LEDMOTIVE

Turn on the future

Natural and dynamic illumination with multispectral LED technology for OFFICES and 24H ROOMS

Contents

1. Introduction

LEDMOTIVE offers an intelligent lighting system, versatile and with the highest quality through the combination of multiple LED channels, allowing to obtain **any light spectrum** in the visible range. This light can be adapted to people's needs, influencing both in the visual response to light as well as in the **non-visual response**, to improve mood and boost the feeling of well-being for a greater concentration or to focus better to mention few examples.

Wide scientific evidence demonstrates the **significant impact daylight has over humans** (production/suppression melatonin hormone, immune system, Vitamin-D generation, performance, perception around us…). The biological impact varies depending on the type of illumination we are exposed to (natural and/or artificial light).

The NEW multispectral lighting solution by LEDMOTIVE allows to illuminate a closed space with the most natural light possible, creating an ambient that favors the level of concentration during work periods, **increasing productivity and reducing errors due to fatigue**, while at the same time providing the non-visible benefits of light in the health of people subject to shift changes (such as 24-hour room workers).

Furthermore, the system facilitates **the complete removal of blue light** when being necessary to avoid potential ocular hazards due to blue light as well as **to improve the rest** of shift employees avoiding the suppression of melatonin.

This allows to illuminate a closed space area considering the needs of the people who are in it and the **economic and environmental impact**

The developed control software allows programming the luminaires to emit any light spectrum, to adapt future's needs with simple modification of commands and without changing the whole fixture installation.

Based on this peculiarity, the lighting system can be used, once integrated in the Building Management System (BMS) as an **illumination and signalization system** in case an event or alarm is produced

*"LEDMOTIVE allows to translate the **dynamism of natural daylight in a corporation environment** increasing the feeling of well-being and providing an adequate atmosphere to improve productivity, comfort and/or concentration".*

2. Scientific and technological justification

2.1 Human Centric Lighting

LED technology is breaking into the lighting market thanks to its low consumption, high light output, long life and use of non-polluting materials. Given its great modulation capabilities, LEDMOTIVE has developed a disruptive technology to offer a light source with the **highest illumination quality**, far superior to the current available white LED, static of dynamic, commercially available. Our company, leader in the spectral reproduction, offers a holistic solution in the lighting industry known as Human Centric Lighting (HCL), centered 100% around humans

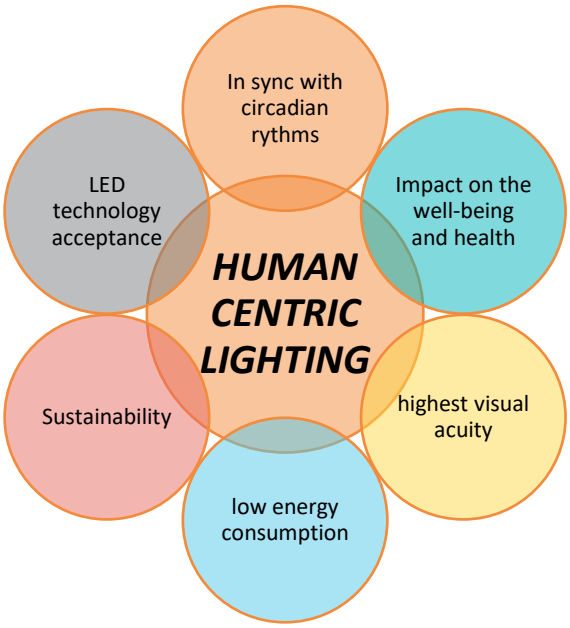

Figure 1. Human Centric Lighting

Sunlight or daylight is the most natural light possible for human beings. We have evolved with it and our biology is being governed by its daily circle. But, what properties does this type of light have?

Sunlight is a radiation characterized by a curve called spectrum:

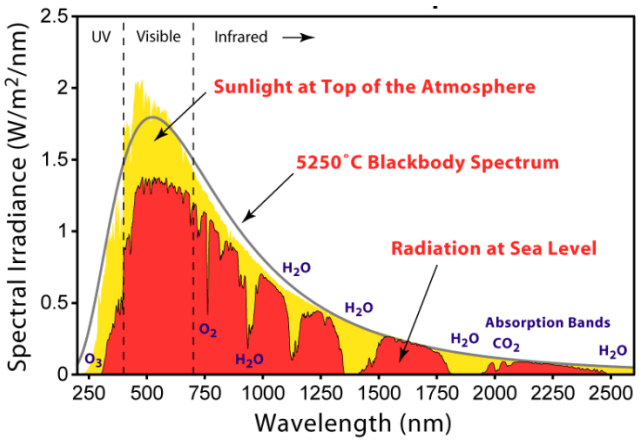

Figure 2. Spectral radiation

The interaction of sunlight with the atmosphere (depending of the sun height from the horizon and light dispersion in the air) modifies the solar spectrum throughout the day observed on earth. For instance, we observe a white light at noon but a more reddish light at sunset or dawn.

