www.led-professional.com

ISSN 1993-890X

LED professional Review

LpR

The Global Information Hub for Lighting Technologies

Jan/Feb 2019 | Issue 71

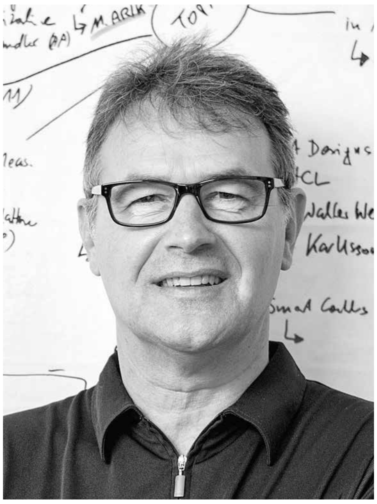
Interview: Octavio Perez

Research: Medical & Human Centric Lighting

Technologies: Voice Control & Advanced LEDs

Special Topics: Healthy Light & Blue Light Issues


REYNOLDS COLISEUM
ACC
CREE® XLAMP® LEDs
CREE® HIGH-BRIGHTNESS LEDs
CREE® J SERIES™ LEDs
BARRIER-BREAKING, GAME-CHANGING, INDUSTRY-LEADING—WE MAY RUN OUT OF ADJECTIVES, BUT
WE'LL NEVER RUN OUT OF INNOVATION
SEE THE COMPLETE PORTFOLIO AT: CREE.COM/LED-COMPONENTS
CREE



Triggering Innovation

We all know that the lighting sector is subject to enormous transformation and this is what came to mind when I recently watched a documentary film about the automobile manufacturer, Borgward. Even though Borgward's products were innovative, creative and unique, the company ended up having to lay off over 20,000 employees. The major problem seems to have been the large variety of models. The founder was constantly expanding the product range with new ideas. And this is where I saw an important connection between Borgward and the lighting industry. Having a variety of types is expensive, and, as we see in other industries, the key to a solution lies in platforms and modular concepts.

For more than a year now, we have been working in a consortium that deals with this topic. Repro-Light is a project sponsored by the EU that aims to generate new impulses for the lighting industry. Together with the SciPIL network (a combination of leading scientific organizations and the lighting industry), we work toward creating new innovations. What we have to keep in mind is the cost structures, type diversity and effectiveness in production – a lesson we have learned from Borgward. These things are just as important as technological advances for the progress of industries.

Developments can be seen in new fields of application, especially in the field of Human Centric Lighting. This issue of LED professional Review looks into how HCL is a trigger for light innovations. It also delves into our need for more and deeper knowledge about the effectiveness of HCL.

I think you'll find it an interesting read.

Yours Sincerely,

Siegfried Luger
Publisher, LED professional

COMMENTARY

08 Well-Being, Light and Exhibition Lighting
by Prof. Dario Camuffo, Polytechnic of Milan & Tech. Committee for Cultural Heritage

TECH-TALKS BREGENZ

32 Dr. Octavio Perez, Adjunctant Researcher, Mt. Sinai Hospital
compiled by Dr. Guenther Sejkora, LED professional

RESEARCH

40 Implications for Human-Centric Lighting Design in Tropical Nursing Homes: A Pilot Study
by Dr. Szu-Cheng Chien, Singapore Institute of Technology

48 Flex LED Based Smart Light System for Healing of Chronic Wounds
by David Kallweit, CSEM

TECHNOLOGIES

54 Voice Controlled Lighting that Protects Privacy and Data
by Genia Shipova, Snips

58 Circadian-Friendly Light Emitters: From CCT-Tuning to Blue-Free Technology
by Aurelien David, Soraa

64 Technical Progress Improves Efficacy of Green LEDs by 40%
by Dr. J.-P. Ahl & Dr. A. Bauer, Osram Opto Semiconductors

SPECIAL TOPICS

68 Healthy Light - LED Technology for Health and Care Applications
by Peter Haumer, Lumitech/Kiteo

74 Melanopic Green - The Other Side of Blue
by P. Eng. (Ret.) Ian Ashdown, SunTracker Technologies

REGULARS

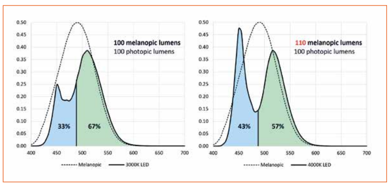
04 EDITORIAL
08 COMMENTARY
10 PRODUCT NEWS
20 APPLICATION NEWS
24 RESEARCH NEWS
26 REGULATION NEWS
28 CIE RESEARCH
30 ORGANIZATION NEWS

66 ABOUT | IMPRINT

HIGHLIGHTS

40 Implications for Human-Centric Lighting Design in Tropical Nursing Homes: A Pilot Study
by Dr. Szu-Cheng Chien, Singapore Institute of Technology

74 Melanopic Green - The Other Side of Blue
by P. Eng. (Ret.) Ian Ashdown, SunTracker Technologies



ADVERTISING INDEX

FLS-SIGNIFY	1	M.A.L. EFFEKT TECHNIK	12	INSTRUMENT SYSTEMS	39
CREE	2	M.A.L. EFFEKT TECHNIK	15	CREE	53
TAIWAN INT. LIGHTING SHOW	3	HEP	19	GRE ALPHA ELECTRONICS	63
EVONIK	5	GUANGZHOU INT. LIGHTING EXHIBITION	21	TIL	77
FLS-SIGNIFY	7	TOPLITE INTERNATIONAL	23	LPR	79
LPS	9	FORUM LED EUROPE	27	WÜRTH	80

Philips Advance Xitanium LED Drivers with ComfortFade

50W (XI050C140V054PST1)

Features & Benefits

- ComfortFade Technology for Smooth On-to-Off and Off-to-On Transitions
- Dim to Off Capability
- SimpleSet NFC based Programing
- 1% Min Dim
- 0-10V Dimming
- CSA, ETL, and UL Class P
- 50k hour Lifetime[1]
- 5-yr limited warranty

Applications

Indoor Linear

- Troffers
- Suspended
- Retrofit

75W, 40W, and 30W drivers will be introduced over a period of time into 2019

[1] Philips Advance Xitanium LED drivers are manufactured to engineering standards correlating to a designed and average life expectancy of 50,000 hours of operation at maximum rated case temperature. Minimum 90% survivals based on MTBF modeling.

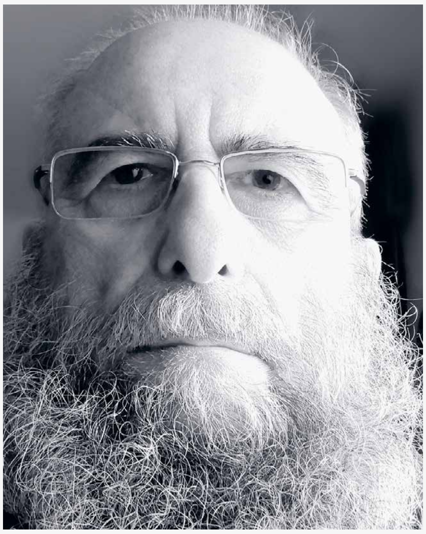
For up to date warranty information please go to http://www.usa.lighting.philips.com/support/support/warranty

FUTURE Lighting Solutions

Making LED Lighting Solutions Simple™

www.FutureLightingSolutions.com

signify



Dario Camuffo
Prof. Dario Camuffo is a Physicist, Emeritus Research Director at CNR and a specialist in atmospheric physics, climate, microclimate and the conservation of cultural heritage. He is a lecturer of Environmental Physics at the Polytechnic of Milan, and formerly at the University of Padua and Cignaroli Academy, Verona. He is an active member of the European Committee for Standardization (CEN), Technical Committee for Cultural Heritage (TC346), convener of the Working Groups on indoor/outdoor climate (WG7) and exhibition lighting (WG6). He has led 16 international research projects and published over 400 scientific papers. He has investigated several museums and monuments of the UNESCO World List of Cultural Heritage, including the Sistine Chapel, Rome.

WELL-BEING, LIGHT AND EXHIBITION LIGHTING

Well-being is the state of feeling healthy and happy, a good or satisfactory condition of existence, including the emotional and psychological sphere. In 1810, Goethe published a theory based on a human-based approach, combining visual appearance with harmony, culture, sensations and psychology. His color wheel was entitled “allegorical, symbolic, mystic use of color” and was composed of six hues, i.e. red (the beautiful), orange (the noble), yellow (the good), green (the useful), blue (the common) and violet (the unnecessary). The position on the wheel was harmonically relevant and, in particular, the colors in opposite positions generated a strong psychological contrast and were called “opposite colors”. Primary colors were yellow, blue and red, and the opposites were green, violet and orange, respectively. Goethe’s wheel and the particular matching of opposites soon became popular and was used by the Impressionism movement, especially by Vincent van Gogh and Claude Monet. In this artistic movement, the special impact given by the combination of opposite colors were deliberately aimed to create special psychological effects and sensations.

No doubt that one of the most appealing satisfactions of life is the enjoyment of cultural heritage. However, visual arts require sustainable lighting, because several materials are light sensitive, e.g. silk and most textiles, prints and drawings with fugitive colorants, most graphic and photographic documents, watercolors, manuscripts, botanical specimens and many others. The main deterioration mechanisms caused by light are: color fading, photochemical degradation, radiation heating effects, and growth of biological organisms. The first two mechanisms are especially due to ultraviolet (UV) and the shortest wavelengths (i.e. violet and blue). Heating implies moisture loss and shrinkage, air motions and deposition of airborne particles, and is especially due to incandescent lamps. The halogen lamp that is particularly appreciated in museums and galleries for its high color-rendering index has the highest infrared (IR) emission and warming potential. Biological phototrophic organisms may require specific wavelengths: for instance, cyanobacteria, algae and other chlorophyll based organisms need light bands in the blue and orange-red part of the spectrum.

In museums and galleries, the choice of lamps should not only be based on the best enjoyment, using lamps with the highest color rendering, but should be primarily oriented to conservation (to damage artworks is forbidden by law) and then to enjoyment. In the real world, a reasonable compromise between the two needs is necessary, by limiting the illuminance (i.e. the light intensity in lux) and the annual exposure time (i.e. the number of hours) in order to stay below a sustainable threshold of annual luminous exposure.

Incandescent bulbs are much less efficient than other types of electric lighting and, in several countries they have been replaced with other types of more sustainable lamps. The most popular among the recent light sources are LEDs (Light Emitting Diodes). The light emitted by a warm white LED is visually cold, because it has a peak on blue and is defective in the orange-red band of the spectrum. When a fresco is lighted with LED light, the color of lapis lazuli in the sky and the vests of the Virgin become much too saturated, vivid and sparkling, and need attenuation. However, this light source has other attractive performances that justify efforts to improve the color rendering. The Sistine Chapel, Rome, has been lighted with a combination of 7000 LEDs, the majority of which are warm white, and others selected in order to dampen the blue peak with the complementary color (i.e. yellow), and to enhance the red band. Another methodology to improve LED’s color rendering is to use colored filters.

The most recent sources are OLEDs (Organic Light Emitting Diodes) that are light emitting panels made from organic (carbon based) materials. They are flexible and their light is diffuse. They have a high potential in exhibition lighting, because they could stay inside showcases without overheating them; they could adapt to niches or surround the specific shape of objects, generating diffuse light without shadows. However, they are the last-born and need to grow in the every-day experience to make known their pros and find a solution for their cons, if cons are found in this particular field of application. ■

D.C.

New LUXEON SunPlus 2835 Line Is Designed To Maximize Crop Yield

Lumileds today introduced the LUXEON SunPlus 2835 Line of LEDs, which provide the color options and high photosynthetic photon flux (PPF) needed to maximize plant growth rate and crop yield of a variety of plants and vegetables. Growers can select specific color points or design a customized spectrum using the industry's only LEDs specifically engineered for horticulture applications. The LED's compact 2.8x3.5 mm footprint allows minimal spacing between plants and lighting so that higher crop yield can be realized in interweaving canopy or vertical farm applications. The LEDs are offered off-the-shelf or configured in the Lumileds Matrix Platform for faster time to market of lighting fixtures.

LUXEON SunPlus 2835 Series LEDs enable faster plant growth and greater crop yield

Growers can choose a specific color point using LUXEON SunPlus 2835 Purple or Horticulture White LEDs, or design a spectrum using the LUXEON SunPlus 2835 Deep Red, Far Red, Lime and Royal Blue emitters.

Horticulture White provides an ideal broad spectrum for growing many different crops. In tests, Horticulture White produced red leaf lettuce with significantly greater nutrient levels than RGB LEDs.

LUXEON SunPlus Purple LEDs are made with a customized phosphor solution designed to provide the maximum PPF output in the Deep Red and Royal Blue range of the spectrum.

"We are seeing great demand for Purple LEDs in vertical farms. When the Purple LEDs are combined with Lime, a white color point is achieved, enabling ease of visual inspection and harvest," said Jennifer Holland, Product Line Director at Lumileds.

The LUXEON SunPlus 2835 Series LEDs solve an industry challenge by matching polarity across all of the colors in the product range. This simplifies the PCB layout and system design. Emitters are binned at 120 mA (25°C) but can be driven at up to 480 mA for greater lumen output and fewer LEDs per fixture. Lumileds is the only supplier that bins all its horticultural LEDs by PPF. ■

Luminus' Gen 4 COBs - 70 Watt Metal Halide Spotlight Meets Its Match

Luminus Devices has released its fourth generation chip-on-board LED technology (Gen 4) that will open new opportunities in retail lighting as well as a wide range of indoor and outdoor lighting applications. Luminus Gen 4 COB technology combines significant improvements in efficacy, flux density, high maximum drive current, and high-temperature capability to enable breakthrough changes in form factor for luminaire makers.

Visitors at Light + Building saw first-hand how Luminus' Gen 4 COBs delivered illumination comparable to the 70 Watt metal halide lamps and how quality and efficacy improved from Gen 1 to Gen 4 (pay attention to the heat sink dimensions in the image)

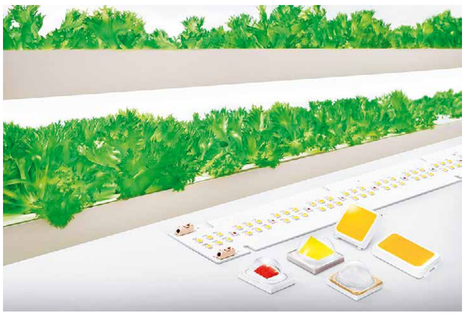
With Luminus' Gen 4 COBs, it is possible for an LED to deliver the output and punch of a 70 Watt ceramic metal halide lamp in an identical form factor. Luminus has eliminated the barriers that, until now, had required LED luminaires with comparable center beam candlepower to be larger than the incumbent CMH technology.

"We've seen LED replacements for lower wattage CMH lamps, but we're finally able to displace the 70W lamp which has been the go-to choice of many retail lighting designers when they need a narrow beam spot to make the merchandise sparkle," said Tom Jory, VP of Illumination at Luminus. "Only Luminus Gen 4 COBs enable small form factor fixtures with the punch of 70 Watt CMH in combination with our unique spectral tuning technologies AccuWhite™ and Sensus™."

Unique to Luminus Gen 4 COBs are the very high operating temperature of 120°C and the capability to be overdriven at 3x the nominal current. The advances in this generation of LED technology enable the extended operating conditions while maintaining color performance over time and temperature with reliability and longevity. ■

Samsung Electronics Expands Horticulture LED Lineups

Samsung Electronics Co., Ltd., a world leader in advanced digital component solutions, today announced new horticulture LED lineups, including full-spectrum packages and modules as well as color (monochromatic) LEDs. Optimized for lighting in greenhouses and vertical farming*, the new LEDs provide a broader spectrum of light for healthier plant growth, enhanced farming environments and reduced lighting system costs.



