



Special Topics: Healthy Light -  
LED Technology for Health and Care Applications

Special  
Excerpt



# Healthy Light - LED Technology for Health and Care Applications

The right light, at any time during the day or night, is absolutely essential for health and well-being especially in health and care applications. Peter Haumer, Head of Technical Sales at Lumitech/Kiteo reveals why, besides full spectrum and high color rendering, mimicking real daylight conditions with extended daylight curves, a direct and an indirect component (CCT 1.800–16.000 K), are essential. The article explains the basics of the circadian rhythm and discusses benefits that can be derived from special colors for medical staff, patients and residents.

The Nobel-Prize for Medicine 2017 was awarded for the research on circadian-rhythm, which is mainly influenced, respectively, triggered by the color-temperature and intensity of the light. Light is an important “Zeitgeber” for the inner clock (cell rhythms, sleep-wake cycle, organ rhythms) Also, the effect of the CCT of the typically backlit displays of mobile devices and computers as well as laptops is a widely known aspect. Applications that change the CCT to warm-white user-driven or follow a timing e.g. towards the end of the day are intended to reduce the problem of falling asleep significantly later etc. The influence of CCT is almost common knowledge. Light has a perceptible effect on a human beings’ vitality and health. The well-being of the human organism and all involved biological processes depend strongly on natural daylight. As large parts of modern life take place inside buildings, using static lighting, the natural course of daylight is not perceived anymore, since only static artificial lighting is used. This is especially critical for

areas like hospitals and homes for the elderly, where humans - patients and/or residents, as well as staff - typically (have to) stay indoors for long periods of time, but is of course also relevant for offices and work places. It is obvious that conventional artificial lighting with, in most cases, uniform, invariable static characteristics, does not have a positive effect on human health, wellbeing and performance.

Human Centric Lighting takes up this challenge. It simulates the spectral quality of natural daylight over the entire day, thus keeping the human hormone levels balanced, even under artificial lighting. This has a positive effect on both body and mind. An increase in performance and improved concentration are the consequence [1].

So the logical compelling next step, after integrating LED sources into general lighting, is to use the given and existing possibilities for going beyond efficiency, leading to one of the most promising and fastest growing segments in the world of light [2,3].

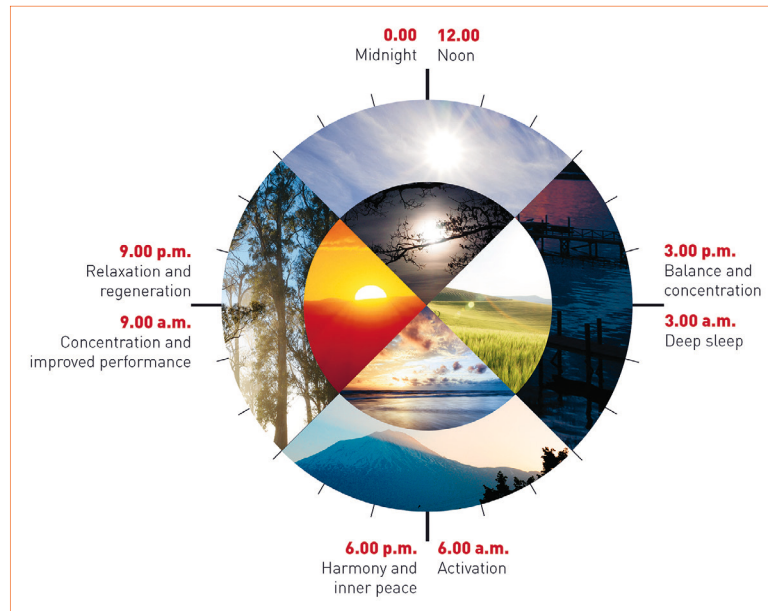
## The Circadian Rhythm

Natural day-night-rhythm is designed to allow humans to sleep well and regenerate while it is dark and to be active and reach high performance levels when it is light. In the course of human evolution, our body has developed a biorhythm on the basis of this sequence – this is called the circadian rhythm.

Apart from the rod cells and cone cells which are responsible for our vision, the human eye also has so-called non-visual photoreceptors which noticeably influence the circadian rhythm (Intrinsic photosensitive retinal ganglion cells [ipRGC] - sensitive to blue spectral wavelengths). These receptors control our hormonal balance, in particular the regulation of melatonin, cortisol and serotonin, which are responsible for our sleep-wake pattern. This is exactly where authentic Human Centric Lighting based on PI-LED takes effect - with the aim of supporting the human circadian rhythm and keeping natural melatonin production in balance.

