the Reading Light into the lighting scenarios of an aircraft cabin. Depending on daytime the light color can be adjusted to increase well-being on a long-distance flight.

From now on the airline will be able to adjust the illumination so that food looks delicious, fresh and healthy. Even salmon or salad will look as if was prepared fresh on demand.

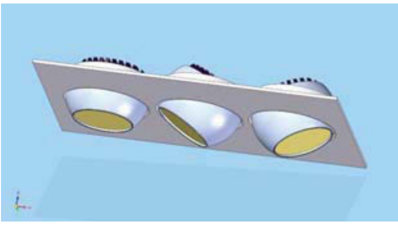



FIGURE 10: Reading Light Demonstrator

5. ABBREVIATIONS

LED	Light Emitting Diode
PC-LED	Phosphor Coated LED
RGB	Red Green Blue
F/C	First Class
CRI	Color Rendering Index
CIE	Commission Internationale de L`Eclairage

6. REFERENCES

DIN 5033-8 Colorimetry; measuring conditions for light sources

CIE 177 Color Rendering of white LED sources

CIE 13.3 Method of measuring and specifying Color Rendering properties of light sources

P. Makus: “Untersuchung des Verfahrens und des Forschungsstandes zur Berechnung des Farbwiedergabeindex und Optimierung der Farbwiedergabeeigenschaften einer LED Lichtquelle für den Einsatz in der Flugzeugkabine" Diplomarbeit HAW / Airbus 2008