Samsung's new horticulture LEDs are designed to promote healthier plant growth and enhance farming conditions for indoor growers

Full-spectrum light encompasses a continuous range of wavelengths from blue and green to red, creating a light blend suitable for horticultural uses. Compared to narrow spectrum lighting, Samsung's full-spectrum-based LEDs encourage healthier and more balanced plant growth by stimulating photosynthesis, enhancing plant immunity and increasing nutritional value. Additionally, the LEDs can help to improve the overall farming environment by enabling growers to observe plant conditions more easily and spot diseases, like damping-off, at an earlier

stage under bright white lighting.
As high-efficiency and cost-effective alternatives to higher-priced red LEDs, full-spectrum LEDs can help lower the costs of a grower's entire lighting system.

"Samsung's full-spectrum-based horticulture LEDs present a new way of using LED lighting to improve plant cultivation at reduced system costs," said Un Soo Kim, senior vice president of LED Business Team at Samsung Electronics. "We plan to further expand our horticulture offerings by integrating the latest in smart LED lighting technology, including Samsung's leading sensor and connectivity solutions."

In addition to its full-spectrum white LEDs, Samsung has added blue, red and far-red LEDs to its horticulture family to offer an extensive variety of wavelength combinations and meet the different design needs of horticulture lighting manufacturers.

Built on Samsung's market-proven LED technologies, the new full spectrum and color LED lineups feature a high degree of reliability, making them well-suited to withstand high temperatures and humidity levels as well as agricultural chemicals used in greenhouses and vertical farming.

Samsung's horticulture LED packages are now in mass production for lighting manufacturers and growers worldwide. The modules will become available in the first quarter of 2019.

Osram's New Long-Life LED for General Lighting - Osconiq S3030

Osconiq S3030 enables customers to build luminaires with optimum quality, extra-long life and exceptional robustness. The market for LED lighting is moving forward very fast and the demand for professional components with long lifetimes and extraordinary robustness is growing. In announcing the new professional Osconiq S3030, Osram Opto Semiconductors is successfully facing up to these challenges. These LEDs are state-of-the-art components designed to meet professional demands in various general lighting applications and characterized by long life, high performance and first-class reliability.

Osram's Osconiq S3030 LED is suitable for outdoor, indoor and industrial lighting applications

Osconiq S3030 is Osram's entry into the professional mid-power market. The LED is ideal for use in outdoor and industrial lighting. It offers customers LED lighting of the highest quality and great durability even in extreme operating conditions.
The individual components provide flexibility in forward voltage and luminous flux with an exceptional lifetime of 75,000 hours even at high temperatures. Together with an optimized phosphor, lead frame and chip design, the development of the Osconiq S3030 raises LED technology to a new level of performance with an impressive efficiency of 146 lm/W. The 0.2 W applications are especially suitable for linear lighting and fluorescent tube replacement. Overall, Osconiq S3030 achieves competitive values for reliability, lifetime and brightness.

"With Osconiq S3030 we have succeeded in developing an LED that is ideal for professional lighting solutions in outdoor, indoor and industrial applications", said Wong Kum Yih, Marketing Manager for General Lighting at Osram Opto Semiconductors. "With high-grade materials such as the proven Osram designed sapphire chip and robust silicone, we have taken the stability of LED lighting to the next level. In addition to outstanding lifetime values, our customers also benefit from superior quality and improved performance."

Osconiq S3030 is available in two versions (CRI 70 or 80) with a power rating of 1.0 W at 6 V and a luminous flux of 138 to 148 lm. The footprint of both versions is comparatively small at 3.0x3.0x3.0 mm. The color temperature ranges from 2,700 to 6,500 K. The beam angle of 120° and the extremely low thermal resistance of around 8.9 K/W make the LED ideal for outdoor lighting. In addition to the technical improvements, Osconiq S3030 features professional grade materials such as high-quality long-life packaging subcomponents and proprietary coatings. These materials have been validated by extensive robustness testing under extreme overload conditions. What's more, the EMC (epoxy molding compound) lead frame material provides the basis for much longer life and better reliability than conventional PPA and PCT materials.

Tridonic Spotlight and Downlight LED CoB Offer Improved Efficiency

Tridonic's seventh generation of SLE ADV modules benefits from a chip upgrade resulting in even greater efficiency, longer life time and improved thermal management – all with excellent color rendering. The modules are available with light-emitting surfaces of 9 to 15 mm (LES 9 to LES 15), with 17 and 21 mm variants set to follow soon.

The seventh generation of SLE modules impresses with, as yet, unequalled efficiency, excellent color rendering, high color consistency and the best temperature behavior

Tridonic is updating the portfolio of CoB modules for spotlights and downlights.
The seventh generation of SLE-ADV modules impresses with 14 percent greater efficiency, longer life time and improved, intelligent thermal management based on current CoB technology. Another hallmark of the series is the excellent color rendering. The dimmable modules cover color temperatures of 2,700, 3,000, 3,500 and 4,000 K. They achieve peak values at color temperatures of 3,000 K and 4,000 K: With an efficiency of 191 lm/W and CRI > 90, they demonstrate unequalled performance levels.

Higher luminous flux and excellent color quality:
The higher efficiency of the modules means that they require less power than before to deliver defined lumen values. Depending on the module size, the color temperature and the current flow, they can achieve a luminous

High Speed SMD Assembling
R&D Department
Light Laboratory
Customized & Unique Solutions
ISO Standards
After Sales Service
High Quality
m.a.l.®
modern.art.of.light.
Standard redefined.
iX-led Linearis – standard modules with top specifications
Order your sample now:
www.mal-effekt.de/sample
Made in Germany
m.a.l. Effekt Technik GmbH | Wiesenweg 6 | 36179 Bebra
Phone +49 (0) 6622 9133-0 | Mail info@mal-effekt.de

flux of up to 6,180 lm. In addition to the high luminous flux and excellent light quality, all modules also offer a high level of color consistency, which corresponds to MacAdam 3. They are compatible with various SELV constant current drivers from Tridonic, which are tailored to the modules, and allow many different lighting solutions. The SLE G7 ADV modules with the corresponding drivers demonstrate their flexibility and strengths in shops and exhibitions in particular, as well as in different areas of the hospitality sector.

For the time being, the module series covers the entire range of light-emitting surfaces from 9 to 15 mm. Versions with LES 13 and LES 15 will be available in future in a robust, new D50 housing, which guarantees an even more stable connection between the chip and the housing, and further improves thermal conductivity. ■

LG Innotek - "Nexlide-L" for Automotive Ultra-Slim Line Lamps

LG Innotek announced that it has developed "Nexlide-L", a line lighting module for automobiles. It emits bright and uniform light from the module's sharp line of 3 mm width. It is the thinnest width among automotive exterior lamps. Since the quality and mass production tests are already completed, the company can supply customized designs according to customer orders.

With "Nexlide-L", a 3 mm thin, sharp and uniform LED lamp, it is possible to match the shape, brightness and color of the lighting according to its use

Automotive lighting is an important device that reveals the identity of a car and determines its first impression. Lighting is an element that is newly designed whenever a new car is developed. It indicates a driver's intention to change direction or whether the brake is engaged, being directly linked with safety.

LG Innotek implemented its proprietary "LED lighting structure design technology" to realize the ultra-slim line lamp "Nexlide-L". This cutting-edge technology makes the original dot-shaped LED light shine uniformly in a line or plane shape.

"Nexlide-L" is good for improving the design completeness of an automobile. This is because the product produces the light that is uniformly bright from one end to the other end along a slim and smooth lighting line. In addition, according to the design concept, various shapes of lightings such as straight lines, curves, and waves can be made without limit.

The color and brightness of the product can be customized according to its application and mounting position. The lightings can be designed in a variety of ways to produce, for example, red light for brake lamps and center high mount stop lamp (CHMSL), yellow light for turn signal lamps and side-view mirror lamps, and white light for position lamps.

Especially, "Nexlide-L" has excellent luminous efficacy to give a bright light of 7,500 nit (cd/m^2). It can be used for a brake lamp because it fully meets the brightness the lamp requires.

LG Innotek has further expanded its automotive LED lighting lineup with the development of "Nexlide-L". The company has a total of 20 kinds of package lamp modules, including exterior LED lamps such as headlamps, daytime running lamps (DRLs), position lamps, turn signal lamps, side-view mirror lamps, tail lamps (brake lamps) and center high mount stop lamps (CHMSL) as well as interior lamps and dashboards.

The company plans to accelerate its efforts to conquer the global automotive LED market with the development of "Nexlide-L". The company is already ready to supply LED lamp modules stably, according to customers' requirements. It is equipped with technology patents, production facilities, and quality control system. The company has a total of 215 related patents.

An LG Innotek official said, "The Nexlide-L is a lighting module that can enhance the design, quality and safety of a vehicle at once." He also said, "Car manufacturers and drivers will be satisfied with the high-quality lighting component." ■

Everlight Demonstrated Smart Automotive at Electronica 2018

Everlight Electronics, a leading player in the global LED and optoelectronics industry, not only demonstrated infrared and lighting products but also, the latest automotive LEDs and modules, such as an ADB matrix headlamp and a Mini/Smart Multi Array Rear Lamp at Electronica 2018, Messe Munich.

Everlight's new Mini Rear Lamp is manufactured with fine pitch display components to provide exceptional design options

Everlight's ADB matrix intelligent LED headlamp can automatically turn off the light source in the region to avoid interference from high beam when the CCD sensor detects an oncoming vehicle. 24 LEDs of the EVL-EL ALFS 1x1 (EU) series (size: 2.0x1.6 mm) were used, where 245 lm can be provided for a single LED at the operating current of 700 mA. Due to a combination of smart control, fisheye lens, control module, guide prism in special arrangement and CCD, the headlamp can be more accurate on identification and lighting. The products comply with ECE R112 class B Driving Beam and were jointly designed and developed with all OEMs involved.

The new Mini Rear Lamp was manufactured with fine pitch display components from Everlight that meet 27.63 Pixels Per Inch. It implements an Adaptive Rear Lamp System and flexibly adjusts the displayed figures and texts to provide a clearer quality of image and to conform to all requirements of a rear lamp. The Smart Multi Array Rear Lamp uses Everlight's Smart Multi Series (3.5x3.5x0.8 mm) and a built-in drive and control ICs to achieve the information delivery and a diversified figure display in a most convenient way. The technology can be used to design rear lamps, brake lamps and turning lamps. The new Mini Rear Lamp provides a priority solution for rear lamps due to the visual effect combined with performance quality.

In terms of infrared products, Everlight also demonstrated many transmitting/receiving components (IR, PD/PT) in different sizes, radiant intensities and viewing angles, widely applied for e-books, smart boards, oximeters and household vacuum cleaners. Suitable for oximeters for instance, the IRRG25-16C is an SMD transmitting component with three-color wavelengths: red (660 nm), green (525 nm) and IR (940 nm).

With the optical spectrum from different wavelengths reflected by a flat lens on top, the blood oxygen saturation can be further tested together with Everlight's PD51-40 series (dimensions: 5.1x4.0x0.85 mm), to provide a most accurate diagnosis of the heartbeat. Together, IRRG25-16C and PD51-40 series can retrieve the heartbeat rate in a most convenient way in wearable applications such as sports watches. Optocouplers, another key product segment, was demonstrated at Electronica 2018 as well, including Standard Coupler, High Speed Coupler, Photo Triac and Solid State Relay (SSR) series to match different package sizes to meet all possible applications, including power meters, communication equipment, UPS and industrial control. ■

Lighting Scenes at the Touch of a Button - Tunable White System

The DLE G2 PRE Tunable White system is pre-calibrated at the factory and has an adjustable color temperature range of 2,700 to 6,500 K, so it covers the entire white range from warm white to cool white. Luminous flux remains constant at all times. The system provides a simple way to create dynamic lighting solutions such as Tunable White and human centric lighting applications.

The DLE G2 PRE Tunable White system kit is pre-calibrated at the factory and consists of a two-channel DALI-DT8 driver and DLE G2 PREMIUM LED module

The DLE G2 PRE Tunable White system for downlights not only has an adjustable color temperature of 2,700 to 6,500 K at constant luminous flux but also an impressively high color rendering index of Ra > 90. It is available as a pre-calibrated kit consisting of perfectly matched components: a compact LED driver and a Tunable White LED module. Tridonic is therefore ensuring both high quality of light and high color consistency (SDCM 3) while considerably simplifying Tunable White lighting solutions.

Flexible operation via pushbuttons or software:
The system includes a dimmable two-channel DALI-DT8 surface-mount driver with an adjustable output current of 350 to 1,050 mA and a maximum output of 38 W. The driver is equipped with a digital interface (DALI DT8, DSI, switchDIM, corridorFUNCTION) to which either a digital control signal (DALI) or a standard pushbutton switch (switchDIM) can be connected. At the touch of a button, the light can be dimmed from 100% to 1% without any change in the selected color temperature. The rate at which the light switches on and off can be set between 0.2 s and 16 s via the Power-up-Fading and Fade-to-Zero functions. The color temperature can also be set via colourSWITCH using conventional pushbutton switches. The memory function remembers the last dimming value and color temperature.

The corridorFUNCTION can be programmed via a DALI-USB interface using masterCONFIGURATOR. This function can be activated manually by applying a voltage of 230 V to the switchDIM connection for five minutes. Overtemperature, short-circuit, overload and no-load protection as well as reduced surge current amplification round off the range of functions. The LED downlight module is available with a luminous flux of 2,000 lm or 3,000 lm.

The Tunable White system has a high system efficiency up to 100 lm/W and is extremely economical in standby mode with a power draw of only 0.25 W. It is also suitable for emergency lighting systems in accordance with EN50172 and has a life of 50,000 hours. The manufacturer offers a 5-year system guarantee. ■

EnOcean - the First Self-Powered Bluetooth® Sensor for Intelligent Lighting Control

At CES 2019 in Las Vegas, EnOcean has launched a new ceiling-mounted solar-powered occupancy sensor (PIR) for Bluetooth lighting control systems communicating via Bluetooth® Low Energy (BLE). It will be the first self-powered Bluetooth® occupancy sensor on the market integrating EnOcean's field-proven energy harvesting technology and offering best customer experience by being maintenance-free, freely positionable, highly flexible and easy to install. The new sensor, in a small and functional housing design, will add to EnOcean's Easyfit portfolio of battery-free Bluetooth® switches and perfectly support the company's strategy to easily provide precious data for the digitalization of buildings using LED lighting systems as data backbone for intelligent control. The new sensor will be available on the market from January 2019.

EnOcean's solar-powered occupancy sensor for Bluetooth® lighting control system is the first of its kind on the market

"Adding the solar-powered occupancy sensor to our EnOcean Easyfit Bluetooth® portfolio, we prove once again the extensive opportunities of our energy harvesting technology to power wireless communication by the surrounding environment," says Andreas Schneider, CEO of EnOcean GmbH. "At the same time, the self-powered Bluetooth® occupancy sensor will meet the growing market demand for Bluetooth®-based wireless control which leverages lighting systems as data grid for smart building services on the route to the IoT. Our Bluetooth® partners will benefit from a complete plug & play energy harvesting portfolio which they can easily integrate into their Bluetooth® lighting systems, offering installers a most flexible ready-to-use solution – self-powered and wireless."

