BIO-LOGIC LIGHT - The New Standard for Daylight-like Lighting as a Bridge Between Theory and Practice

Peter Haumer, Product Management at Lumitech

Lumitech and Bartenbach describe a new standard for human-centered lighting design. BLL leads to control curves that combine the natural light requirements of humans and the demands of indoor environments like office, education and health.

The aim of the research project was to develop - based on the current state of scientific knowledge - specifications for biodynamic lighting design using a high-end 3-channel LED technology (CCT: 1.800-16.000 K). These specifications resp. target values primarily include the time-dependent values at the eye for vertical MEDI (daylight equivalent illuminance in lx), color temperatures [K], and spatial light distributions with direct and indirect component.

"Human Centric Lighting" – Terminology

The term Human Centric Lighting – back then it was still abbreviated as HumCL - derives mainly from a study published in autumn 2013 from LightingEurope, ZVEI and A.T. Kearney and is not protected. Therefore, different understandings have been summarized / subsumed under this expression, up to and including potentially abusive appropriation. The full headline of the mentioned study provides more clarity: Human Centric Lighting: Going beyond energy efficiency.

In a professional understanding HCL is by far much more, than merely/simply switching On & Off and Dimming.

There are several definitions: e.g. HCL is biologically effective light. Spoiler: every light-source is more or less biological effective, because every light source has a melanopic action factor - regardless of whether it is stated or not. Much better and more precise: So at least it is about what daylight – meaning the sun and the sky – offers over the course of the day.

In a nutshell: It has to mimic natural daylight – which is a quite challenging task!

This means direct and indirect light components with the required proper CCT-range. One fixed prerequisite for this is also the topic of at least following Planckian Locus. So of course, the goal is to go even beyond e.g. by taking social timing into account and by implementing specific accordingly adapted curves, because sunlight on earth deviates slightly from the ideal Planck curve, primarily due to atmospheric absorption.

Indoor-Society

Why is it so important to pay special attention to artificial lighting conditions with regard to their similarity to daylight?

Several studies show that the average time spent outdoors per day, or the time per day with direct contact to sunlight, is alarmingly low. And this change in behavior occurred mainly only within a few generations, so from an evolutionary point of view, in a very short time. This makes adequate indoor lighting all the more necessary to compensate for this deficiency.

Which Technology Regarding the Light Source is Suitable or Required?

All this leads to the following requirements: In order to optimally support the human biorhythm, it is important that the lighting can imitate the intensity and color temperature of sunlight. Physics tells us, that sunlight on Earth moves approximately along the Planck curve throughout the day. That´s the reason why, for evolutionary reasons, artificial light is only perceived as natural light near the Planck curve.

Simple tunable white solutions based on mixing cold and warm white do not meet these requirements. They have a very limited range of color temperatures and are unintentionally located - particularly centrally - far away from the Planck curve. This inevitably results in a severe deviation from Planckian Locus which is inherent to the design.

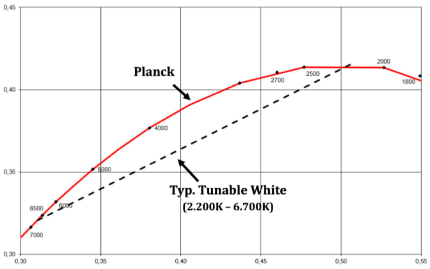

Figure 1: Conventional tunable white solutions based solely on mixing warm and cool white LEDs deviate significantly from the Planckian locus—particularly at mid-range color temperatures—resulting in limited CCT coverage and reduced color quality. © by Lumitech.

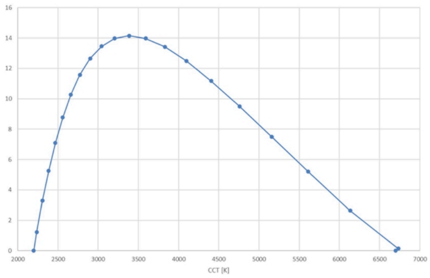

Figure 2: Typical chromaticity deviations exceeding 10 SDCM from the Planckian locus (CIE 1976 u'v' UCS), illustrating the limitations of conventional two-channel tunable white systems. © by Lumitech.