In summary, the **spectral composition of sunlight changes throughout the day and our biology has evolved with it as well**. Depending on the time of the day, our body prepares for different biological process. But, **what makes the light spectrum so important?**

According to recent research, our eyes contain a different photoreceptor cell to the well-known con and rod cell (responsible of the visual path to capture colors and the shape of objects around us) whose information is processed in a different part of the brain. This photoreceptor is called Intrinsically Photosensitive-Retinal Ganglion Cell (IP-RGC). It has a unique spectral sensitivity and is **responsible for the non-visual path** on the biological system and the **circadian rhythms**[1].

A solution proposed by LEDMOTIVE offers a **dynamic, versatile and illumination with a highest quality** through the combination of multiple LED channels to **re-create any light spectrum in the visible range**.
This type of light can be adapted to people's needs influencing both on the visual and non-visual response to improve well-being, mood and productivity, offering a **more comfortable and healthy environment**, especially critical in working areas such as **24h control rooms**

Color Coordinates (x,y), Correlated Color Temperature (CCT), Color Rendering Index (CRI) and illuminance (lux) are generic terms to describe light properties when trying to illuminate in space. They work well to describe basic properties of light and the professionals in the lighting industry are familiar with them, nevertheless those are simplifications of a much more complex process. When there are physical and biological processes involved as a response of a **non-visual stimulus**, is necessary to work and talk in terms of a **light spectrum**.

Several scientific studies have shown that **the light spectrum can be optimized to change the state of alertness and mood** as a function of the time of the day and the task to carry. Biosensors detecting heart rate and body temperature can measure responses to changes in light so quantitative data has been measured to analyze the impact of light in humans.

[1] https://en.wikipedia.org/wiki/Intrinsically_photosensitive_retinal_ganglion_cells

Finally, it is well known that **blue light**[2] (embedded in most of the electronic devices containing LED as back-lighting illumination such as mobiles and tablets) may have a **harmful** effect on our health. Not only they can cause eye disorders resulting from prolonged exposure to blue-ultraviolet light, but also disorders in our circadian cycle.

As an example, we cite several references in this field:

- Impact of light over the production of melatonin, the hormone that helps to fall asleep and regulates our circadian rhythms: [3], [4], [5], [6]
- Impact of light over mood and how circadian rhythms contribute to our health and well-being: [7], [8], [9], [10], [11], [12]

It's important to highlight that the **Medicine Nobel Laureate 2017** was awarded to the North Americans Jeffrey C. Hall, Michael Rosbash and Michael W. Young for their discoveries on the molecular mechanisms controlling the circadian rhythm.

The award-winners were able to explain how plants, animals and humans have adapted their biological rhythm to synchronize it with earth's rotation, known as the **biological clock**. This is applicable to the jet-lag produced by transoceanic flights as well as the chlorophyll function of plants. The clock adapts the physiology drastically to the circadian rhythm, regulating hormone levels, body temperature or metabolism.

---

[2] http://www.pointsdevue.com/article/blue-light-scientific-evidence-patient-care

[3] Santhi N, Thorne HC, van der Veen DR, Johnsen S, Mills SL, Hommes V, Schlangen LJM, Archer SN, Dijk DJ (2011) *The spectral composition of evening light and individual differences in the suppression of melatonin and delay of sleep in humans*. J Pineal Res 53: 47-59. 10.1111/j.1600-079X.2011.00970

[4] Mishima K, Okawa M, Shimizu T, Hishikawa Y (2001) *Diminished melatonin secretion in the elderly caused by insufficient environmental illumination*. J Clin Endocrinol Metab 86: 129-134

[5] Czeisler CA, Shanahan TL, Klerman EB, Martens H, Brotman DJ, Emens JS, Klein T, Rizzo JF, III (1995) *Suppression of melatonin secretion in some blind patients by exposure to bright light*. N Engl J Med 332:6-11