Self-powered occupancy and light intensity detection:
The new, self-powered Easyfit sensor (EMDCB) uses a passive infrared (PIR) sensor to detect motion and integrates tiny solar cells to harvest ambient light. These solar cells generate the energy for the sensor's operation, making it self-powered and maintenance-free. An energy storage element stores the harvested energy bridging a period of time when no light is available to ensure an uninterrupted operation. Besides occupancy detection, the new Bluetooth® sensor integrates a light sensor that allows light level control based on the actual light intensity. Like the battery-free Easyfit switches, the sensor also has a Near Field Communication (NFC) interface to be easily integrated and commissioned for lighting control systems via a NFC reader, a smartphone or a tablet.

Secure telegram authentication:
In addition, the EMDCB offers advanced security mechanisms for protected data communication. The sensor's algorithm uses AES 128 authentication based on the device-unique random security key to generate a 32-bit signature, which is transmitted as part of the radio telegram. Therefore, all transmitted radio telegrams are authenticated via AES 128 to ensure data integrity and authenticity.

Data for intelligent Bluetooth® lighting control:
With the self-powered occupancy sensor for Bluetooth® systems, EnOcean will offer a complete control solution for Bluetooth® lighting systems for worldwide use enabling its Bluetooth® partners a fast market adoption. Besides the battery-free Easyfit switches which allow a direct control of LED lights, the PIR sensor will enable a more complex control logic delivering data on room occupancy and light intensity via Bluetooth®. This data lays the foundation for smart services such as demand-based lighting control or room occupancy management, making LED lighting systems an integrated part of networked building intelligence.

In a future step, EnOcean will further expand its Easyfit portfolio of self-powered Bluetooth® sensors to deliver additional building data such as temperature and humidity for more intelligent control abilities.

Battery-free Easyfit Bluetooth® switches:
The new EMDCB sensor will add to EnOcean's self-powered wireless Easyfit switches for Bluetooth® lighting systems. The Easyfit switches are battery-free, gaining their energy by the press of a button. Therefore, they are maintenance-free, freely positionable and allow flexible control as well as intuitive usage. The self-powered switches can be commissioned by Near Field Communication (NFC) to allow simple or complex lighting scenes and effects, and enable easy, flexible installation of lighting applications. Easyfit Bluetooth® switches are being employed in hundreds of lighting solutions, offering self-powered control for Bluetooth® lighting systems in 2.4 GHz. EnOcean's Bluetooth® partners include Aruba – a Hewlett Packard Enterprise company, Casambi, Fulham, Helvar, Feilo Sylvania, Silvair, Vossloh-Schwabe Lighting Solutions, Wirepas and Xicato.

In addition to its Easyfit Bluetooth® portfolio, EnOcean will also be demonstrating self-powered switch and sensor solutions based on the open wireless standards of EnOcean (ISO/IEC 14543-3-1X) and Zigbee 2.4 GHz all with integrated energy harvesting technology from EnOcean. ■

12-bit, 29 kHz RGB LED Driver Family Enables Vivid Color and Seamless Animation without Audible Noise

Texas Instruments today introduced a new family of LED drivers with integrated, independent color mixing, brightness control and a power-saving mode. The LP5018, LP5024, LP5030 and LP5036 enable smooth, vivid color and reduce system power consumption.

Key features and benefits of the LP5018, LP5024, LP5030 and LP5036 LED drivers:

- High-resolution PWM dimming: The devices in TI's LP50xx family integrate a 12-bit PWM generator that operates above a human-audible frequency, at 29 kHz per channel, enabling smooth, vivid color with zero audible noise.
- Ultra-low quiescent current: An integrated power-saving mode dramatically reduces power consumption to as low as 0.01 mA from the typical 9 mA offered in existing devices, improving total system efficiency in standby mode.
- Multichannel options: 18-, 24-, 30- and 36-channel options provide independent color mixing and brightness control, while three integrated, programmable banks enable simplified software coding and ease of design.

New LED drivers from TI help designers reduce power consumption and improve total system efficiency in human-machine interface applications

The devices are the industry's first to offer a 29-kHz dimming frequency, above human-audible range, to help designers of applications that use a human-machine interface, such as portable electronics, building automation and appliances, eliminate the noise typically heard when dimming lights. Additionally, designers can achieve smoother color and brightness-level adjustments compared to standard pulse-width modulation (PWM) solutions, by taking advantage of the devices' integrated 12-bit PWM generator.

New LED drivers from TI help designers reduce power consumption and improve total system efficiency in human-machine interface applications

Tools and support to speed design:
Designers can download LP50xx graphical user interface software to easily configure the LP5018, LP5024, LP5030 and LP5036 LED drivers. Engineers can jump-start their designs with the LP5024EVM and LP5036EVM evaluation modules.

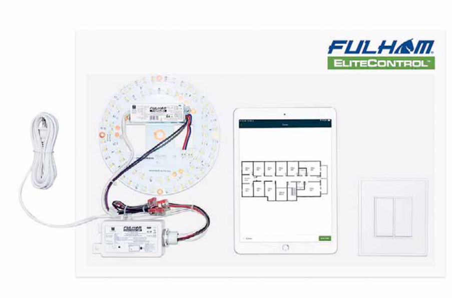
See how to implement sophisticated lighting patterns for end equipment with a constant voltage supply using the "Various LED Ring Lighting Patterns" reference design. The design utilizes two LP5024 LED drivers to dynamically adjust brightness without impacting contrast ratios in ambient lighting situations.

These new LED drivers with integrated PWM join TI's extensive LED driver integrated circuit (IC) product portfolio, design tools, and technical resources that can help electronics designers add innovative lighting features to their systems.

Availability and additional information:
The LP5018 and LP5024 LED drivers are available now in the TI store. Additionally, preproduction samples of the LP5030 and LP5036 are available now in the TI store. ■

Fulham EliteControl Bluetooth Mesh LabKit - Fast, Easy Evaluation and Development

Fulham has just released a new Bluetooth Mesh LabKit to make it easy for OEMs to quickly test and evaluate wireless LED controllers for commercial lighting systems. The LabKit comes ready to use, complete with Fulham's Bluetooth mesh mobile commissioning application.



Self-contained EliteControl LabKit makes it easy to understand and test wireless Bluetooth mesh lighting control systems

The EliteControl Bluetooth Mesh LabKit is a self-contained, 120 V unit. The LabKit includes a Fulham LED light engine, a Fulham SmartBridge Bluetooth controller, an EnOcean wireless Bluetooth switch, and an Apple iPad loaded with Fulham's controller software. Using the LabKit, the user will have a fully operational BT mesh LED control system in minutes.

With the EliteControl LabKit you can configure and manage wireless control zones. The Fulham controller app allows users to set up a new lighting project that can encompass one or more floors of a building. Zones made up of a group of Bluetooth mesh devices such as fixtures, sensors or switches are used to define controlled spaces on a specific floor or even within rooms. Custom configuration scenarios can be created using the Fulham app and stored for office spaces, restrooms, etc., to simplify controller commissioning.

Once the zones are configured, the LabKit can be used to connect and control the lighting system. Luminaires can be added to each zone as needed and the LED engine will flash to show connectivity has been established. Once connected, the dimmer switch included in the LabKit can be used to test and control the zone lighting infrastructure.

"We wanted to offer a simple Bluetooth commissioning and evaluation kit to show customers how easy it is to set up a Bluetooth mesh control network," said Alvaro Garcia, Senior Director, Product Management, for Fulham. "The EliteControl LabKit is ideal for understanding Bluetooth mesh for smaller projects, as well as for demonstrating and testing other Bluetooth mesh wireless LED devices."

SIG qualified Bluetooth mesh is rapidly gaining momentum as the preferred approach for wireless LED lighting control. Bluetooth is an open standard so any qualified device will be interoperable. The mesh architecture also is highly reliable with built-in failover and Bluetooth-enabled luminaires can be added or removed without disruption. Bluetooth mesh also is secure and highly scalable so it can connect thousands of nodes, and it provides a full stack communications platform so it can become the infrastructure for the Internet of Things (IoT). ■

Tridonic smartSWITCH Sensors Detect Presence and Ambient Light

The compact smartSWITCH HF 5DP f and HF 5DP Sf switch sensors have an extra-wide detection range and, as built-in devices, require very little space in the luminaire. The sensors employ microwave technology and switch the light using the respective LED driver when they detect presence and ambient light.

Tridonic's compact smartSWITCH HF switch sensors have an extra-wide detection range and, as built-in devices, require very little space in the luminaire

With the new smartSWITCH HF 5DP f and HF 5DP S f switch sensors for luminaire fixtures, Tridonic has once again expanded the detection range for presence and ambient light compared with the previous model. The sensitivity of the sensors can now be adjusted from 100 to 10% as required. This prevents the light from being switched on unnecessarily because the detection range is too large.

Flexible settings:
In addition to the detection range, a threshold for the ambient light and the delay time before switch off can also be set by the nine dip switches in the sensors. The bright-out function prevents the light being switched on if the illuminance of the daylight is sufficient. The light only switches on if the sensor detects the presence of people and the ambient light is too weak. To prevent the light being switched on and off too often, automatic switch off can be delayed. The delay time before switch off begins after the last movement in the detection range and can be anything from 5 seconds to 30 minutes.

Space-saving and convenient:
The switch sensors have a maximum mounting height of 5 meters but the largest detection range is achieved when the sensors are mounted at a height of 3 meters. With different housing dimensions (70x36.5x24.5 mm and 58x48.5x24.5 mm), both sensor models are suitable for various luminaires. A mounting frame means the sensors can be mounted directly in the luminaire housing. The sensors are particularly easy to install in modules that are already fitted with corresponding recesses for mounting, for example the CLE G3 ADV LED module. Thanks to the microwave technology, the sensors are also suitable for closed luminaires, because the high-frequency waves penetrate glass and other thin materials (except for metal). Combining the sensors with the relevant LED drivers and their integrated functions, such as corridorFUNCTION, creates a sophisticated and cost-efficient lighting solution. ■

Infineon Automotive LED Driver - Most Flexible LED Load Diagnosis

LED lighting is taking over on the roads. It enables new design trends in cars, such as flexible styling and animation, and increases safety in traffic. If LEDs fail, this affects the reliability of the light. With LITIX™ Basic+, a new LED driver family, Infineon is launching the most flexible single LED short circuit diagnostic feature available on the market at Electronica 2018. The new Active Retry function mode reduces the likelihood of misdiagnoses. This can save drivers unnecessary garage visits.

Infineon's LITIX Basic+ LED driver family is able to detect single LED short circuits in addition to detecting both open load faults and short circuit to ground faults

The American market and many German car manufacturers are now demanding LED drivers that are able to detect single LED short circuits. The LITIX Basic+ family includes three devices with this feature: TLD2132-1EP with one input and one output channel (1in/1out), TLD2131-3EP (1in/3out) and TLD2331-3EP (3in/3out). For fault diagnosis, they compare the voltage of the LED chain with a freely configurable reference voltage. The reference voltage can be adjusted by means of a resistor depending on the LEDs used and the expected working range.

In case of an error, the LED driver reports the status, e.g. to a microcontroller. Depending on the diagnostic requests from the system, it either deactivates the affected channel or leaves it activated. Unlike other solutions on the market, the LITIX Basic+ devices have the additional Active Retry option when the channel is deactivated. Active Retry describes the cyclic scanning of the LEDs by briefly reactivating the channels. This allows an automatic restart if the error condition no longer exists.

In addition to the single LED short circuit, LITIX Basic+ products detect both open load faults and short circuit to ground faults. Again, the diagnosis is flexibly configurable.

The LITIX Basic+ LED driver family consists of a total of six devices (single and three-channel versions) and supports an LED current range from 5 mA up to 360 mA. In addition to the devices with single LED short circuit detection, it offers two devices with an integrated PWM timer module (pulse width modulation): TLD2141-3EP (1in/3out) and TLD2142-1EP (1in/1out). This allows combined tail light functions (such as brake and tail light) to be implemented cost-effectively. The required light intensity is achieved precisely thanks to the pulse width modulation. With the TLD1114-1EP (1in/1out) device, the integrated power shift function allows power loss to be dissipated externally. Infineon LITIX Basic+ LED drivers complement the successful LITIX Basic family already on the market. ■

Upowertek - World's First CCR Mode 0.1% Dimmable LED Driver

Most of the low dimming drivers are designed with PWM mode to get low output, but they have the problems of strobe flickering under cameras and potential audible noises. To solve the problems, Upowertek released the first constant current reduction mode 0.1% dimmable LED driver in the world, the BSR-055 series.

Upowertek's latest LED drivers are not just dimmable down to 0,1% but also NFC programmable by a notebook or android device

Compared to other CCR mode LED Drivers, it has a much lower dimming level and with a great regulation of +/-0.05% and consistency, thanks to the digital control circuitry inside. To make sure of the smooth dimming control, BSR series has built 2048 digital dimming levels inside, and it supports customization of linear, logarithmic or even square dimming curves.

It is the first linear slim line driver that integrates DALI, 0-10V, PWM and time dimming in one model. Also, it has the NFC programming laptop software and android APP available. ■

New BT Mesh Controllers - Enhanced Wireless LED Lighting Control

Environmental Lights, a leader in LED lighting solutions, announced the launch of Mini Bluetooth Mesh Controllers. The Mini Bluetooth Mesh Controllers enable users to control LED lights from a mobile app. Available in single color, tunable white, RGB and RGBW, the controllers have a wireless range of up to 45 feet in an ideal environment and can be networked together to create up to four separate lighting zones. The Bluetooth mesh network, created by digitally linking multiple controllers, enables users to manage all configured lighting zones when in range of any of the devices.

Environmental Lights' feature-rich Mini Bluetooth Mesh tunable white controller provides up to 7 amps per channel

Options:

- Single Color: 15 amps per channel
- Tunable White: 7 amps per channel
- RGB: 5 amps per channel
- RGBW: 2.5 amps per RGB channel; 4 amps on the white channel

"Our customers have been asking for a robust wireless controller that allows them to link and control multiple runs of LED lights from a smartphone or tablet," stated Jordan Brooks, President of Environmental Lights. Vice President of Sales Keith Zeber added, "We are excited about our new Mini Bluetooth Mesh Controllers because they utilize Bluetooth mesh technology to connect multiple controllers together for extended range of control. Users can adjust multiple LED lights by being near any of the controllers in the network."

The integration of Bluetooth Mesh technology allows users to create a wide network of multiple connected devices. The devices speak to one another as a unified whole, resulting in more reliable data transmission throughout the network. Using the Light Mesh app, users can create timed scenes using the controller's internal clock to set pre-programmed recurring scenes based on the time of day and day of week.

The Mini Bluetooth Mesh Controllers are equipped with full-circuit protection and feature a compact, ultra-slim design. They are compatible with constant voltage LEDs from 12V DC to 24V DC, and their CE marking and RoHS certification makes them safe for use in a variety of LED lighting applications. ■

Inventronics Expands Narrow Input, Constant Voltage Driver Series

Inventronics is pleased to announce the expansion of their constant-voltage EBV Series to include 75 W, 100 W and 150 W models that operate at a narrow input voltage range from 176-305 Vac. Narrowing the input voltage range has allowed Inventronics to reduce manufacturing costs and offer significant savings to regions that do not require a universal input voltage range. This series of LED drivers are made with a compact, extruded-metal housing, enabling more creative freedom on luminaire design. They are IP67 rated, which is ideal in architectural, decorative and signage lighting projects.

Inventronics' new narrow input, constant voltage drivers offer significant costs savings if no universal input solution is required

The EBV-075SxxxSV series provides output voltages of 24 V, 36 V and 48 V and supply up to 75 W at output currents from 0-3.2 A with a full-load efficiency up to 90%. The calculated lifetime of these drivers at 70°C case temperature is 97,000 hours.

The EBV-100SxxxSV series provides output voltages of 12 V, 24 V, 36 V and 48 V and supply up to 100 W at output currents from 0-8.4 A with a full-load efficiency up to 92%. The calculated lifetime of these drivers at 70°C case temperature is 85,000 hours.