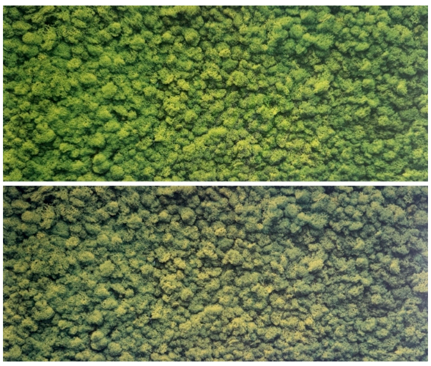

Figure 3: 3,500 K light source on the Planckian locus (top) versus a 3,500 K tunable white source with a deviation of >10 SDCM from the Planckian locus (bottom). © Lumitech. Real photographs; no image editing or AI used.

Key message: Tunable white solutions typically only meet Planck's curve at two color points and are therefore far from the Planck curve in the central color temperature range, which leads to a perception that tends to be redder.

This means they do not meet the requirement for perfect daylight white!

Unbeatable advantages of a multi-channel LED solution calibrated along the Planck curve as clearly visible in the photos: Natural color perception (especially improved green perception and non-red-visualizing properties compared to tunable white) All this results in richer colors, better brilliance, and higher contrast as well as noticeably improved comfort, performance, and concentration.

BIO-LOGIC LIGHT (BLL)

Motivation - with first focus on the demands of modern working and learning environments: Due to social timing/rhythm e.g. like typical office-hours or school-timetables there is a corset independent from season. Therefore, the challenge was to define a daylight-curve that takes social timing into account and is universally applicable during the year and that triggers the circadian-rhythm properly.

Activating, Supportive, and Calming Interventions

Like individual building blocks, so-called interventions combine to form optimized 24-hour control curves that generally follow the natural course of the day. However, interventions are specifically incorporated as targeted measures that improve human well-being or consciously support certain behaviors at a particular time of day. For example, bluer, cooler white light at the beginning of the day facilitates the resetting of the circadian rhythm because the relevant lift is greatest at this time of day. Well-being at midday is addressed by lowering the color temperature slightly beforehand to initiate the rest phase, while afterwards it is raised to mobilize activity.

In the evening, a very warm white light – even after sunset – ensures a relaxed transition into the rest and sleep phase. The sum of various interventions, tailored to the daily routine, results in: light according to BLL criteria.

Human-Centered Implementation of White Light

The Planck curve has so far been the gold standard when it comes to the basis for deciding on the optimal color point of white light. For BIO-LOGIC LIGHT, Bartenbach Research & Development has explored a complementary concept based on perception and focused on optimal white light perception at different color temperatures according to the Judd´s curves. It turns out that while human perceptual preference comes very close to the Planck curve, specific slight deviations from it are necessary to achieve a pure white color impression. The result is greater brilliance. This optimizes contrast and makes visual tasks such as reading easier and therefore less tiring. This modified Planck curve forms the basis of the BLL curve and is incorporated accordingly into the lighting designs.

So this means, that In addition BioLogic-Light uses the possibilities of slight, deliberate deviations from Planckian Locus for the sake of improved human white light perception.

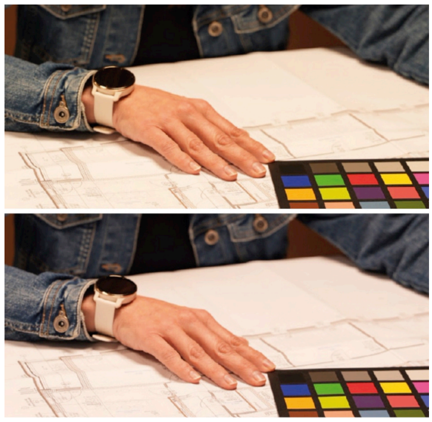

Figure 4: 3,000 K @ Planckian locus (top) versus 3,000 K BLL (bottom) with higher contrast and richer color impression. © Lumitech. Real photographs; no image editing or AI used.