[6] J. M. Zeitzer, D. J. Dijk, R. Kronauer, E. Brown, and C. Czeisler. *Sensitivity of the human circadian pacemaker to nocturnal light: melatonin phase resetting and suppression.* J. Physiol 526 Pt 3:695-702, 2000

[7] T. Partonen and J. Lonnqvist. *Bright light improves vitality and alleviates distress in healthy people*. J. Affect.Disord. 57 (1-3):55-61, 2000

[8] G. W. Lambert, C. Reid, D. M. Kaye, G. L. Jennings, and M. D. Esler. *Effect of sunlight and season on serotonin turnover in the brain*. Lancet 360 (9348):1840-1842, 2002

[9] M. Aan Het Rot, D. S. Moskowitz, and S. N. Young. *Exposure to bright light is associated with positive social interaction and good mood over short time periods: A naturalistic study in mildly seasonal people*. J Psychiatr. Res, 2007

[10] A. Tuunainen, D. F. Kripke, and T. Endo. *Light therapy for non-seasonal depression*. Cochrane. Database.Syst.Rev. (2): CD004050, 2004

[11] R. N. Golden, B. N. Gaynes, R. D. Ekstrom, R. M. Hamer, F. M. Jacobsen, T. Suppes, K. L. Wisner, and C. B. Nemeroff. *The efficacy of light therapy in the treatment of mood disorders: a review and meta-analysis of the evidence*. Am.J. Psychiatry 162 (4):656-662, 2005

[12] A. Wirz-Justice, F. Benedetti, and M. Terman. *Chronotherapeutics for Affective Disorders: A Clinician's Manual for Light and Wake Therapy*, Basel:Karger, 2009

2.2 Illumination for the circadian rhythm

The metric Circadian Stimulus (CS), developed by researchers from the *Lighting Research Center*[13] is used to assess the effectiveness of a light source for stimulating the circadian system by measuring the suppression of the body's production of melatonin resulting from exposure to that source.

The following figure shows the absolute sensitivity of the human circadian system plotted as a function of light level, where the spectral power distributions (SPD) of various light sources used in previous studies are weighted according to circadian light (CL_A), as seen on the x-axis. The y-axis on the right, labeled circadian stimulus (CS), is scaled to be proportional to the y-axis on the left, which shows the amount of melatonin suppressed after exposing the retina for 1 hour, ranging from 0.1 (no measurable suppression) to a maximum of 0.7 (70% suppression).