The EBV-150SxxxSV series provides output voltages of 12 V, 24 V, 36 V and 48 V and supply up to 150 W at output currents from 0-10 A with a full-load efficiency up to 91.5%. The calculated lifetime of these drivers at 70°C case temperature is 83,000 hours.

All three EBV Series provide a higher input surge protection with 4 kV line-to-line and 6 kV line-to-earth and incorporates many added protections such as over-current protection, over-voltage protection, short-circuit protection and over-temperature protection.

The EBV-075SxxxSV, EBV-100SxxxSV and EBV-150SxxxSV are approved to CE, CB, ENEC, CCC, BIS and KS standards. They provide SELV output, are suitable for independent use. This series is not suited to be used in North America due to the narrow input voltage range. Production quantities of these drivers are available now. ■

TE Connectivity Presents Corcom MRI LED Lighting EMI Filters

In medical applications very often, strict EMI suppression and clean power is required. One especially critical application is Magnetic Resonance Imaging (MRI). Unfortunately, standard LED drivers and LED lighting products don't provide sufficient EMI suppression. Even LED lights outside the MRI room may influence the MRI equipment. Especially designed filters can eliminate this problem. TE Connectivity's new Corcom MRI LED lighting filters is such a product.

TE's Corcom MRI LED Lighting Filters are available as 2, 3 and 4 channel versions

TE Connectivity's (TE) Corcom MRI LED lighting filters target MRI Rooms that are using Class II LED drivers to power the LED lights in an MRI room. MRI LED lighting filters will be located outside the shielded MRI room and will clean up conducted Electromagnetic interference (EMI) noise between 10KHz and 1GHz with a powerful 3 stage attenuation circuit that will bring insertion loss to 100dB.

The electrical power within the MRI room needs to be supplied by clean power, allowing OEM light fixture manufacturers to comply with the low noise levels required by MRI equipment manufacturers.

MRI LED lighting filters are also available to installers for drop-in replacements and come in 2, 3, and 4 channel versions providing the scalability needed in developing fixtures for their customers. This also allows contractors the flexibility to choose the correct number of circuits to accommodate a specific installation.

TE Connectivity Presents LUMAWISE Endurance N Base with Vent

TE Connectivity's (TE) LUMAWISE Endurance N base with vent is ANSI 136.41 compliant for photocontrols and accepts sleeves and covers in varying heights. These components are assembled to provide a total power and signal interface between the photocontrol module and a lighting fixture's mating receptacle.

TE's LUMAWISE Endurance N are offered with an integral vent. They are assembled to provide a total power and signal interface between the photocontrol module and a lighting fixture

Applications:

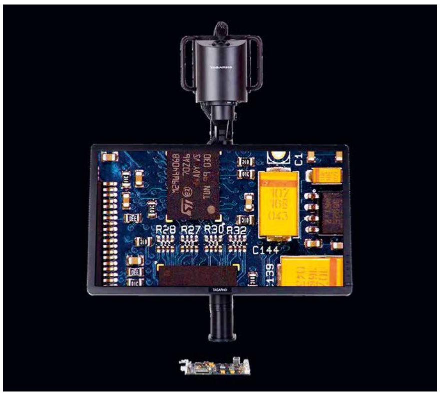
- Roadways and street lighting
- Parking lots
- Pathways and trails
- Parks

The LUMAWISE Endurance N controller interface is used in applications such as LED outdoor roadway, street and area lighting fixtures. The base assembly solution includes power twist lock terminals, spring leaf signal contacts and a separately packaged foam gasket. When coupled with the 5-VA rated cover or in combination with optional side or topside aperture sleeves, the fully assembled photocontrol achieves an IP66 seal rating.

The LUMAWISE Endurance N's vent provides rapid pressure equalization inside the sealed photocontrol and minimizes condensation through vapor diffusion. The vent also prevents the entry of contaminants including dust, dirt and debris that can negatively impact the performance, long term reliability and life expectancy of the sensitive electronics.

Inspect Large PCBs in Ergonomically Correct Working Positions

Tagarno is now announcing a modified digital microscope solution, promoting ergonomically correct working conditions and new possibilities to inspect large PCBs with plenty of work space beneath the camera.



Tagarno FHD ZAP has a range of unique technical specifications when put together with the new +2 lens and inline flex arm

Technical specifications (with the +2 lens and inline flex arm):

- Magnification levels from 0,8x up to 26,2x
- Lens to object distance is 500 mm
- Field of view ranges from 21 mm up to 600 mm

By incorporating a new lens and flex arm, compatible with the Tagarno FHD ZAP digital microscope solution, the user is now able to be positioned directly in front of the camera, in an optimal working posture due to the placement of the flex arm, camera and control box as well as the monitor and the object itself.

The new Flex arm inline and Lens +2 enable the operator to use Tagarno FHD ZAP with larger samples sized up to 600 mm in width. This is made possible because of the distance from lens to object with a +2 lens and the fact that the solution is integrating both the camera head and monitor on a table mounted flexible arm, freeing a large amount of table space.

The flexible part of the arm also enables the user to easily rotate and set the system completely aside from the working area if it is not in use.

This solution is ideal when inspecting large PCBs, where low magnification ranges are sufficient and the user wants the ergonomic advantages. If necessary due to, e.g. the height of the user, a circular tilting table will raise the object from the table and thereby create more distance between the camera head and the table, enabling the user to easier view the monitor. ■

PAR30 Gimbal Spot - Biological Spectrum with High Color Quality

Lighting Science, a global leader in circadian lighting technology, is pleased to announce the release of the Series A+™ Par30 Gimbal, a specification-grade lamp created for discerning clients and lighting designers. Series A+ features a healthy, circadian spectrum with high color quality, beam precision, and directional flexibility.

Lighting Science's new circadian PAR30 gimbal lamp offers a light spectrum similar to daylight - including the 480 nm wavelength range - in 3000, 4000 and 5000 K with minimum 90 CRI

The Series A+, like many of Lighting Science's award-winning products, incorporates patented, engineered spectrum technology to provide a rejuvenating feel with a crisp, white light that is unencumbered by any visual hints of wavelength peaks in circadian blue. Occupants of indoor environments will feel awake and alert from the stimulating spectrum at 480 nm, the wavelength found in natural daylight. Available in three color temperatures (3000, 4000 and 5000 K), each lamp generates high-quality spectral output with a minimum 90 CRI, adds vibrancy to every illuminated scene, and offers appealing contrast and vivid color.

Lighting Science understands that versatility without trade-offs reigns, and the Series A+ delivers with three beam angles that are ideal for accent, task and wall wash applications – a spot (15°), narrow flood (25°) and flood (40°). The discreet gimbal design provides even more functionality, accomplishing precision directional control with 85° rotation at the base and 56° pivot at the lens. A threaded lens cap enables users to add or interchange optical materials such as diffusers or films for even more creative license. The Series A+ is dimmable to 10% and compatible with most TRIAC dimmers, simplifying installation for replacing existing incandescent/halogen lamps.

"At Lighting Science, we strive to create products that provide people with healthier built environments in which to live and work. The Series A+ takes the advancements in optics and circadian research to the next level," said Fred Maxik, CTO and Founder of Lighting Science. "Lighting designers, specifiers and consumers now have the flexibility to have healthy, circadian light with high CRI to maximize the impact of any illumination project they pursue. It's the ultimate in lighting, without compromise."

The Series A+ proves that healthy circadian lighting does not preclude flexibility in design. This adaptable spot will find applications in both commercial and residential spaces requiring precision optical and directional control and provide the added value of a biological impact. ■

GlacialLight Announces GL-BL190-GR 185 W Horticulture Lights

GlacialLight's two new models – GL-BL190-GRP and GL-BL190-GRR come in different functions: the GL-BL190-GRP is designed with L2C5-SPP11825G3200 of LUXEON SunPlus CoB 1825 for use in general plants including cannabis; and the GL-BL190-GRR is designed with L2C5-SPR11825G3200 of LUXEON SunPlus CoB 1825 for use in flora gardening for visual feeling.

The GL-BL190-GR horticulture lighting luminaires spectrum is designed to match both vegetative growth and flowering, respectively fruiting

The GL-BL190-GR horticulture lighting series is structured with pure aluminum housing, stainless steel bracket and screws, as well as IP66 waterproof level. It also features the superior GlacialPower driver inside. This kind top lighting is quite suitable in the high humidity greenhouse or outdoor application. Weight is 3.9 Kg, totally power BL190-GR-driver-accessory consumption is 185 W and deliver high quality light spectral composition is 246 µmol/s. There are three optional beam angles available in 45°, 70° and 120°, that enable the lighting designer can use in the specific plants and crops.

Horticulture lighting can supplement or increase natural daylight to maintain or speed photosynthesis for plants. Nowadays, horticulture lighting is more popular which benefits from LED technology. Unlike traditional HPS luminaires, LED-based horticulture lighting can efficiently focus on the wavelengths to meet different plant and photosynthesis process requirements.

The spectral composition of the different wavelength including royal blue, green, yellow, red, far red and invisible of UV or IR. During photosynthesis, the blue and red wavelength area are important for growing, stem development, flowering and fruit production. It can improve and optimize the appearance of plants or taste texture of crops.

Cree - FLEX Series LED of Specification-Grade Troffers

Cree, Inc. announces the FLEX Series LED Troffer, a new lighting system that gives architects and lighting specifiers remarkable design freedom. This represents an enormous opportunity for a switch to energy-efficient LEDs, as recessed fluorescent troffers comprise 50 percent of all luminaires used in the U.S. commercial market, according to the Department of Energy.

The FLEX Series LED Specification troffer combines aesthetic appeal, design flexibility and premium performance into a slim luminaire design that fits virtually any ceiling type. With five customizable inner-optic choices, architects and designers can create distinctive environments across diverse applications – from corporate offices to hospitals, schools and retail – with just one fixture to spec. Featuring standard one percent 0-10V dimming and optional SmartCast® Technology for intelligent lighting control, illumination levels are easily adjusted to adapt to changing conditions.

Cree introduced the FLEX series LED of specification-grade troffers offering unique adaptation opportunities to extend design freedom of lighting designers

"What makes the FLEX Series unique is that it not only offers the industry-leading efficiency our customers have come to expect, but it was specifically designed to meet the needs of architects and lighting designers," said Craig Atwater, Cree senior vice president and general manager, lighting. "From its high-quality light and designer dimming and control, to its extensive lumen packages and inner optic choices, every detail was designed to promote creativity and ease of specification."

The FLEX Series adds style and energy efficiency even in the most challenging designer applications. Higher lumen packages can be mounted up to 20 feet and offer up to 6,000 lumens of superior, low-glare illumination, ideal for more light-intensive applications. By drastically reducing flicker, the FLEX Series troffer can minimize fatigue, headaches and stroboscopic hazards, and help increase productivity and improve video telepresence applications in the office and classroom. Add to this superior efficacy up to 145 LPW, and the FLEX Series boasts DLC® Premium status, qualifying for the largest rebates and driving fast paybacks nationwide.

Ecolighting's Medusa Is the Latest Generation of LED Streetlight

The Medusa is designed with a Philips advanced xitanium driver, Samsung or Cree LEDs and a NEMA five-pin plug comes as standard for telematics such as TELENSA or similar open protocol. Robust and weatherproof to IP65, the Medusa luminaire is easy to maintain, lightweight and has a stylish aluminum body with adjustable pole mounting.

Medusa is Ecolighting's latest generation of LED streetlight. The before & after comparison demonstrates the improvements over HPS lights

Ideal for use in streets, security, car parks and building exteriors, the Medusa luminaire allows public sectors to benefit from huge cost savings and makes a substantial difference to energy bills.

By using top quality LEDs in Medusa, Ecolighting ensures high thermal conductivity, minimal light decay, pure light, very stable performance and a 50,000-hour lifespan. As a result, Ecolighting is able to offer a 10-year conditional guarantee with optional photocell control and a pre-programmed dimming cycle for smaller projects.

The Medusa comes in three body sizes and 10 different LED power outputs from 14 W to 250 W. The system uses LEDs producing 115 lumens per watt and a color temperature of 5000 K, top quality modular drivers and has surge protection to 10 KV.

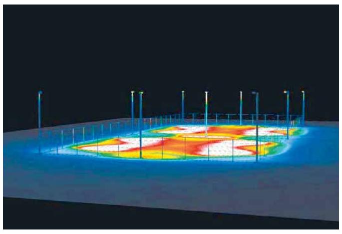
Eco-friendly and energy-saving, the Medusa has no radiation or emitting heat, is free from mercury, lead and other harmful substances. Its head can be adjusted from 0-90°, the optical design suits different roads, and it has a 70:30° road to pavement ratio. Its innovative thermal management design has an effective low LED junction temperature, ensuring the lifespan of the light source and its power supply.

For ease of installation, the streetlight has a built in spirit level and there are different power supply solutions available whether dimming or not dimming. The body comes with an advanced clip for tool-less operation and an easy to maintain fixed brace.

The installation of Ecolighting's LED solution provides higher lux levels whilst reducing power consumption.

Multi-Court LED Tennis Lighting Package from Access Fixtures

Access Fixtures is pleased to introduce another complete LED tennis court lights package, in addition to their other tennis court packages already available. This package was specifically created for 2 + 2 tennis courts, or four tennis courts in total. 30' 7-gauge square steel poles support the luminaires, which are fitted to the poles via quad bullhorns, double bullhorns, or slip-fitters.



As playing tennis at night is becoming more popular, the demand for appropriate lighting is increasing

The lighting package is equipped with a total of nine poles and 20 APTI lighting fixtures, as well as the necessary mounting bullhorns, slip-fitters, and mounting hardware. Access Fixtures conducted photometric analyses and additional research to determine the correct quantity, height, and wattage of the fixtures in this package. When lighting a tennis court, care must be taken to eliminate dark areas and shadows. This package reaches over 30 foot-candles and a max/min ratio of 2.0. A ratio of 3.0 or under indicates even lighting across a sports court.

Sports LEDs that Deliver:
The lighting fixture used in this new tennis court package is the APTI, a high-powered LED sports lighter that boasts 200,000 hours of life and 80+ CRI. In addition, these modular fixtures are IP67 rated and completely protected against dust and water. Individual modules make this luminaire simple to replace if the need arises. APTI fixtures combine modern design with practical durability. The APTI sports lighters in this package are fitted with two different styles of optics in order to create the most natural and even lighting over four courts.

Lighting Science - Dual-Spectrum Technology in the Palm of Your Hand

Lighting Science, a pioneer in biological LED lighting, is excited to announce the newest addition to its family of circadian lighting products. JOURNI™, a portable and versatile LED task light, provides engineered spectrums designed for circadian regulation in one convenient device. Whether you are a jet-setter or a college student pulling an all-nighter, the appropriate JOURNI setting enables you to sync your circadian rhythm – either to boost wakefulness and productivity or to wind down and prepare for sleep.

JOURNI™, a compact, portable circadian task light, is designed to sync the circadian rhythm

JOURNI™, the scientifically advanced and compact light, integrates 20 years of circadian neuroscience into a device that gives you control over your sleep/wake cycle, no matter where you are. Designed to slide easily into a computer bag, backpack or suitcase, JOURNI is the perfect light for busy business executives, travelers, students or anyone looking to feel their best while on the go.

The engineered, dual-spectrum circadian technology of JOURNI means you always have the right light for the right time. JOURNI allows you to easily change from the blue-enriched spectrum of Lighting Science's patented GoodDay® technology that boosts energy and performance to the blue-depleted spectrum of the GoodNight® technology to promote a more restful night's sleep.