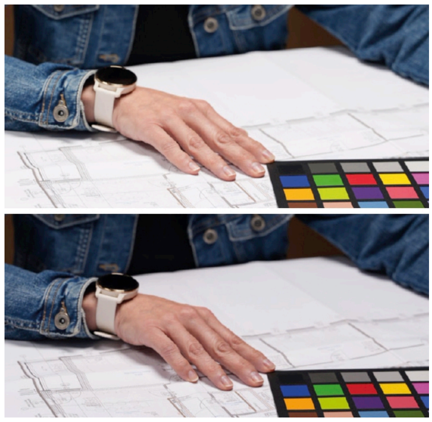

Figure 5: 4,000 K @ Planckian locus (top) versus 4,000 K BLL (bottom) with higher brilliance and richer color impression. © Lumitech. Real photographs; no image editing or AI used.

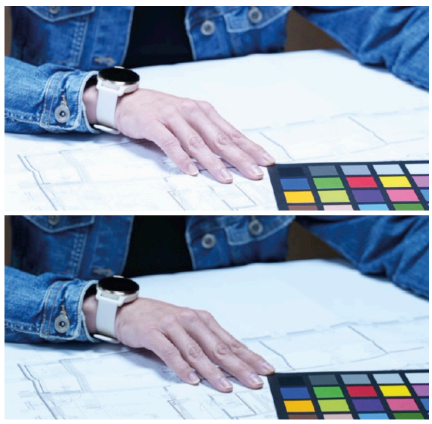

Figure 6: 6,000 K @ Planckian locus (top) versus 6,000 K BLL (bottom) with better contrast and richer color impression. © Lumitech. Real photographs; no image editing or AI used.

Exemplary Lighting Concepts for Specific Applications

Reference examples can serve as an inspiring starting point for creative lighting planning in individual room environments: BIO-LOGIC LIGHT[1] presents various lighting solutions based e.g. on office lighting planning – including key figures, concept details and photometric variables. They serve as a basis for further planning steps that take additional aspects into account, such as user preferences, spatial concepts, architecture and design requirements.

From exemplary solutions for specific planning - an approach that is also suitable for other industries and applications can be adapted. This allows different planning approaches that can be selected to achieve the required light requirements with the BLL control curves.

Figure 7 shows the example of brightening the surface of the room using wall washers and directional downlights. Alternatively, suspended luminaires with direct lighting can also be used for work surface and indirect light on the ceiling (**Figure 8**).

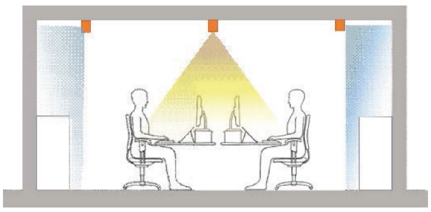

Figure 7: Application example 1: Direct and Wallwash Solution with Downlights for directional task lighting and Wallwashers utilize walls as reflective surfaces to brighten surfaces in the room.

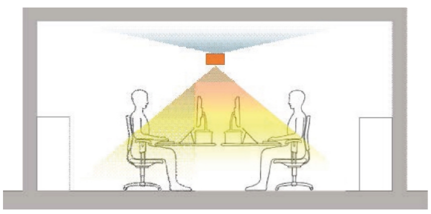

Figure 8: Application example 2: Pendant luminaires or free-standing lamps with two independently controllable light components: i) Directly onto the work surface and ii) Indirectly onto the ceiling (as a reflective surface).

[1]BLL: BIO-LOGIC LIGHT, PI-LED: Phosphor Innovation LED.