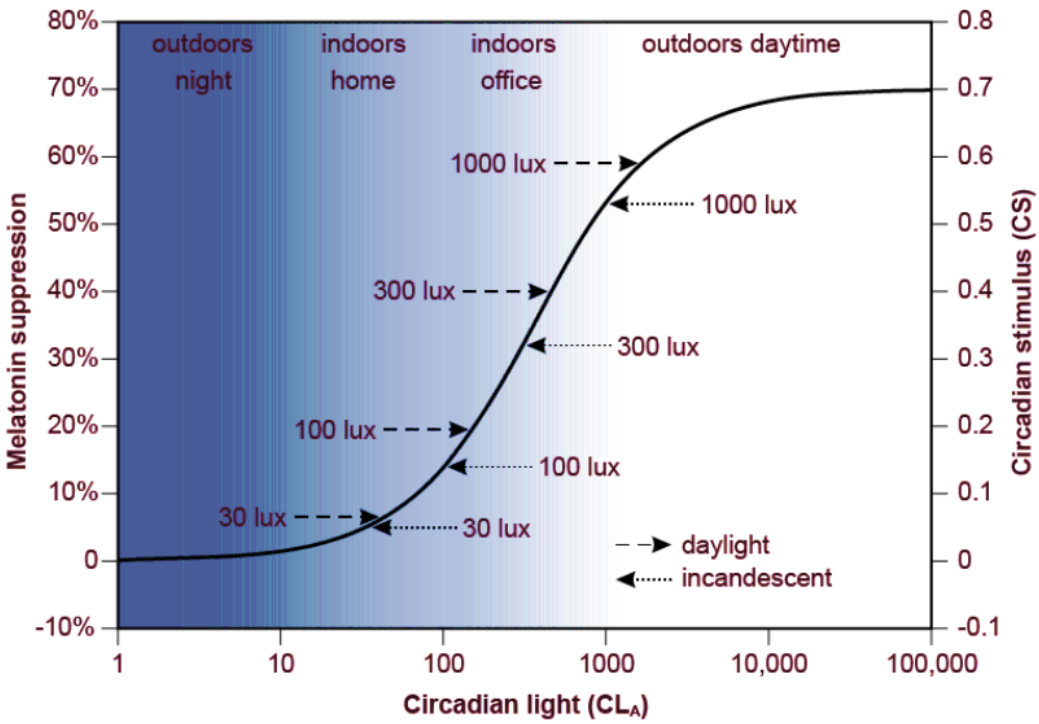

Figure 3. Sensitivity of a human circadian system

Several previous studies employing the CS metric and involving diverse populations have shown that exposure to high levels of circadian-effective light (CS > 0.30) during the day, particularly at the beginning of the workday, is associated with **improved sleep quality, mood**, synchronization of circadian rhythms to a 24h pattern as well as **greater**

[13] http://www.lrc.rpi.edu/

subjective and objective alertness. People who receive morning CS ≤ 0.10, on the other hand, are unlikely to be well synchronized to the natural day–night cycle and the various schedules that are associated with everyday life[14].

In a close and windowless area, a static lighting system using a light source with a CCT of 4000K would require an average illuminance of 400 lux to reach a CS target of 0.3. A light source with a CCT of 5000 K able to provide 300 lux to the eye level (not direct light) would deliver a CS=0.3 while another light source with shorter wavelengths (for instance high content of 460 nm) it would only require on average 50 lux to reach a CS=0.4. In this sense, the use of a spectral adjustment system offers much more flexibility and prevents potentially harmful retinal exposures[15].

Therefore, when we talk about a **spectral light control system**, such as the LEDMOTIVE system, the **impact on the circadian rhythm stimulus (CS)** is **maximized**, obtaining much more beneficial results for the same (or even lower) levels of photopic illumination.

[14] http://www.lrc.rpi.edu/
[15] http://lightingpatternsforhealthybuildings.org/content/20

2.3 Scientific results using the LEDMOTIVE module

Below are some of the **scientific results after using LEDMOTIVE LED modules** and their favorable effects to **control the circadian rhythms** in humans during the **Hi-LED Project** (http://www.hi-led.eu) **funded by the European Commission with a budget of 5M€**:

- **Institute of Neuroscience** (**INN**), research center linked to the Newcastle University. The INN has been using during the whole project for 3 years[16] the LED modules manufactured by LEDMOTIVE. They have **demonstrated, using our multispectral light source, that the alertness levels, performance and mood can be adjusted depending on the time of the day and task requirements**. Through a series of wireless biosensors, it has been possible to monitor the physiological state of people (such as melatonin levels in saliva, heart rate, cardiac variability and body temperature) to find the light spectrum that maximizes or minimizes these parameters related to circadian rhythms.

- More specifically, what has been shown is the ability to **selectively stimulate the visual and non-visual pathway** by changing the light spectrum in real time. The non-visual pathway responds better to light for short wavelengths, through melanopsin, a photopigment expressed by intrinsically photosensitive retinal ganglion cells (iP-RGC). The levels of perceived light intensity and its chromaticity ("color") are determined by photoreceptors called cones. The INN has developed methods to generate variable light spectra with LEDMOTIVE luminaires, which allow us to compensate for the quantities and effects of non-visual ("melanopic") and visual ("photopic") illumination.

- The INN has shown that:
  - ✓ "Blue" light of a narrow bandwidth, at low photopic illumination intensity, suppresses the levels of melatonin with the same effectiveness as a "white" light of a wide bandwidth with the same melanopic illumination intensity but with a higher photopic illumination.
  - ✓ "Cold" white light of a wide bandwidth suppresses the levels of melatonin more effectively than a "warm" white light with the same photopic intensity.
  - ✓ White light suppresses subjective drowsiness as effectively as "blue" light that contains the same melanopic intensity and much more effective than "warm" light. Despite "blue" and "warm" light suppresses melatonin and reduces drowsiness, the effects associated with fatigue don't

[16] Research carried out by Group from the director of the INN in Newcastle (UK), Prof. Dr. Anya Hurlbert, http://www.ncl.ac.uk/ion/staff/profile/anyahurlbert.html#background

"The impact of illumination (and above all, of a spectrally tunable light) will soon have an important role in the design process of a light source that, until now, has been based solely in terms of energy efficiency. It will not only benefit humans, but the return of investment will be compensated in terms of welfare and productivity by a wide margin."

diminish nor they don't seem to improve performance when completing the tasks proposed to the study subjects. In contrast, "warm" light increases performance in visual attention tasks. "Warm" light, of low melanopic intensity but high photopic is also considered more pleasant than the "blue" light. In this way, it is recommended that, at nightfall, mood and visual performance are being prioritized, while melatonin levels increase naturally using a "warm" light with high photopic intensity, but with a low melanopic intensity.