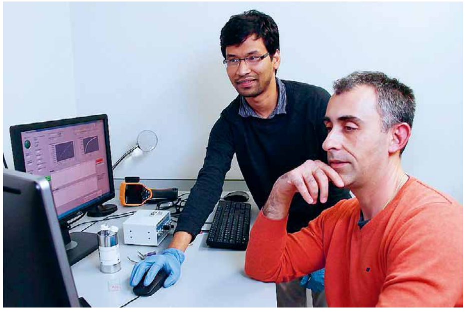
Crafted from aluminum alloy, JOURNI's modern space-gray body comes with a versatile magnetic black leather cover that protects the lamp and doubles as a multi-position stand to allow the user to control light direction. JOURNI can be positioned to create a stream of light for focused tasks such as reading, or redirected to provide soft, ambient illumination. The dimming adjustment feature allows you to control the exact setting you desire while providing high-quality, energy-efficient light.

Smith Johnston, M.D., Flight Surgeon, Board-certified Preventive and Aerospace Medicine Specialist, and Scientific Advisor to Lighting Science, has embraced the multi-faceted benefits of JOURNI, stating, "The dual spectrums are ideal for world traveling executives, athletes, pilots, and even astronauts, who face multiple light/dark cycles, but must always work at peak performance and optimal health."

JOURNI is a sleek, battery-operated circadian lighting solution that offers unmatched utility and portability for all-day lighting that works with your body's biological rhythms, without boundaries. ■

Colloidal Quantum Dots Make LEDs Shine Bright in the Infrared

ICFO researchers report on the development of a colloidal quantum-dot light emitting diode with unprecedented quantum and power conversion efficiencies in the infrared range. The ideal optoelectronic semiconductor material should be a strong light emitter i.e. should emit light very efficiently upon optical excitation as well as be an efficient charge conductor to allow for electrical injection in devices. These two conditions when met can lead to highly efficient light emitting diodes as well as to solar cells with the possibility to approach the Shockley-Queisser limit. Until now the materials that have come close to meeting these conditions have been based on epitaxially-grown costly III-V semiconductors that cannot be monolithically integrated to CMOS electronics.



Dr. Santanu Pradhan, first author, shows the experimental results to Prof. Gerasimos Konstantatos (Credits: ICFO)

The ICFO team has reported a solution processed nanocomposite system comprising infrared colloidal quantum dots that also meets these criteria and at the same time offers low cost and facile CMOS integration. Colloidal Quantum Dots (CQDs) are extremely small semiconductor particles or crystals, as small as a few nanometers in size, and because of their size they are capable of having unique optical and electronic properties. They are excellent absorbers and emitters of light, having their properties change as a function of their size and shape: smaller quantum dots emit in the blue range while larger quantum dots emit in the red.

The use of colloidal quantum dot (CQD) light-emitting diodes (LEDs) has become one of the key ingredients in leading technologies such as, for example, 3rd generation, solution processed, and inorganic solar cells. The implementation of these nanocrystals in devices for optical sensing in the short-wave and mid- infrared have triggered a vast number of applications including surveillance, night vision, product, process and environmental monitoring and spectroscopy.

In this recent study published in Nature Nanotechnology, ICFO researchers Santanu Padhan, Francesco Di Stasio, Yu Bi, Shuchi Gupta, Sotirios Christodoulou, and Alexandros Stavrinadis, led by ICREA Prof. at ICFO Gerasimos Konstantatos, have developed CQD infrared emitting LEDs, which have achieved unprecedented values in the infrared range, with an external quantum efficiency of 7.9% and a power conversion efficiency of 9.3%, a value never attained before with this type of devices.

The key feature of this work has been the development of a CQD composite structure engineered at the suprananocrystalline level to reach unprecedentedly low electronic defect density. Prior efforts in suppressing electronic defects in CQD solids have been primarily based on chemical passivation of the CQD surface, something that could not solve the problem in PbS QDs. The researchers at ICFO took an alternative path of creating the appropriate matrix in which they embedded the emitting QDs, to serve as a remote electronic passivant for the emitter CQDs. Moreover, the energetic landscape of the matrix was engineered in order to facilitate efficient charge funneling into the QD emitters in order to achieve efficient electrical injection.

With these new blend devices, the team of researchers took a step further and constructed solar cells to test their performance in the infrared range. In doing so, they discovered that the effective passivation achieved in these nanocomposites along with the modulation of the electronic density of states has resulted in solar cells that deliver open circuit voltage very close to the theoretical limit. The open circuit voltage (VOC), which is the maximum voltage available from a solar cell, increased from 0.4 V for a single QD configuration, up to ~0.7 V for the ternary blend configuration, an impressive value considering the lower bandgap of the cell at ~0.9 eV. As ICREA Prof at ICFO Gerasimos Konstantatos comments, "The most surprising finding of this study is the extremely low electronic trap density that can be achieved in a conductive QD material system that is full of chemical defects arising on the surface of the dots, the very high quantum efficiency of those LEDs has been the consequence of this passivation strategy we demonstrate. The other exciting outcome has been the potential to reach so high Voc values for QD solar cells that was synergistically achieved thanks to the very low trap density as well as to a novel engineering approach of the density of states in a semiconductor film". Santanu Pradhan, the first author of this study adds: "Next we will focus on how to further exploit this reduction of electronic density of states synergistically with other means to allow for simultaneous achievement of high Voc and current production, thereby targeting record power conversion efficiencies in solar cell devices"

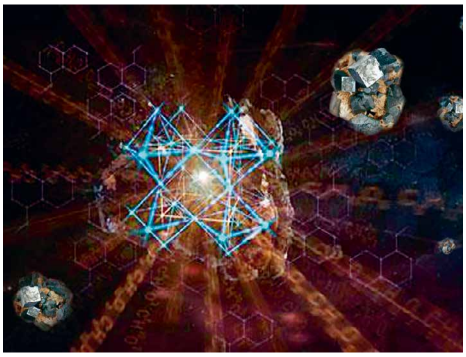
The results obtained in this study prove that the engineering of QCD infrared-emitting LEDs at the nanoscale integrated in solar cells can significantly improve the performance efficiency of these devices in the infrared range. Such results open the pathway into a range of the spectra that is still to be fully exploited and offers amazing new applications, such as on-chip spectrometers for food inspection, environmental monitoring, manufacturing process monitoring as well as active imaging systems for biomedical or night vision applications.

About ICFO:
ICFO is a young research institution that aims to advance the very limits of knowledge in Photonics, namely the science and technology of harnessing Light. Light, especially laser light, is one of the major enabling technologies currently available to humankind. Our research thrusts target the global forefront of photonics, and aim to tackle important challenges faced by society at large. We focus on current and future problems in Health, Energy, Information, Safety, Security and caring for the Environment.

Acknowledgements:
The original paper, "High-Efficiency Colloidal Quantum Dot Infrared Light-Emitting Diodes Via Engineering at the Supra-Nanocrystalline Level" from Santanu Pradhan, Francesco Di Stasio, Yu Bi, Shuchi Gupta, Sotirios Christodoulou, Alexandros "Stavrinadis and Gerasimos Konstantatos has been published on December 3rdat Nature Nanotechnology: www.nature.com/articles/s41565-018-0312-y

Researchers Push Perovskite LEDs' Efficiency To Rivaling Best OLEDs

Compared to OLEDs, which are widely used in high-end consumer electronics, the perovskite-based LEDs, developed by researchers at the University of Cambridge, can be made at much lower costs, and can be tuned to emit light across the visible and near-infrared spectra with high color purity. Now, researchers have set a new efficiency record for LEDs based on perovskite semiconductors, rivalling that of the best Organic LEDs (OLEDs).



Researchers have set a new efficiency record for LEDs based on perovskite semiconductors, rivalling that of the best organic LEDs (OLEDs)

The researchers have engineered the perovskite layer in the LEDs to show close to 100% internal luminescence efficiency, opening up future applications in display, lighting and communications, as well as next-generation solar cells.

These perovskite materials are of the same type as those found to make highly efficient solar cells that could one day replace commercial silicon solar cells. While perovskite-based LEDs have already been developed, they have not been nearly as efficient as conventional OLEDs at converting electricity into light.

Earlier hybrid perovskite LEDs, first developed by Professor Sir Richard Friend's group at the University's Cavendish Laboratory four years ago, were promising, but losses from the perovskite layer, caused by tiny defects in the crystal structure, limited their light-emission efficiency.

Now, Cambridge researchers from the same group and their collaborators have shown that by forming a composite layer of the perovskites together with a polymer, it is possible to achieve much higher light-emission efficiencies, close to the theoretical efficiency limit of thin-film OLEDs. Their results are reported in the journal Nature Photonics.

"This perovskite-polymer structure effectively eliminates non-emissive losses, the first time this has been achieved in a perovskite-based device," said Dr Dawei Di from Cambridge's Cavendish Laboratory, one of the corresponding authors of the paper. "By blending the two, we can basically prevent the electrons and positive charges from recombining via the defects in the perovskite structure."

The perovskite-polymer blend used in the LED devices, known as a bulk heterostructure, is made of two-dimensional and three-dimensional perovskite components and an insulating polymer. When an ultra-fast laser is shone on the structures, pairs of electric charges that carry energy move from the 2D regions to the 3D regions in a trillionth of a second: much faster than earlier layered perovskite structures used in LEDs. Separated charges in the 3D regions then recombine and emit light extremely efficiently.

"Since the energy migration from 2D regions to 3D regions happens so quickly, and the charges in the 3D regions are isolated from the defects by the polymer, these mechanisms prevent the defects from getting involved, thereby preventing energy loss," said Di.

"The best external quantum efficiencies of these devices are higher than 20% at current densities relevant to display applications, setting a new record for perovskite LEDs, which is a similar efficiency value to the best OLEDs on the market today," said Baodan Zhao, the paper's first author.

While perovskite-based LEDs are beginning to rival OLEDs in terms of efficiency, they still need better stability if they are to be adopted in consumer electronics. When perovskite-based LEDs were first developed, they had a lifetime of just a few seconds. The LEDs developed in the current research have a half-life close to 50 hours, which is a huge improvement in just four years, but still nowhere near the lifetimes required for commercial applications, which will require an extensive industrial development program. "Understanding the degradation mechanisms of the LEDs is a key to future improvements," said Di.

Acknowledgements:
The research was funded by the Engineering and Physical Sciences Research Council (EPSRC) and the European Research Council (ERC).

Reference:
Baodan Zhao et al. "High-efficiency perovskite-polymer bulk heterostructure light-emitting diodes." Nature Photonics (2018). DOI: 10.1038/s41566-018-0283-4

TECHNICAL REGULATORY COMPLIANCE UPDATE

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Functionality and Labeling	Lighting Products	SASO	KSA	SASO and SEEC are organising a workshop on Energy Efficiency Standard for functionality and labeling requirements for lighting products. More information on the SASO website.
Safety	Lighting Devices and Electric Lamps	Gov. Resolution	Russia	Russian Government published resolution No.:1312 which is meant as amendment for the existing resolution No.: 1356 approving requirements for lighting devices and electric lamps. Aim is increase of energy efficient lighting solutions. The resolution specifies several design and other characteristical requirements of certain types of lighting devices besides others. • New definitions for LED lamps using filaments and directional lamps • Luminaires for public use or industrial premises should have a luminous flux control • Besides others also specific requirements for lamp power factor with built-in control devices • Minimum light output of lamps with LEDs • Requirements for searchlights
Safety	Luminaires	ANSI Standard	USA	ANSI/UL 1598 4th Edition for the luminaire standard with additional horticultural lighting testing: ANSI/UL 1598, the Standard for Safety of Luminaires, is generally used to guide testing of all types of luminaires, including LED luminaires used in horticultural lighting applications. The Standard, which runs more than 300 pages in length, specifies a number of general requirements regarding mechanical and electrical construction, as well as supplementary requirements for a variety of specialized luminaires, including those utilizing incandescent, fluorescent, high-intensity discharge (HID) and LED technologies.
Performance	Lighting Products	DLC	USA	DLC released the new specification for LED-based horticultural lighting on 19th Nov. 2018. Besides other topics new policies that will allow high performance, energy efficient horticultural lighting products, DC and PoE products, and field-adjustable light are part of the content.
Performance	LED	IEC	World	IEC 62612:2013+AMD2:2018 / EN 62612:2013/A2:2018 Self-ballasted LED lamps for general lighting services with supply voltages > 50 V - Performance requirements It now includes the use of data from ANSI/IES LM-80-15 as alternative method to reduce the test time of LED lamps. Further the accelerated operational life test was clarified to bypass any thermal protection device during this test.
Binning	LED	IEC	World	IEC 62707-1+AMD1:2018/EN 62707-1:2014/A1:2018 LED-binning - Part 1: General requirements and white colour grid intended for automotive applications The scope of the standard was changed to be now only applicable to automotive application. A new cl. 5 was added with binning test procedures.

A free training can be arranged for a clear understanding of the upper stated standards.
For further information on the latest upgrades and testing standards and training, please contact cps@tuv-sud.com

"Glare" Is to Light as "Noise" Is to Sound - CIE Research Roadmap on Glare

Glare has always been a relevant topic, especially since electric light levels began to increase. With high intensity light sources like LEDs, the problem culminated in the last few years. CIE addresses this topic in its recent publication CIE 205:2013: "Review of Lighting Quality Measures for Interior Lighting with LED Lighting Systems". Furthermore the Joint Technical Committee JTC 7 is still working on this topic. A short overview on the topic and CIE's activities is presented.

Excessive light intensity, regardless of the source type, can have several unwanted effects on people. The presence of bright sources in the periphery of the field of view may cause a reduction in visibility or cause feelings of discomfort. The discomfort might be associated with the bright peripheral light sources detracting the eye from the intended gaze direction, although the exact mechanism causing this discomfort is not fully understood. Another effect occurs when the field of view itself is experienced as too bright or dazzling, typically in daylight conditions that require sunglasses.

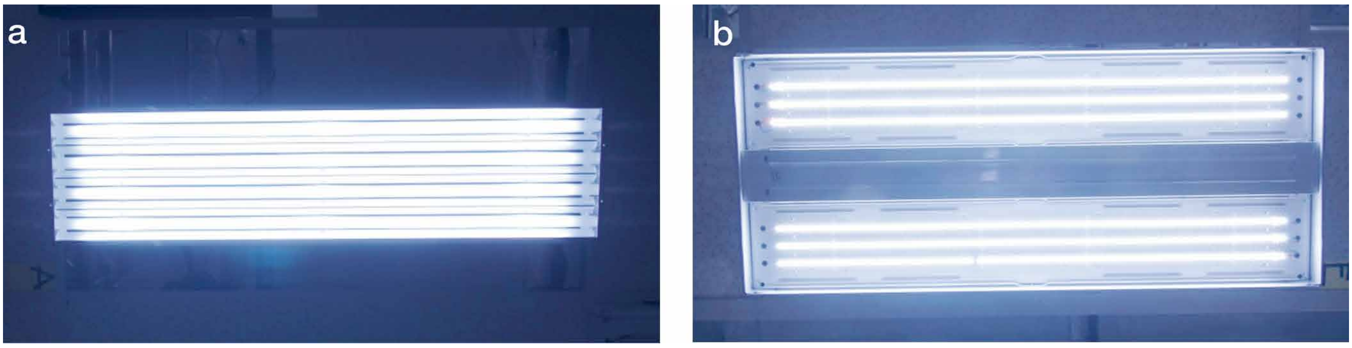
Glare has been under study for over a century, but it really took off in the 1940s when increasing electric light levels gave rise to complaints about discomfort caused by excessive light. As a result, a multitude of glare formulae were proposed, each formula being based on a limited set of experimental results on a specific light source (gas discharge lamps, fluorescent tubes, daylight through windows, …) in a specific application (office lighting, street lighting, sports lighting, …).