The underlying principle is as follows:

- Cold light with a high percentage of blue has a vitalizing effect and promotes the release of serotonin and cortisol while at the same time reducing melatonin. Physical fitness, mental performance and vigilance are significantly increased.
- Warm light with a very low percentage of blue does not suppress the release of melatonin, thus encouraging relaxation and regeneration. There are findings that warm-white light with a high percentage of red does not suppress the melatonin and still increases alertness.



**Figure 1:**  
In rhythm with the biological clock [7]



**Figure 2:**  
The effect of different CCTs on humans [7]

### Inspired by the Sun

The more closely artificial lighting manages to imitate sunlight, the more pleasant and perfect we experience this light to be. Human Centric Lighting solutions imitate the continuous spectrum of sunlight during the course of the day without emitting any undesirable ultraviolet or infrared radiation. This exceptional light quality could not be achieved with conventional lighting concepts. This is beyond other restrictions and limitations also not possible with a simple, 2-channel white-white system, especially because of the

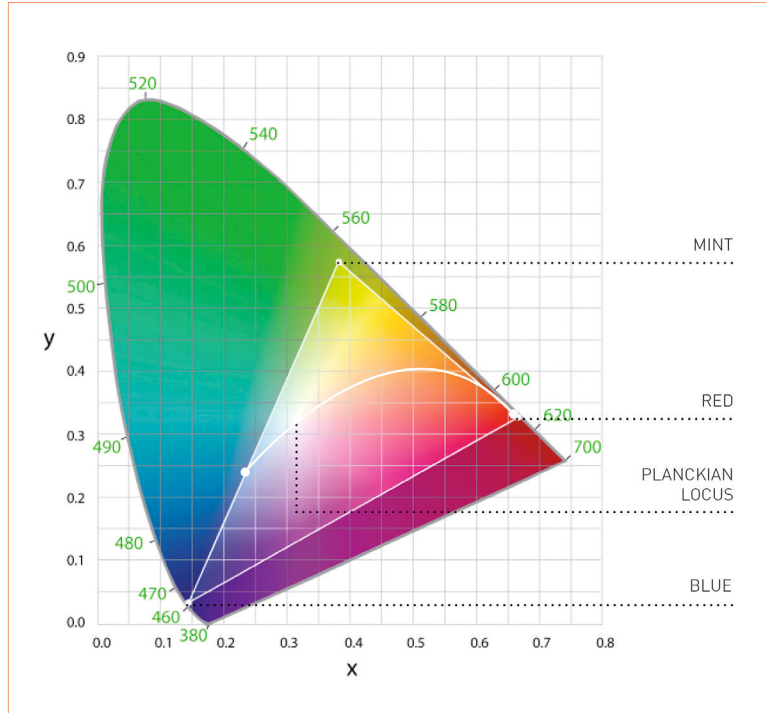
limited CCT-range which does not follow the Black Body Curve.

### Prerequisites to imitate sunlight

Color temperatures should be automatically adjustable along the Planckian locus to mimic natural daylight during the course of the day (including seasonal and non-seasonal changes), with a color temperature range from 1,800 K ("sunrise") up to 16,000 K ("blue sky") and all this with continuous spectrum and with high color rendering for the highest

color-authenticity and individual control of the colors. A further requirement for this is 100% calibration and temperature compensation for minimum color tolerances (MacAdams 1). This can be achieved based on a high-end 3-channel PI-LED-technology consisting of red, blue and mint-white, which are controlled individually and are optimally matched in terms of temperature and intensity. Thanks to the red-channel a high color-rendering in the R9-index is feasible. Due to the possible colors, mood lighting is also realizable. By controlling the

**Figure 3:**  
CIE-chart high-end  
3-channel PI-LED-  
technology [7]



blue channel independently, a pleasant amber light can also be generated - e.g. for night-light to avoid unwanted activation, which is required in hospitals and homes for the elderly. All this is done by using one and the same light source, following the principle to animate and not to manipulate.

### Direct and Indirect Light

Daylight is always a combination of direct sunlight and diffuse radiation from the sky. Sunlight is absorbed by the atmosphere to varying degrees, depending on the wavelength. On an annual average, most light reaches the earth's surface in the form of direct light; the lesser part is indirect light due to air molecules, aerosols or clouds scattering the radiation. Only a certain part of this total solar radiation is visible and can be perceived by the human eye. The intensity of the radiation energy, however, strongly depends on the position of the sun at different times of the day and year. Crucial for a solution that takes this into account, is an automated proper control, that by itself, takes into consideration the time of day within the year and the degree of latitude.