- Finally, the INN has shown that the LEDMOTIVE luminaires can be used in "feedback" mode, together with a series of biosensors and actigraphy monitoring human rest/activity cycles. It has also been demonstrated that changes in the spectral content of light can be activated automatically when warning alert levels drops and these changes in photopic or melanopic intensities serve to regulate alertness.

- **Conclusion**: the use of **LEDMOTIVE** technology in a highly demanding environment **allows for the modulation of the circadian cycle**, as well as other parameters associated with productivity and alertness **of people**.

To summarize, we can say that LEDMOTIVE offers a **dynamical, versatile and very high-quality lighting system, by means of the combination of multiple LED channels** allowing to produce **any light spectra in the visible range**. This light can be adapted to people's needs to affect both the visual and non-visual pathways to improve mood and increase the sense of well-being to reach a better concentration and comfort, for instance in **working spaces with an absence of natural daylight** or **24h control rooms**.

The new LEDMOTIVE lighting system can reproduce natural daylight, including (or emulating) its changes throughout the day. This light favors the level of concentration during the job, to boost productivity and decrease errors due to fatigue. Furthermore, it supplies the unseen health benefits from light to people under shift working conditions (such as employees in 24h control rooms).

3. System dimensioning

3.1 Light design

To optimize the proposed solution, it is necessary to know different items in the installation such as room(s) dimensions and its limitations due to other types of existing installed equipment like air ducts or machinery to mention few. Furniture distribution and how it's being used and the existence (or lack of) daylight in the room are other type of parameters that should be taken into consideration.

By means of this information and following the recommendations set by the international norms, LEDMOTIVE design team can analyze and propose the **best solution in terms of functional use, costs and environmental impact.**