Disability caused by glare has been successfully attributed to light scattering in the eye. The scattered light of bright sources creates a veiling luminance on the retina, which reduces the contrast of the retinal image. As a result, this glare effect could be well defined and tested experimentally. The prediction formula for disability glare, as described in CIE 146:2002 "CIE equations for disability glare", is therefore widely accepted and applied without reference to a specific application.

The situation is completely different for discomfort, where the mechanism, or possibly multiple mechanisms, is not clearly identified nor easily determined experimentally. Although discomfort metrics based on direct measurement of pupillary constriction, eye movements, or contractions of facial muscles have been examined, most scientific studies on glare that causes discomfort are based on subjective evaluations of the discomfort experienced in response to various stimuli.

The various formulae to predict discomfort experienced in interior lighting were successfully replaced by the Unified Glare Rating (UGR) in 1995 (CIE 146:1995 "Discomfort glare in interior lighting"). The UGR, like its predecessors, is an empirically-derived formula, based on discomfort ratings of lighting characteristics as produced by lighting technologies and applications predating the 1990s. It is generally considered as a practical method based on consensus, rather than science.

Meanwhile, the introduction of LED light sources has enabled luminaires and lighting systems with characteristics (such as peak luminance, luminance contrast or intensity cutoff) that were not previously possible. A recent CIE publication (CIE 205:2013: Review of Lighting Quality Measures for Interior Lighting with LED Lighting Systems) questioned the validity of conventional lighting quality measures for interior lighting with LED lighting systems. The report identified an important problem: A luminaire with visible LED sources in some cases seems to provoke more discomfort than a more conventional looking luminaire (which might also be LED based) with the same intensity and source area, but with a uniform source luminance. This issue has been addressed by CIE Joint Technical Committee JTC 7. The observed issues related to glare from sources with a strongly non-uniform luminance appear to be linked to ambiguity in the definition of the glare source area. The committee proposes



The luminaire on the left has a diffuser over the LEDs so it has a larger surface area. The one on the right has individual visible LEDs. Both of these luminaires would exhibit glare undercounted by the UGR formula because UGR would use the full luminaire aperture as the luminaire size, not just the size of the diffusers or the sum total area of the LEDs
Photos courtesy Pacific Northwest National Laboratory, Richland, WA, USA.

a luminance measurement protocol to eliminate this ambiguity, such that UGR may also be correctly applied to the non-uniform glare sources that may be encountered in LED lighting. The report of JTC 7 is expected to be published mid-2019.

For application areas other than interior lighting no such consensus has been achieved. Consequently, the lighting community has been forced to work with many different glare formulae for applications like daylight through windows, road and street lighting, or sports lighting (Daylight Glare Probability (DGP), Daylight Glare Index (DGI), Cumulative Brightness Effect (CBE), Glare Control Mark (GCM), Glare Rating (GR), et cetera). Another complicating factor is the large variation in individual glare sensitivity, which may depend on, for instance, age, chronotype ("being a morning or an evening person"), or the type of activity. The visual interest of the scene can also influence whether or not viewers experience discomfort from glare sources.

Because of this scattered approach and large variation in individual responses, the evaluation of glare, though seen as relevant to lighting design, is often considered too difficult to quantify. To counteract this tendency, a unified glare prediction method that can be applied to any lighting application and is independent of the glare source technology needed. Being able to predict discomfort arising from glare will be beneficial to end users because it will enable its prevention. Manufacturers will be better able to develop suitable products and to categorize the suitability of their products for various configurations and applications. This will facilitate better choices by lighting designers and specifiers to balance cost to lighting comfort.

Although there exist differences between the various discomfort prediction formulae for glare, the formulae for different application areas such as interior lighting and roadway lighting are very similar in form (see J.J. Vos, "Reflections on glare" Lighting Res. Technol. 35,2 (2003) pp. 163–176, or P.R. Boyce, "Human Factors in Lighting" 3rd edition, New York: Taylor and Francis, 2013). They all predict an increase in discomfort with increasing glare source intensity, a decrease when this intensity is spread over a larger source area, and a decrease when the background or adaptation luminance increases. This points in the direction of a commonly shared mechanism that causes the discomfort, independent of the source technology or application area.

The identification of the psychological or physiological mechanism or mechanisms that cause discomfort from glare has been identified as one of the key research questions in the CIE research roadmap. When excessive light in the field of view causes discomfort, is the problem caused by distraction of the eye toward bright peripheral sources, a mismatch between local and global adaptation, uncomfortable variations in pupillary constriction, a lighting pattern or light direction that deviates from what is "natural", a combination of these mechanisms, or by another, unknown mechanism?

The identification of such glare mechanisms is a prerequisite for the construction of a discomfort prediction model in which multiple application conditions and light source types may be incorporated by measurable physical, physiological and psychological parameters such as lighting characteristics (position, size and orientation of glare sources, luminance patterns, lighting dynamics, spectral distribution, etc.) and observer parameters (positions or trajectories, gaze directions, field of view, age, chronotype, visual task, type of activity, etc.). The advancements of neurological science and perception research in unravelling the pathways of the visual system may be instrumental in reaching this goal. This fundamental knowledge will enable a robust and science-based discomfort prediction method that, as for disability caused by glare, can withstand changes caused by future innovation in light sources and can be applied to all lighting applications. ■

EU Policy Offers the Lighting Industry Risks and Opportunities

The European Union is pushing a number of policy initiatives in the coming months and years that will have a profound impact on the business models of firms competing in the European lighting industry.

LightingEurope (LE) is the industry's eyes and ears in Brussels and its foremost representative in dialogue with policymakers. Like trade associations from all industry sectors it is monitoring potential policy threats to its members. But it also identifies growth opportunities that should be embraced by the lighting industry.

In order to minimize the risk and maximize the opportunities the lighting industry, led by LE, engages with policymakers to help them get the policy framework right. Without a clear voice in Brussels the industry risks being on the receiving end of ill-informed regulations. With the range of different policy initiatives currently underway or about to begin, the potential risk now is greater than ever.

As both the lighting industry and the EU agenda evolve there are more and more policy areas to monitor and help steer. Rules related to energy and the environment still are the most relevant and numerous. They include laws governing the use of hazardous substances, durability and reparability, rules designed to minimize waste and reduce the amount of it that ends up in landfill sites, rules on energy efficiency, energy labelling and eco-design.

Add to them internal market rules, and in particular, the complex legislative packages in the area of digitization and the data economy. These policy areas impact a wide range of industries that are all adapting to take advantage of the potential offered by the emergence of Big Data and the Internet of Things (IoT).

In such a complex legislative environment, the lighting industry can learn from other industries such as automotive, consumer electronics and home appliances, how they have been affected by, for example, CE-marking requirements or new data protection rules.

But in the area of environmental protection the lighting industry often leads the way. Hardly any other industry has done more to optimize the ecological footprint of the products it builds: LED technology has enabled further energy savings and coupled with lighting systems offers even more opportunities.

The same is possible with serviceability and the so-called "Circular Economy".

One of the four loops in the circle involves servicing products in use in order to extend their technical and economic lifespan. This isn't only good for the environment and the end user, it is also opening up lighting firms to new business models, and the move is very similar to what has been seen in other industries, such as the computer industry, where manufacturers like IBM and Microsoft are moving towards a business model based around service contracts rather than product supplier contracts.

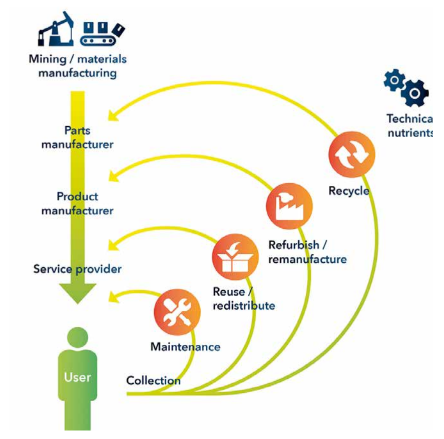
In the lighting industry this trend is still at an early stage, and it is most evident in business-to-business markets. The Lighting-As-A-Service model has been piloted in airports and warehouses for example and is now also becoming common in some municipal areas such as street lighting.

The benefits to the lighting industry of moving towards serviceable luminaires are numerous. It creates new opportunities for professionals to offer customers added value through monitoring and maintenance services. Also, as service providers, manufacturers get much closer to their customers, allowing them to build stronger relationships with them.

The EU has a dedicated Circular Economy Action Plan and is looking to drive more circular products and business models in Europe. It's not all about serviceability, and it's not all good news. There are elements in the EU Circular Economy Action plan that pose serious challenges to many players in the industry. For example, some policymakers, especially in some EU countries and in the European Parliament, who are pushing for longer-life products that are easy to repair and recycle, are asking for modular products that can be opened up, and the components easily separated and replaced by the customer.

A proposal for mandatory removability of light sources and control gears was introduced into a draft text for the next set of energy efficiency rules for lighting products.

This poses problems for a wide range of manufacturers: from those that build heavy-duty, airtight luminaires designed for extreme conditions; to those that make the popular integrated household LED luminaires sold in retail outlets where the long-life light source inside the luminaire cannot be removed and replaced. The problem extends beyond the lighting industry – think of the manufacturers of furniture or home appliances that integrate light sources and control gears in their products (e.g. kitchen, bathroom cabinets).



How circular economy works (Credits: Ellen MacArthur Foundation, drawing from Braungart & McDonough)

It is vital for the lighting industry to explain to policymakers why mandating the removability of all light sources and control gears from all products and irrespective of the application for which they are intended, would be a serious mistake.

While LE members fully subscribe to the objectives of the Circular Economy, individual players must be allowed to choose the technology, design and business model for their products to deliver on the Circular Economy.

LE has been very active on this issue, making it clear that while some mandatory requirements are acceptable, EU policymakers must avoid pursuing a one-size-fits-all approach to removability and circular product design.

LE has had some success explaining why it would be undesirable to force all luminaires to have removable light sources, irrespective of where and how they are used. Some policy makers understand but others are less willing to consider the fact that in some circumstances forced removability would be against the interests of consumers. And in other cases – like an airtight, dust-resistant luminaire in a road tunnel - it could even be dangerous to insist that light sources are made removable.

LE calls for clear guidance from regulators, and it advocates an approach to the removability question that is fully in line with the position developed in the standardization body CEN CENELEC - JTC10 (Energy Related Products – Material Efficiency Aspects for Ecodesign) which requires removability only for the purposes of verification by market surveillance authorities and for recycling of light sources and the luminaire, all its containing components included, at the end of life.

LE has been talking regularly with the decision-makers in Brussels and, thanks to the support of the LE member national associations, to ministries in the EU countries. In addition to the removability question, it also urged policymakers to avoid setting rigid timeframes for the removal from the market of non-LED lighting technologies, such as some small halogen light sources or very common fluorescents lamps (e.g. T8, CFL, T5, HID), as well as lamps used in specific applications (a.k.a. special purpose lamps).

The phase out of conventional products and technologies is another aspect of the EU Circular Economy, looking to move away from the use of hazardous substances that risk harming people and the environment. Currently conventional lamps are being addressed by two separate EU processes.

Mercury containing lamps such as T8, CFL, T5, HID and Special Purpose lamps, already regulated by EU energy rules, are under threat in a parallel legislative initiative on the restriction of hazardous substances. The European Commission's Environment directorate is currently evaluating whether to renew RoHS exemptions for most conventional lamps on the market and may decide to ban many of these products from the market inconsistently and quicker that in the energy proposal (which foresee a phase out in September 2021), i.e. removing more products and even by 2020.

LE is asking policymakers to carry out a detailed impact assessment on removal of products and in particular on circular economy in time for the next review of eco-design rules expected to start around 2024. And it has urged the Commission not to introduce any other Circular Economy measures before the 2024 review.

There are two other potential regulatory challenges in the pipeline in Europe: the development of a scoring system to rate the ability to repair and – where relevant – to upgrade products. For the time being, this initiative excludes luminaires but there is every possibility that the reparability scoring system may become mandatory and may be extended to cover lighting.

The other potential challenge on the horizon is the EU Product Policy Framework. This broad initiative will examine options and potential action to adopt a more coherent policy framework from the different strands of work of EU product policy in their contribution to the circular economy. It will include among other things an analysis of the use of chemicals at all stages of manufacture and their impact on the recycling and reuse of materials. It will consider whether to use Green Public Procurement and Extended Producer Responsibility fees to boost circular products and incentivize consumers to choose them.

Both upcoming initiatives fall under the Circular Economy plan. The current Commission is unlikely to pursue any concrete steps in either case, beyond the consultations it has launched, leaving it for the next Commission to pick it up in the following year as of 2020.

These policy initiatives are not going away. The lighting industry must engage with policymakers to transform current policy initiatives into business opportunities and to avoid the risk of serious mistakes that could undermine firms competing in Europe's lighting market. LE is doing just that. It has established a good working relationship with a wide range of policymakers in all the Commission departments involved in these initiatives, in the European Parliament and in the EU countries.

The lighting industry has its work cut out for it in the months and years ahead. LE is the voice of over 1,000 lighting companies competing in Europe. It is a strong voice in Brussels, and it always welcomes others to help it shape the debate and the future. ■

Tech-Talks BREGENZ - Dr. Octavio Perez, Adjunctant Researcher, Mt. Sinai Hospital

Dr. Octavio Perez

Dr. Octavio L. Perez is a passionate professional, researcher and scholar who contributes to exploring, developing and bringing to the real world the benefits of light and lighting for human wellbeing and wellness, and ultimately health.

He works internationally as an independent consultant, focused in translational research in human centric lighting (HCL), more precisely "affective lighting". Currently developing the HCL business intelligence for LLEDO Lighting in Madrid, Spain, he is also an adjunct researcher at Mount Sinai Hospital in NYC, NY, USA. Dr. Perez serves in several international technical committees and he is a WELL Building Standard Accredited Professional.

Dr. Perez received the LED professional Scientific Award 2018 for his paper on “Light and ED Clinical Wellness and Performance Improvement", which was published in LpR 70. The evaluation jury had the following to say about why they selected his paper: “The paper is based on the clear definition of the research question, hypothesis and objective of the research. The methodology of the screening study is described in detail and both subjective and objective parameters have been measured. Although Emergency Department lighting is a very special application, the paper provides interesting results.” This interview provides background information on Octavio Perez, his work in general, his opinion on human centric lighting risks, opportunities and applications and how he became involved in this interesting research topic. Dr. Perez also provides additional details about the presented paper.


Dr. Perez is carefully listening to the questions and makes notes

LED professional: Thank you very much for coming here to talk to us. We’d also like to congratulate you again for winning the award for the best scientific paper in 2018.