### Melanopic Action Factor

The changing color temperature and intensity of daylight are not the only decisive factors for synchronizing the "internal clock" – other important elements are the direction and planarity of the light source that reaches our eyes. Biologically effective lighting takes all these factors into account. Most importantly, all of this occurs at the right time of day. This requires a holistic design approach, which also consists of light-planning that includes the melanopic action factor acc. to CIE DIS 026/E:2018.

Proper lighting design has to consider the critical values for melanopic lux-level on the eye for activation (> 250 melanopic lux) and relaxation (<100 melanopic lux). For this, the values indicated in table 1 are required.

**Table 1:**  
Example of stating  
the melanopic action  
factor [7]

CCT [K]	VISUAL DATA		MELANOPIC ACTION FACTOR
	Luminous flux [lm]		alpha (smel)
	K-SOLIS	K-SOLIS Pure	
1,800	1,480	1,650	0.226
2,000	1,745	1,945	0.252
2,500	2,170	2,495	0.324
2,700	2,090	2,400	0.357
3,000	2,000	2,300	0.407
3,500	1,910	2,195	0.484
4,000	1,850	2,130	0.554
4,500	1,815	2,085	0.618
5,000	1,790	2,055	0.676
5,500	1,775	2,040	0.728
6,000	1,765	2,025	0.774
6,500	1,755	2,015	0.816
7,000	1,750	2,010	0.852
8,000	1,745	2,000	0.915
9,000	1,740	1,995	0.965
10,000	1,735	1,990	1.033
12,000	1,730	1,970	1.168
14,000	1,720	1,950	1.304
16,000	1,710	1,935	1.439





But while this all sounds reasonable; the key question remains: “What are the expected benefits under the aspect of general lighting and how is this achieved e.g. in hospitals?”

## Expected Benefits in Hospitals

### For patients

**Improved wake / sleep cycle can support healing process and can reduce medication:**

Pleasant activation is possible by natural-like lighting during the day. Undistorted melatonin production due to very warm dimmed light (1800 K) during evenings and nights (no blue light) can be achieved with the possibility of individual control of the blue channel. Individual adjustment of light condition (color temperature curve, light level) according to personal preference and/or health condition are necessary. Mimicking the daylight course including direct and indirect parts helps patients. Especially if they are forced to stay lying down in their beds, they need a sort of horizon for their orientation.

So therefore, a light-situation with direct (“Sun”) and indirect component (“Sky”) is crucial.

### Reduced stress level before surgery:

This can be achieved by using amber lighting for calming a patient down.

### Basal stimulation:

Patients can be effectively stimulated and activated by specific colors (e.g. pastel-tones) on the ceiling in wake-up rooms after surgeries.

### Positive emotional condition:

This can be achieved by combining direct/indirect lighting atmospheres according to the natural lighting. Positive psychological stimulation is also supported by automatic sunrise and sunset light-atmospheres within the patient room

### For the staff

#### Better work performance, vitality and concentration:

Natural light mimic also supports activation in rooms with no

windows. Warm white light with high red component supports alertness in the night shift

### Improved Wake/Sleep Cycle and better health (most likely less breast cancer risk):

Better activation during the day and decreased melatonin suppression in night shift, as well as reduction of the risk of accidents during the night and reduced failure rate.

### Better concentration and attention in emergency cases:

Can be achieved by using high color temperature white light. Lighting has been recognized to have an effect on clinician wellness and performance as well as the occurrence of medical errors [4].

### Improved hygienic situation:

Thanks to better cleaning results with high CRI cool white for excellent visibility of blood and dust.

### Excellent visibility of injuries during the ward rounds:

With very high CRI neutral white lighting (4000 K / 100%) from the same luminaires for ward rounds.

**Figure 4:**  
Example for mimicking horizon [7]

### For surgery & examination

Improved visibility for anatomical details, boosted alertness and reduced stress levels for endoscopic surgeries and examination rooms:

Instead of low light dimming of the room versus high contrast on the monitors, which potentially increases fatigue, the light is switched to green behind the monitors and red behind the surgeons. For X-ray und ultrasonic screens, violet lighting behind the screen is preferred. Screen glare is therefore reduced, the contrast ratio of the monitor improved and the pupils of the surgeons are wide open. For inserting the cannula intravenously, orange and red is chosen due to the better visibility of the blood vessels

#### Cyanosis Observation Index (based on an Australian / New Zealand Standard [5]):

If the oxygen content in the blood is disturbed, it results in the skin turning blue, which is where the name is derived from. For early timely detection, a certain spectrally optimized light emission is advantageous. In the calculation for the COI there is a comparison to 4,000K at Planckian Locus [5].