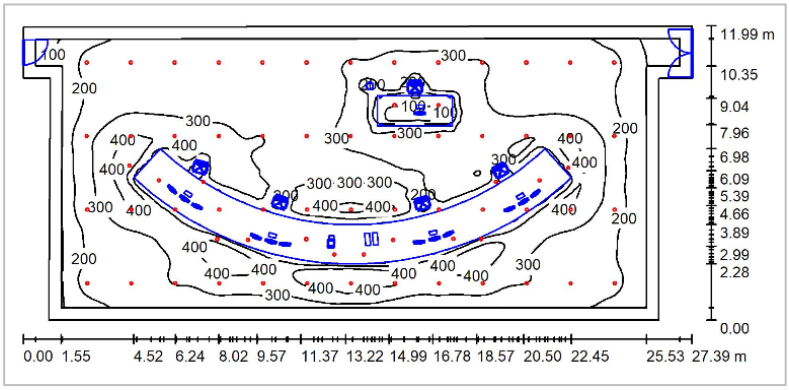

Figure 4. Example of a 24h control room

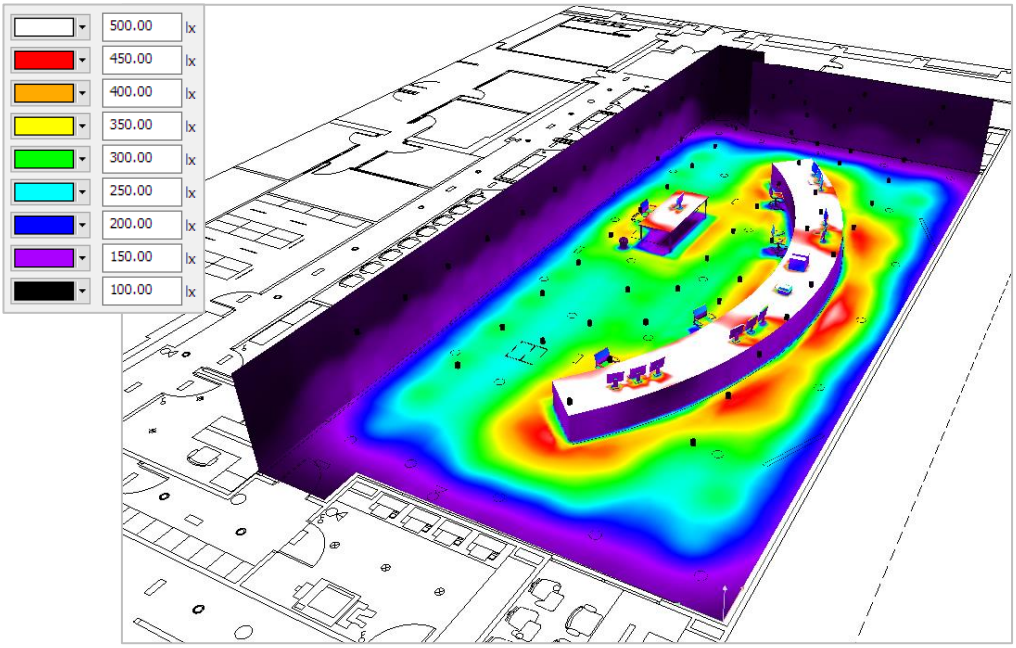

Figure 5. Example of a 24h control room

3.2 Functional design

In the same way, by analyzing the requirements and the functional usage of a room and the people in it, LEDMOTIVE can advise and adapt the solution to modify the luminous flux, the spectral content of light or both to offer the most appropriate illumination at every time of the day, giving control and full flexibility to the users on a regular basis.

As an example, in a 24h control room as shown previously, a lighting sequence could be programmed, for the circadian cycle, oscillating between a spectrum corresponding to a CCT of **2700K** and **5500K** in shifts of 8 and/or 12 hours to emulate the sunlight oscillations during a day. Luminous flux could be kept as a dynamic variable, being more intense coinciding with the highest CCT or the central hours of the day as it happens with natural daylight.

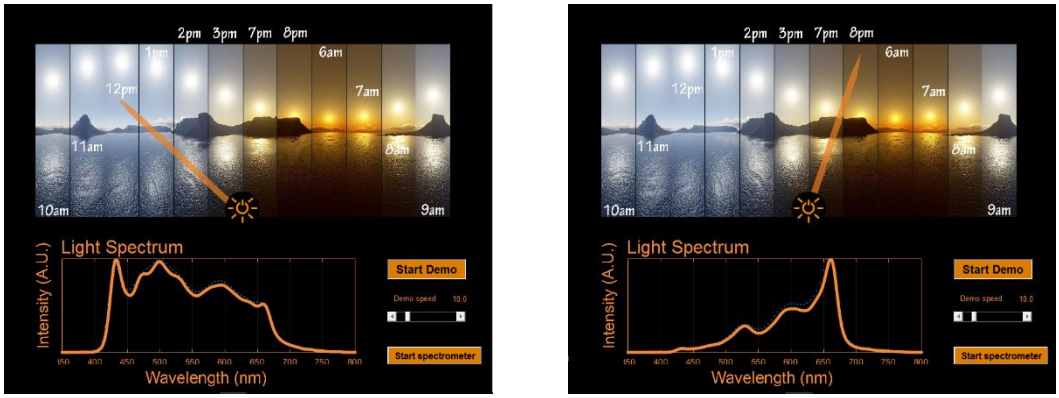

Figure 6. Light spectrum adapted to the circadian cycle

3.3 Architecture

The lighting system consist of a LED module(s) with spectral tunability and a **communications LIGHT HUB device** design and manufactured by LEDMOTIVE. Additionally, **manual controls and signaling lights** can be connected to a LIGHT HUB, using standard market protocols or **using the lighting system itself as a signalization** in certain scenarios.

The system allows to access each LED module embedded in a luminaire from any device, fixed or mobile, connected to the Internet through a *Web App*.

An example of a distribution and schematics of the connections are shown in the following figure:

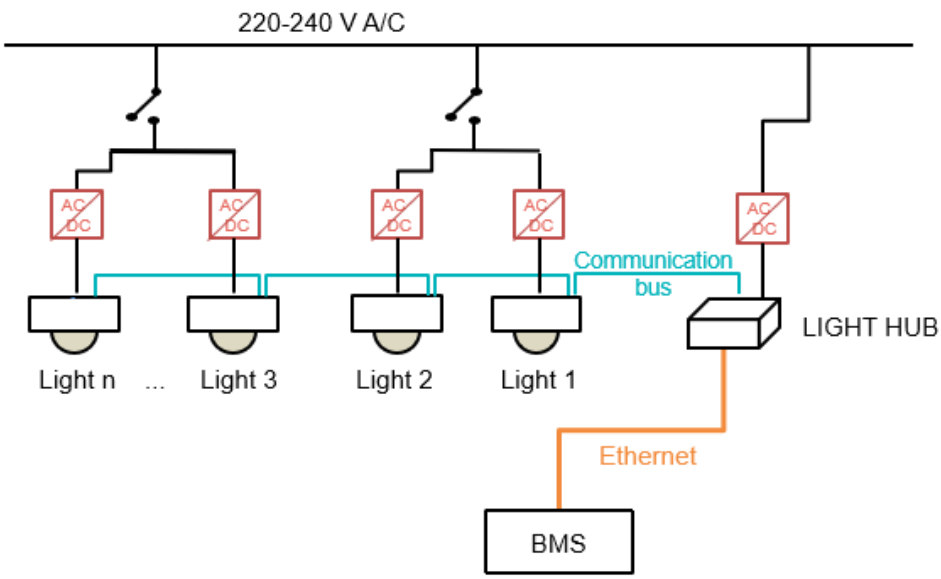

Figure 7. Schematics of the connections to a Building Management System(BMS)

3.4 Main LEDMOTIVE lighting features

The LEDMOTIVE system combines 7 different LED color channels to produce any light spectrum in the visible range. Here are some of its main features:

- **No infrared radiation:** < 5mW/nm in the NIR (780-1400nm). A higher radiation could contribute to the proliferation of bacteria.
- **No ultraviolet radiation:** < 3mW/nm in the UVA (315-380nm). A higher radiation could contribute to the degradation of materials or substances.
- **Independent control of power and color temperature:** thus, it is possible to adjust de level of illumination so that at any color light is always perceived as white(pleasing), to avoid surpassing *Kruithof curve* (where light appears too bluish or reddish)

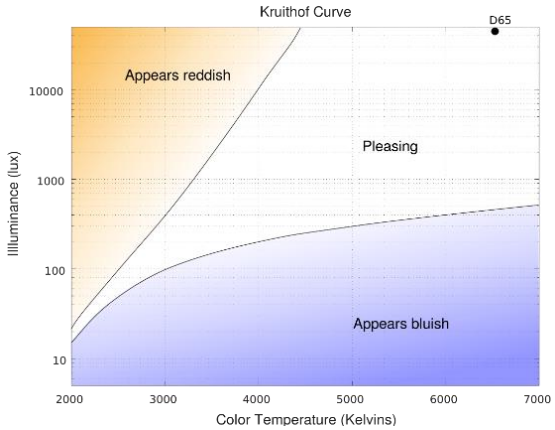

Figure 8. Kruithof curve

- **No flickering:** different LED color channels regulation is carried out at a high frequency to avoid the effect of flickering, which otherwise, could cause discomfort such as fatigue, migraine, photosensitivity and even epileptic attacks.
- **High color accuracy:** The combination of all seven channels avoids of having gaps in the visible spectrum not being covered, assuring a complete color consistency and an illumination with the highest possible quality, reaching a color rendering index close to its 100-max value for any color temperature.
- **Automatic degradation correction** of the spectrum: A closed-feedback loop corrects automatically any spectral degradation due to a temperature fluctuation or ageing of the LEDs.

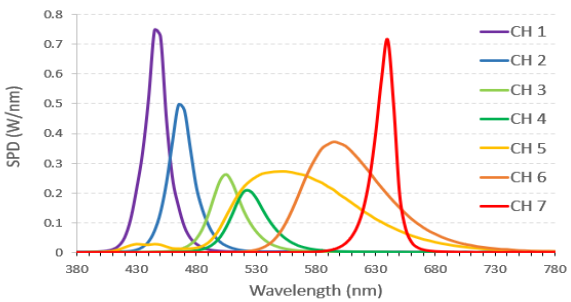

Figura9. LED channels characterization

4. Contact

If you would like to know more details and incorporate the most advanced ***Human Centric Lighting*** system, please contact us and we will advise.

LEDMOTIVE VEGA 07 module responsible for providing an SPECTRALLY TUNABLE LIGHT

Ledmotive Technologies, S.L.
C/ Joan Comorera 8-12, Local 15, Escalera H.
08030. Barcelona, Spain
T. (+34) 934.884.890
www.ledmotive.com
sales@ledmotive.com