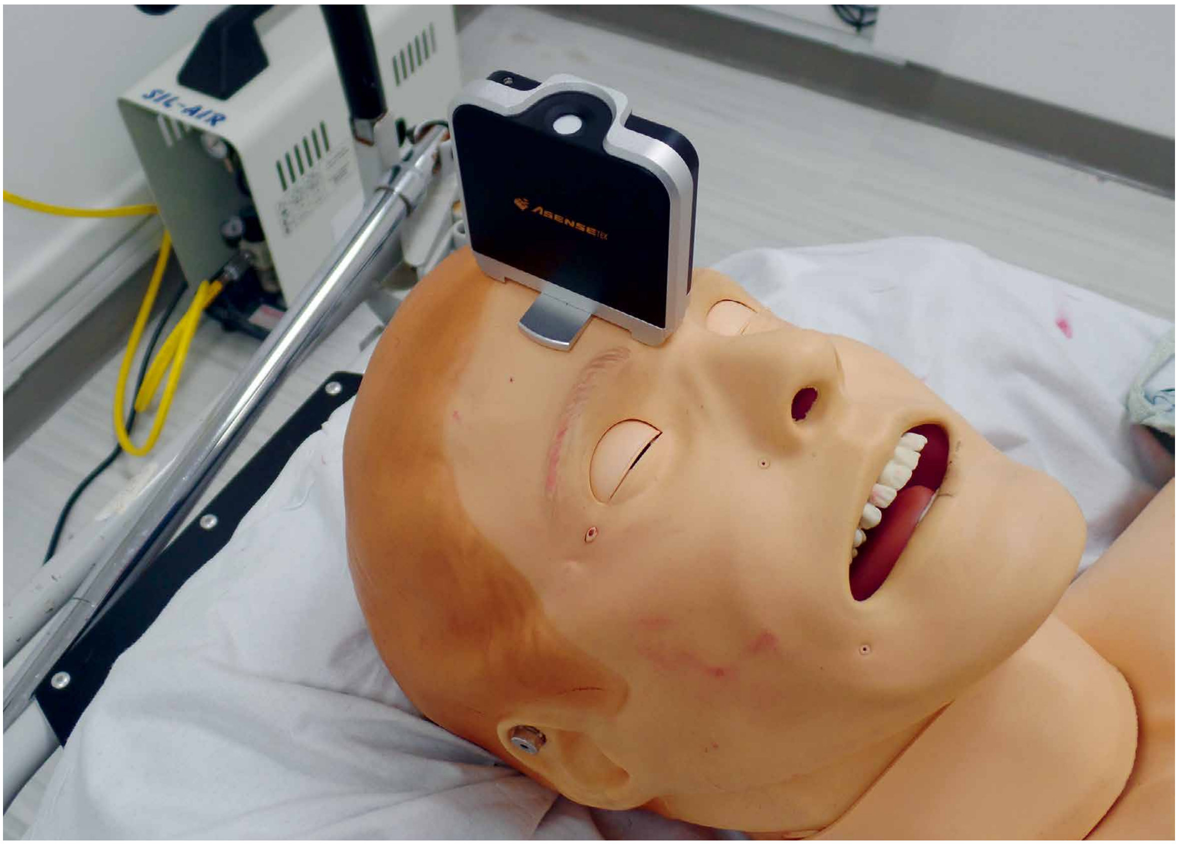
To start off, maybe you could tell our readers a little about you, your work, and the paper that won the award.

Octavio Perez: The paper that was selected as winner of the award was related to my doctorate research that was conducted at Mt. Sinai hospital in New York City in the emergency department simulation center. Now, after finishing my PhD, I’m an adjunct researcher. What we mainly do is look for funding opportunities to set up research in order to provide more evidence, especially in the patient rooms, so that we can improve the patients’ length of stay and healing, using light.

LED professional: What exactly did you study?

Octavio Perez: I studied mechanical engineering – a long time ago! I moved around in different businesses, and then in 2011 I was involved in a very interesting lighting project and then I was invited to go back to university part time, by the Queensland University of Technology to begin my Master’s in lighting. They asked me to go to Mount Sinai to do my doctorate research because it was a new field and we needed to do the work there. Also, Mount Sinai got the funding from the NIH – The National Institute of Health – and this was great because it meant we were getting the money from the top U.S. agency for health.

LED professional: Is your work in the emergency department a central topic for you or does it cover other topics?



Light parameters were accurately controlled to guarantee stable test conditions to avoid possible unwanted side-effects that could affect the results

Octavio Perez: Yes – I work in three main areas. One is the E.D. and how to improve the E.D. clinicians and staff. This is because the burnout rate and suicide for E.D. clinicians is higher than any other profession in the entire world. And this is why I presented the fact that we were able to reduce the perception of sleepiness and the perception of workload. This is extremely important because it is related to stress and this is what you want to reduce. So we proposed to do light treatments – but it is more related to acute effects of light during the day. It's not about circadian lighting. And now, the national academy of medicine in the U.S. has deemed this program a priority. It started a study on clinician burnout in 2017.

Another one, but I can't tell you much about it due to liability issues, is our work on the patients' rooms, where we are focused on improving the sleeping conditions of the patients.

The third one is on surgery rooms. Here we have what I call "competing demands of lighting". The reason for this is because you have different people working in the room: you have the nurses and you have the surgeon and you also have the anesthesiologists. The people from anesthesia are like pilots. They are there at the beginning of the surgery (takeoff), then they are there during the surgery (cruise) and then, at the end of the surgery (landing), they have to be there again. Many times, during the cruise time, they don't pay attention, they are even sleeping, and that's when something can go wrong and sometimes does. So it's important for them to have conditions that support them being awake. Not alert – you don't want people being alert, you want them to be awake! Being alert means stress. What you want, though, is for these people to be awake and focused on their work. And a second point here would be competing demands. You have something like regular surgery, then you have laparoscopy where you need a totally different lighting system, and the third one is remote surgery. These are fields that we are pursuing.

LED professional: So all in all, your research is in the field of medicine.

Octavio Perez: Yes. And the discussion now in healthcare is moving the patient room to homes sometime in the future. This means that we need to think about improving lighting conditions in homes, especially for elderly people. There are two reasons for this: The elderly are the most sensitive population in two areas: One, they fall and they break bones. This is a liability for the hospital. Two, they get hospital acquired infections. So if you don't move the patient to the patient room and you can treat them in their homes, you can avoid both of these problems. If they fall, it's their own fault, and not that of the hospital. And they will not acquire infections at the hospital because they are in their homes.

LED professional: If we focus on your work in the emergency department, could you tell our readers what the main setting and outcome was in the paper that won the Scientific Award?

Octavio Perez: The research question is: Can we improve clinician wellness and performance through lighting? The next question is:

How are we going to study it? You don't go in trying to prove it. You research it. If you want to prove something – that's not science. So we go into this because I have, through my knowledge, an idea that blue-enriched lighting will have an acute effect on clinician wellness and performance during the execution of clinical procedures compared to the lighting that they currently have. And it's very important to have the control conditions because you can find research from very well known people that are saying something like – red light has an acute effect. And this is true, if you compare it with darkness. It doesn't mean that it is the right condition, because you are comparing against darkness.

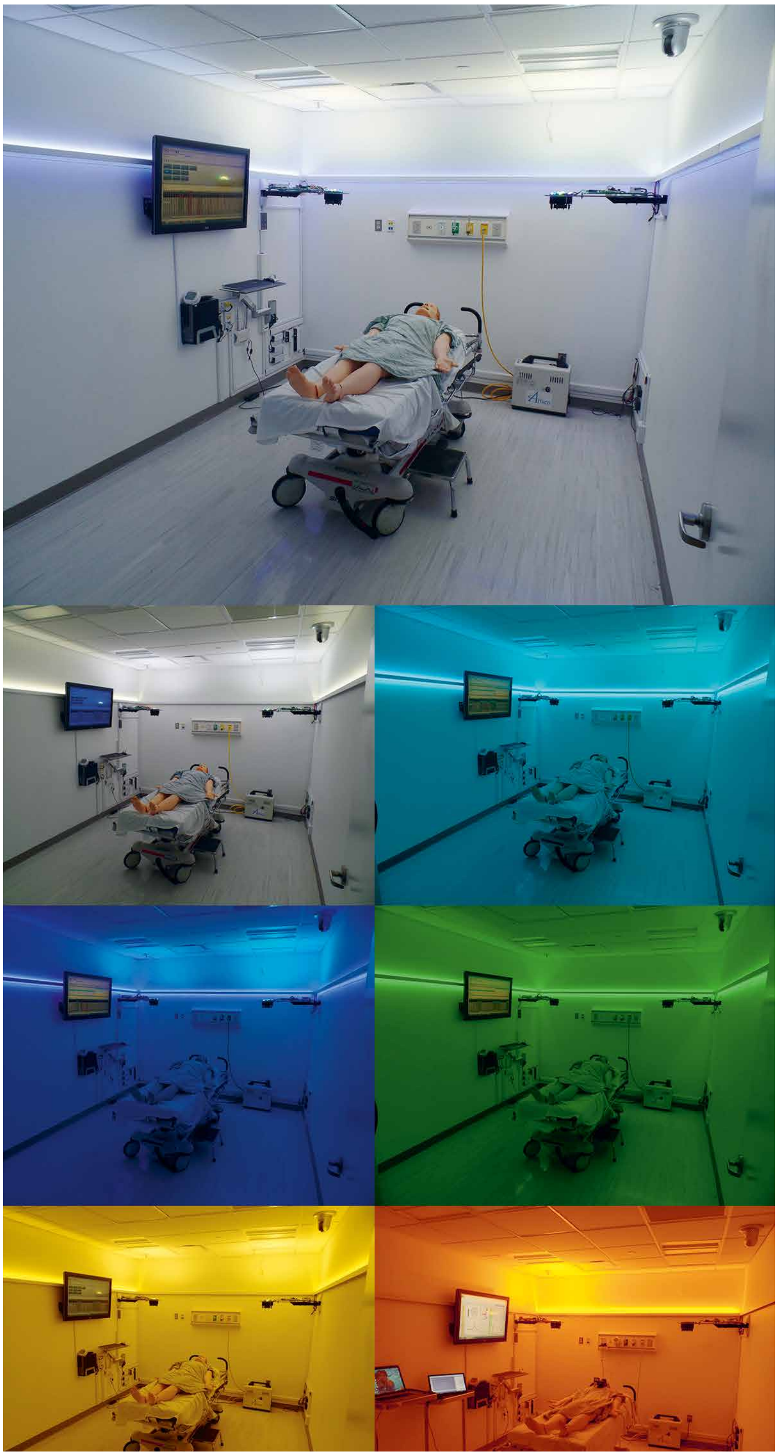
So the hypothesis was to conduct research in a room that was set up for training. And we needed a total intervention. So we painted the room – and this was very important because the room is a part of the lighting system in that it reflects the light. Then we installed a system based on indirect lighting. The system has 54 channels so we can change, not only the spectrum, but also the directionality of light. We can have the light going upwards or downwards and you are also able to change wavelengths.

LED professional: In your lecture you said that you had extremely high color temperature and you also had a very good color rendering.

Octavio Perez: Yes, the color temperature was around 78,000 K and the color-rendering index R9 was perfect at 84.

LED professional: What was surprising to me was the completely changeable directionality. Did you use this opportunity just to find a setting for all of the research or did the research go on for so long that you could try out different settings?

Octavio Perez: During the research we went for a very special setting because it's exploratory research with limited funding and limited experimental grounds. So the idea was to go to an extreme to see if something was going to happen or not. Other studies will show if this is the right parameter or not, but we did show that clinician performance and wellbeing could be improved with lighting.



The system has 54 channels that allow for the changing of the spectrum and directionality of light. For the study the CCT was set to around 78,000 K and the color-rendering index R9 was perfect at 84 (main image). The small images show other color setting possibilities

LED professional: So that means that these opportunities are already implemented and if you get more funding you'll be able to narrow down the most important influence factors.

Octavio Perez: Yes. As it is related to the clinician – the clinician would prefer a different setting. Here we have to be very careful because many people are working on preferences – they go to the clinician and ask them which one he or she prefers. The clinician says, "Oh, I like this one." But what happens is the opposite. People that refused the system at the beginning, even had a feeling of nausea for the first two minutes, but by the end of the experiment, these were the people

that had the highest improvement when compared to the control conditions. The reason for this was that the lighting was affecting them more even if they didn't like it at the beginning. So you have to be very critical of it when you ask for preferences. Most people choose what is in their comfort zone.
But this is the wrong approach. You have to choose the performance zone.

LED professional: I think that is a very critical point because if you are pushing people in the performance zone, how long can they keep it up before they need to come down again and relax?

Octavio Perez: Yes, and that is the main question. It's all about the effects and the dose. The correct term for it is the pharmacal dynamics of lighting. It tells us what is going on with the amount of light you receive, the dose and the effect and how long it affects your body.

LED professional: How long did the clinicians stay in the emergency room?

Octavio Perez: Fifteen to twenty minutes. Without question, you need to adapt to the environment. So we had questionnaires and we did them inside the room before and after the treatment. The ones before were about adapting to the environment.

LED professional: Is the short work period typical for clinicians in the E.D.?

Octavio Perez: Yes.

LED professional: So if they have one emergency case, they treat the patient and then they leave and have a rest.

Octavio Perez: Yes, or another clinician comes in and takes over. In the E.D., you have two different areas: One is called resuscitation. It's the one where, for example, there is someone from a car accident and there are ten people working on that person trying to bring him back to life. But we're not talking about those ones – we're talking about the patients that have an injury on one part of their body and they need to be prepared for surgery.

LED professional: So what happens if you have a critical patient and the clinician needs a minute or two to adapt to the lighting?

Octavio Perez: The adaption process is usually only the first time that the clinician goes into the room. If you work there every day, it will only take seconds to adapt – after the initial adaptation. What I observed was that once you have become familiar with this type of lighting you like it.

But going back to your original question: you cannot say that a certain type of lighting is good for this or that and for how long. You have to be very careful with lighting. It works for a while but then you have to switch to another one. What I proposed at the hospital is to have a type of amber showers to relax and blue showers to activate the clinician before he enters the room.

This is also something that should be considered for the ambulances, because the first fifteen or twenty minutes are critical for saving a life or losing it.

Color rendition is also very important. One of the problems, I'm not sure if you are familiar with it: In Australia, when they first began with fluorescent lighting in the 1960's death rate of patients increased. The fluorescent lighting didn't allow the clinicians to see the color of the lips when the patient was going into cyanosis. And this is very important in an ambulance.

LED professional: I'd like to touch on the more general topic of Human Centric Lighting now. These days, everybody talks about human centric lighting and everybody seems to have a different understanding of what it really is. What is your understanding of human centric lighting?

Octavio Perez: There are a couple of definitions. One is from the ZVEI in Germany, that talks about the emotional, biological and visual effects of lighting. This is what you would call a simplified definition of human centric lighting. CIE has gone with the term "integrity of lighting", where they speak about potentially beneficial psycho-physiological effects on people considering visual and non-visual effects of light. So I think that if you want the big picture you have to add at least two more circles of interaction. One is about ergonomy and the interaction with space.
So the lighting in one space is going to be totally different than lighting in another space and it is going to be related to the activity you are performing. This is very important. And the other one is about energy. We cannot forget about energy. Even if it doesn't have to be the main driver we still have to be very careful because the moment you begin to play with the spectrum you will start introducing wavelengths that are very inefficient from an energy point of view. So you have to consider the energy implications even if they are not a priority.

I think that you have to consider what CIE and ZVEI are discussing, then you have to add the context – ergonomics (including visual ergonomics) – and then you have to consider energy to make the whole thing happen. You cannot speak about human centric lighting without speaking about energy. And you cannot speak about human centric lighting without speaking about the activity that will be performed.