For this purpose, COI should not exceed the value of 3.3 [5]. If applicable this is important visual information. Therefore, suppliers should be able to state the related values in any case.

#### Recommendation:

Due to all these mentioned considerations, lighting should be considered a critical factor in the design and operation of health care facilities, far beyond energy savings.

### Benefits for Residential Homes for the Elderly

Especially in the northern hemisphere, thanks to the peak in fertility rates in the post-war years, the number of elderly people is about to radically increase. The baby-boomers rapidly moving in the direction of "old age". The group of 65+ will presumably grow at a rate much faster than the total population over the next decades. This demographic change forces the age-care sector to a radical rethink. The group of the so-called baby-boomers has higher demands, is more technologically-orientated and has more segmented and

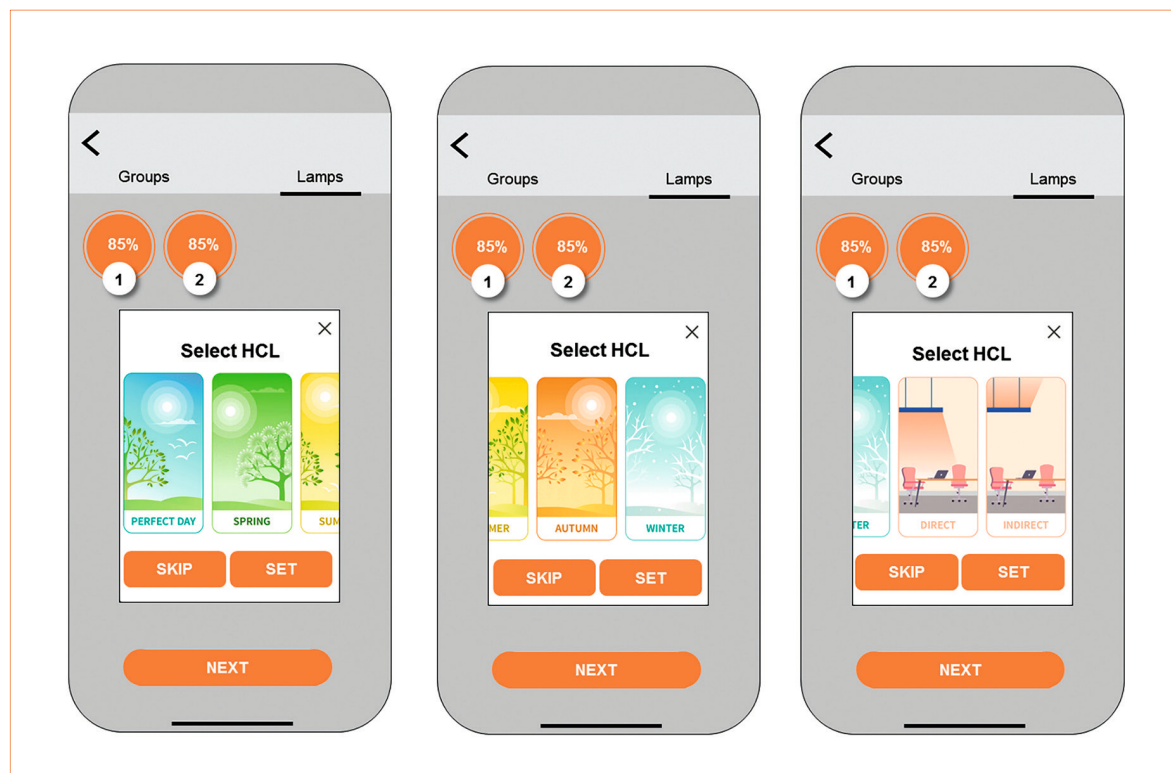
diversified needs respective of their demands than previous generations. To meet these claims, and to support and/or generate the advantages described above, authentic Human Centric Lighting, including a quite sophisticated control-architecture with the possibility of personal settings, lends itself to the following expected benefits under the aspect of general lighting in, for example, homes for the elderly:

### For residents

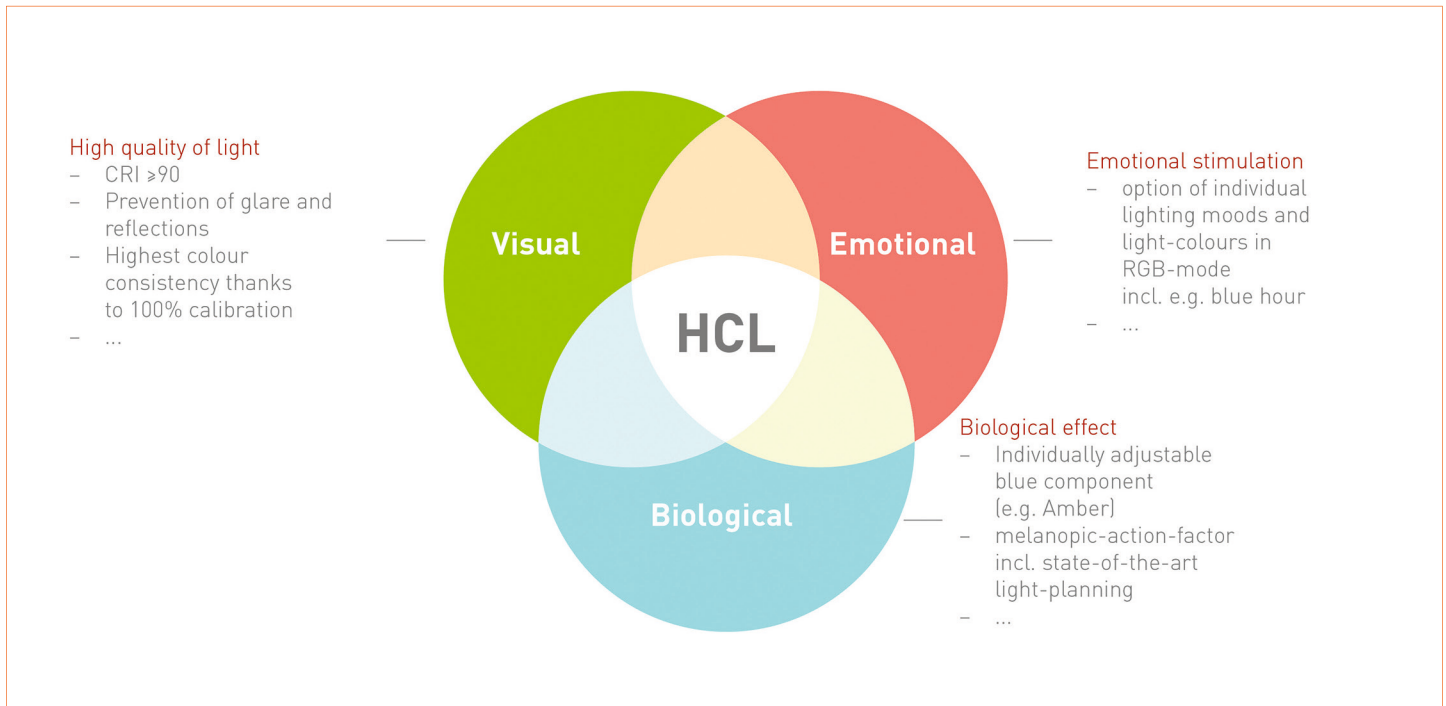
Elderly people suffer from permanent in-house stays: Better sleep at night and increased activity as well as enhanced social-communication during daytime can be observed. This results in higher activity, more socializing and communication.

Especially patients suffering from dementia, lack of a functioning circadian rhythm. In an early phase of dementia usually support of retriggering the "inner clock" [6]. Reactivation and better sleep at night could be triggered due to warm-white light, which presumably might lead to reduced medication.

Figure 5:  
Example for control [7]







### For the staff

Appropriate illumination leads to a reduced stress-level and with a tendency towards less illness.

### For the owner

On the one hand better performance of employees as well as less staff shortage due

to illness, and on the other hand, satisfied patients.

### Conclusion

Authentic Human Centric Lighting fulfills the visual and the biological as well as the emotional aspect and supports and facilitates the long-term health, well-being and

performance of human beings. Certainly, this is especially important in health and care applications. Based on a holistic light-design there is a high potential that can benefit all human beings. ■

**Figure 6:**  
Three pillars of Human Centric Lighting [7]

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- [1] The effect of high correlated color temperature office lighting on employee wellbeing and work performance © Mills et al; licensee BioMed Central Ltd. Peter R. Mills, Susannah C Tomkins and Luc JM Schlangen
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