Summary

Everything that has been described can be achieved with the patented high-end 3-channel PI-LED technology, which offers, on the one hand, the necessary extreme wide CCT-range that is needed for direct and indirect ratio and – due to spanning a triangle in the CIE-color-room - the autonomy to move freely within this, which means beyond colors, precise targeted deviations from Black-Body curve.

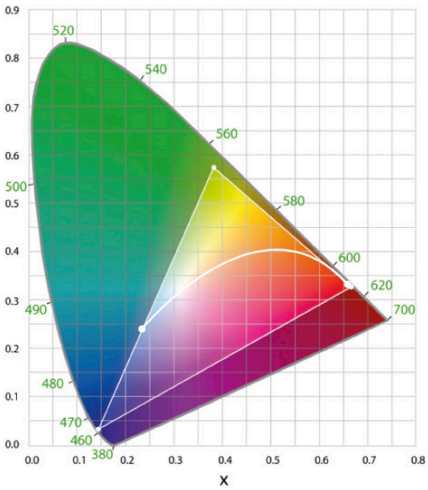

Figure 9: 3-channel PI-LED technology delivers a wide CCT range and accurate color tuning across the CIE color space.

Utilizing the possibilities of a CCT-range of 1,800-16,000K makes it possible, that instead of increasing the intensity, the color temperature of the indirect component is greatly increased (»6500K), and in this way an increase in the MEDI is achieved without an increase in illuminance or light output.

With PI-LED technology, visual demands (visual performance) are partially decoupled from biological demands (melanopic effects). This is achieved by primarily using the indirect light component with cooler color temperatures to meet biological demands, while simultaneously utilizing the direct light component to fulfill visual tasks. In this way, the color temperature in the visual field can be maintained within the comfort range below 5,000 K (preferably 4,300-4,800 K), while the color temperature at the eye is simultaneously increased via the indirect light component to meet biological demands.

As always when we are talking about visible light, there are also more light-quality features necessary and important. Beyond others, it is about color-rendition of the light-source: Ideally, not measured with the outdated and potentially misleading CRI, that only corresponds to some single pastel-shades and deceptive averaging, but based on TM-30.

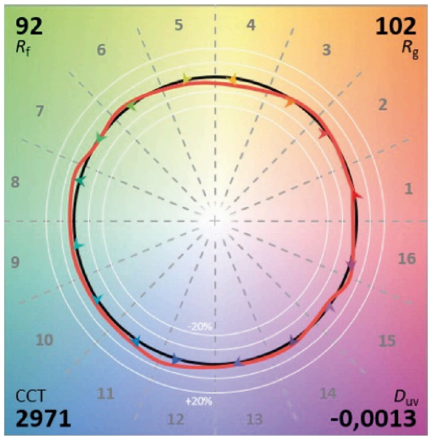

Figure 10: IES TM-30 Color Vector Graphic: Test Source vs. Reference Illuminant (Example: PI-LED Linear System HD).

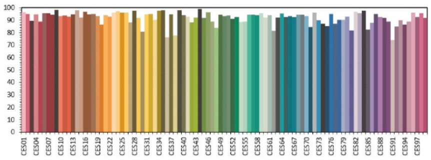

Figure 11: IES TM-30 standardized set of 99 real-world object spectra: CES Color Evaluation Samples (Example: PI-LED Linear System HD).

Furthermore, stating the melanopic action factor alpha (smel) is mandatory for a reasonable melanopic calculation. All the above-described aspects have to be considered for a reasonable solution. Otherwise it is only a gimmick - just playing around with a small range of CCTs.

Peter Haumer is responsible for Product Management at Lumitech Lighting Solution GmbH, Austria. With more than a decade of experience in LED lighting technologies, he specializes in advanced white-light solutions, Human Centric Lighting (HCL), and Lumitech's patented PI-LED technology. He is a frequent speaker and author on spectral light quality, tunable white systems, and next-generation LED lighting technologies.

peter.haumer@lumitech.com