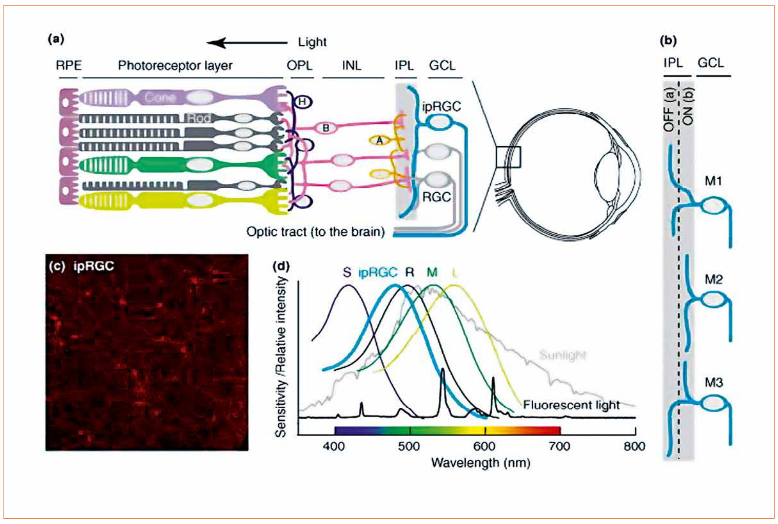
In my doctoral dissertation I introduced an author by the name of Gibson. He talks about something that he called "affordances".
The affordance is very interesting because it's about the information that the space is giving to your sub-conscious mind. So, for example, if you see a door, you should know by looking at it and the

shape of the objects, if it is a push or pull door. And the same thing is true with lighting. And this is where I introduced the term: Non-visual affordances. When you speak about visual, it's clear, but when you speak about non-visual – you don't see it. It's what the lighting configuration is giving to you.

LED professional: Some people talk about improving performance in the patient room using HCL. So I think that there are also some ethical questions, and I was wondering how you see this. When does it start to be an abuse rather than a use of Human Centric Lighting?

Octavio Perez: First of all you have to differentiate between two approaches in ethics. One is precautionary approach, which is very trendy now. It's a misleading "do no harm" approach. Many people say – we don't know enough about it so we don't use it and that way we will do no harm. Then you have the proactionary approach. This approach is based on the concept that "we have the technology, we have the knowledge, we don't need to know the basic science, but with what we know – we can do good." My opinion is that we do more harm by not doing than by doing with the knowledge that we already have. We know basic elements that will improve our conditions and we should use them.

The second thing is – going into doping the spectrum. If you can reproduce daylight with LEDs the ethical question is not there – because you are using a light source that reproduces the light source from which we have evolved. The problems start when you begin to modify the spectrum to have acute effects. It's like you want me to drink coffee instead of water so I will perform better. Let's say the performance raises up 20%. Are you going to pay 20% more money? More free days? More vacation? This is the ethical question – when the company is making more money because the worker is performing better. So when it



Fundamental knowledge of the ipRGC mechanisms, visual mechanisms of the eye and brain and the pharmacal dynamics of light is required to design true Human Centric Light [1]

comes to the lighting – in the future, I think the worker will probably have to sign a paper allowing for HCL lighting to be used. So that's about offices – but what about schools? In schools the ethical question is different. We have studies that show that academic performance can be increased by 20% by using HCL. And what's about students in non- Human Centric Lighting facilities? Should we compensate this somehow?

In healthcare, when you go to the patient room, the patient might tell you that they don't want HCL. When we had fluorescent lighting, even though it wasn't very pleasant, no one complained about it, but now people have started thinking about the lighting. So you have to be very careful. Even though you know that you can improve healing and the length of stay, the patient might say, that he doesn't want this. This means that the patient will have to stay longer – maybe they will pick up an infection. Who will pay for the extra days and treatments? The patient or the insurance company?

What about the clinician? What if the clinicians say they don't want to use the new light? What if they say they want to use incandescent light and then they make an error? Who is responsible for the error? Is it the clinician or the hospital?

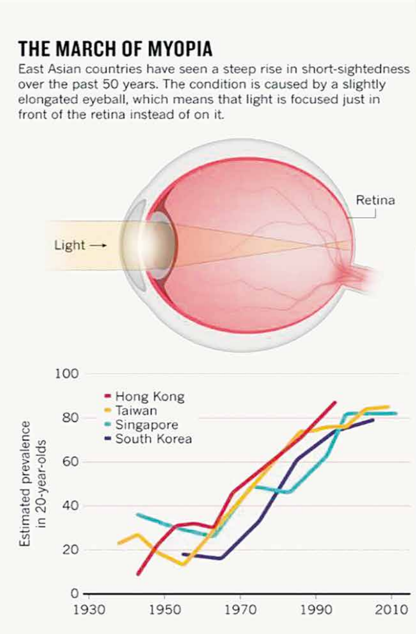
So I think that there will be a lot of ethical issues with human centric lighting. It's not going to be easy, especially when it comes to liabilities and the compensation of workers. This is the debate that we are having.

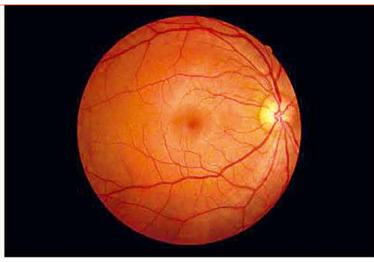
LED professional: Another very interesting point is blue light. On the one side it seems to activate the circadian rhythm and on the other side people are talking about the "blue light hazard" and the possible connection between blue light and cancer. And you are using a very blue light in your experiment. Can you comment on this?

Octavio Perez: I think we have to go back to the pharmacal dynamics of light. You have to know what you are doing because, for example, you can run for one hundred meters, and this can be fine. But if you want to run for one kilometer at a rate of ten seconds per hundred meters, it would probably kill you.

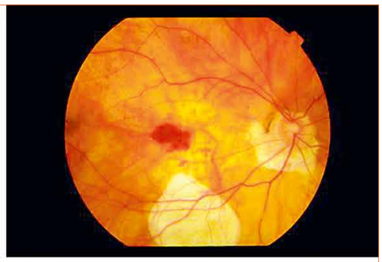
First, we have to define what blue light is. While we are doing that we'll find that we'll be able to differentiate different areas. We know that, depending of the age of the person; something between 460 nm and 490 nm is what will trigger the circadian effect. This will be beneficial in the morning because you will wake up properly but it won't be as good at night. So you would have to have blue depleted light at night. And now you have all these filters and glasses to filter out this wavelength. But the problem is if you filter out this wavelength,

By 2050 half of the world's population is expected to be myopic. However, blue light at 480 nm may reduce the risk of myopia. While there is much talk about the "blue light hazard" it has to be mentioned that this discussion mainly concerns blue light below 470 nm. In addition, part of the problem is due to the fact that in most LED lights the spectrum between 470 nm and 500 nm and the trigger for pupil constriction is missing. It is also important to understand that most of this research is based on in vitro cell cultures that do not provide the body's repair mechanisms [1]





The posterior pole of a healthy eye viewed through the pupil



The retina of high myopia with a large macular haemorrhage causing permanent loss of central vision

*The Myopia Boom

On the math, by 2050 globally, 490 million are at risk of severe vision loss in later life.(*Holden B. et al (2015)*) .

you will fall into a depression during the day. We need it to wake up. And it isn't going to damage you in any way. You have it in the sky and nothing happens. And if I compare my spectra with the spectra of the sun in absolute peaks, the blue peak in the E.D. is only 20% of the maximum of daylight.

Also, the advantage of using this area of the spectrum is that it triggers the pupillary light reflex: You constrict your eye and you reduce the amount of light that goes in. So you regulate the light with your natural mechanisms. If you remove this mechanism from the eye, you get glare and extra light. Many people claim that we need amber light at night. The problem is, if you use amber light, your eye won't constrict the pupil. A Scottish clinician discovered that in the 17th century. He realized that constricting your pupil was a non-visual effect – it doesn't need the brain. So what is going to happen when your body can't constrict your pupil because of all the amber light at night?

We know a few mechanisms, but we don't know exactly what each of them does. My opinion – and this is only my opinion – is that we need to have the spectrum that we had when we evolved because this is what our biology knows. And then the biology will react to it. If you begin to have peaks, you have strange things. So you have to be careful with it. You can use peak performance for a few minutes but then you have to release the systems otherwise you burn it out.

Coming back to the blue light: We have receptors in the blue range. I guess that if our eye has these photoreceptors, or is sensitive to these wavelengths, we need it.

Also, blue light at around 480 nm also controls the axial length growth of the eye and if you don't work with it, you will end up with myopia. And this is what is happening. In regards to physical health, my criterion is that we need a balanced spectrum. So coming back to ethical issues, if you you do peaks, you have to be careful.

LED professional: But you're working with 78,000 K and these are not natural conditions.

Octavio Perez: Absolutely not. Peak performance and the acute effect of light. What did the clinician say about this? At the beginning some of them were very disappointed. At the end, when I talked to them they were really surprised that they had been focused on their work and very relaxed. And this is apparently a contradictory effect of blue light. Again – we don't say it out loud, but we have blue light in our dorm and we put it on before we go to sleep – and it's relaxing. So blue light at a low level is relaxing and at a high level it can affect performance greatly.

LED professional: Prof. Cajochen also mentioned something like that. He said that a low dose of blue at a certain time can trigger dopamine and help you to sleep better.

Octavio Perez: Yes – it's more in the cyan area – 500 to 505.

LED professional: So we have to learn a lot more about blue light.

Octavio Perez: I think all these theses are a big business for people selling filters and glasses. The thing you have to be careful with when it comes to blue light in LEDs is that it has a peak and then it has a valley and then it rises again. This happens around 480 and this means that you are not going to regulate your pupil. This is the real hassle. Because if you fill up the valley – nothing happens with this.

LED professional: Is the eye the only receptor that reacts to light?

Octavio Perez: No, it begins with the skin. And this is one of the questions that was raised in the panel discussion. It came about because I introduced the term: Indoor Daylight. The indoor daylight doesn't contain UV or infrared. Do we need UV and infrared? They are probably more important than the blue light. Do we need this range of the spectrum even if they are non-visual? Yes, we do!

LED professional: I guess we should - unfortunately - slowly start to wrap up the interview, if you don't mind, even though we haven't touched all the topics we wanted to talk about.

Octavio Perez: Yes, no problem. But I would like to touch on why human centric lighting is only happening in research and not happening on the market. The first thing is awareness: Probably not many people in the world know about HCL. And if you don't know about it, you won't buy it or demand it. Even if you have a big budget – you won't buy it.

I have heard people say that they think they can sell human centric lighting fixtures for 20% more than regular ones and I have to say to them: "You don't know what you're talking about." You have to sell solutions, not fixtures. If you sell fixtures – you aren't in the human centric lighting business. You can't go into new markets with old arguments.

We probably have to find new sales channels for HCL solutions. Is it still procurement or do we have to go to Human Resources or the departments that are now created and called "Happiness"? You have these departments in the U.S. and they are beginning to be more popular in Europe.

So who is going to enable this from the infrastructure point of view? IT. Because we talk about dynamic lighting, and who knows how to do these types of things? The answer: IT. When you move like this fixture into power over Ethernet, you are going to control through switches, you're going to be linked to information systems where you can link information from the patient to the lighting – this is IT. Facilities are not going to buy it. Commissioning by IT will make it happen.

So probably the channel is wrong. The argument of sales is that it's only about 20% more. It's another value. It's like when you have a typewriter and you have a computer. They are different products. Even if you can do word processing with both – it's a totally different thing.

This is something that I think is very critical – the arguments and the channels. Wrong arguments. Wrong channels. No value perception.

But the most important one is: "Who are the stakeholders? Who are the players that are going to move this field farther and the comparison they do between railways and airplanes. When we speak about transportation, no one from the railways was promoting airlines. But when air travel started to happen, the railways started to go broke. And this is probably what is going to happen in the lighting industry. Once human centric lighting, intelligent lighting, IoT and what ever else you can think of, begins to happen, lighting industry is going to die and then the IT industry is going to jump in. So we have these two factors that are critical besides all the technology and what's behind it all and how we define it.

LED professional: This was very interesting discussion – thanks so much.

Octavio Perez: Thank you. ■

References:

[1] Image credits: LED professional Symposium +Expo 2018, Bregenz, Tunable LED Lighting and the Retinal Dopamine Response: A Remedy for Myopia, Dr Stephen A. Mason B Optom FAAO Dip.OT., Sustainable Eye Health Pty Ltd

Implications for Human-Centric Lighting Design in Tropical Nursing Homes: A Pilot Study

Light synchronizes our physiological and psychological rhythms to the 24-hour rhythm of the ambient changes. For the elderly, adequate environments to compensate for increasing frailty and sensory loss are crucial. Dr. Szu-Cheng Chien, Assistant Professor at the Singapore Institute of Technology reports from a pilot study that aimed to explore HCL design strategies in nursing homes in Singapore. Pre-/post implementation user surveys and quantitative evaluations were conducted.

For the elderly, an adequate environment to compensate for increasing frailty and sensory loss are crucial. Normal, age-related changes to the eyes decrease the amount of light that reaches the retina, impacting both vision and circadian rhythm. Some attempts have been made recently to conduct white-tunable lighting and vary lighting levels and CCT for health and wellness. However, how to translate such Human-centric Lighting (HCL) concepts proven in laboratory studies into built environments are still in the early stage and lack largely proven practices and strategies on an operational level.

This research project aimed to explore HCL design strategies in nursing homes in Singapore. Firstly, state of the art HCL and aging studies were discussed. We then captured the views to illustrate an HCL framework in a tropical context, whereby the quantitative and qualitative approaches were considered. The preliminary design strategies were developed based on this framework and exemplified in a selected nursing home in Singapore. Also, pre-/post implementation user surveys together with quantitative evaluations (involving horizontal and corneal illuminance measurements) were conducted for assessing the performance of the HCL design strategies. These pilot study findings provide initial insight into HCL design-related knowledge and serve as the solid basis towards the HCL best practices in the environment of nursing homes in Singapore.

Introduction

While typical nursing homes provide insufficient lighting, nursing home residents with greater visual impairment perceive far less bright light exposure for circadian rhythm. That leads to the increase of residents' falls, hip fractures, daytime behavior and sleep problems, etc. Nonetheless, how to translate the HCL concepts proven in laboratory studies into built environments, including hospitals and nursing homes, are still in the early stage and lack of largely proven practices and strategies on an operational level. Specifically, the necessary requirements for the development and effectiveness of control system for HCL in nursing homes have not been formulated in a rigorous and reliable manner.

To date, the designs of lighting systems in nursing homes are primarily made to support visual acuity for staff and secondly to minimize hazards such as staircases. However, to obtain proper visual sharpness and better contrast people of older age require heightened light levels due to age-related failing vision. Furthermore, the nursing home environments are often purpose-made for hygiene, cleanliness and safety and ignore that light sources produce substantial glare due to shiny floors/surfaces and inappropriate light at night disrupts not only sleep but also the timing of the body clock, with negative consequences for cognition and emotions. Properties of current lighting systems are inflexible and not designed to take non-visual effects of light into account for older people's wellbeing in nursing homes.

In the last two decades, much has been learned regarding the non-visual effects of light on human circadian entrainment. Light synchronizes physiological and psychological rhythms to the 24-hour rhythm of the environment [1,2]. Light has also acute alerting and activating effects [3], can affect mood [4], and, when applied at night, suppresses melatonin production [5]. These are some examples of the non-visual effects of light in humans. Studies of the biological clock have shown a reduced neuronal activity in the SCN of the elderly, especially after the age of 80 [6], and reduced circadian rhythm amplitude after the age of 50 [7]. This suggests that, at a molecular level, the SCN becomes less responsive to entrainment stimuli such as light-induced neural signals from the retina. Further, it is suggested that some of the neural processes involved in the entrainment process might be dysfunctional or less effective as we age [8]. Thus, the elderly (specifically those with dementia) commonly suffer from mental and behavioral disorders, such as sleep disturbances, agitated behavior, depression, and risk of falls. Studies [9-16] have shown that light therapy supported by professional lighting control system can effectively offset these issues and add to the quality of life (e.g., consolidate rest/activity patterns, improve sleep efficiency, cognition, reduce symptoms of depression and alter the levels of aggressive behaviors) to the elderly with dementia in spatial and temporal dimensions.

Figure 1: **The layout of the selected residence**

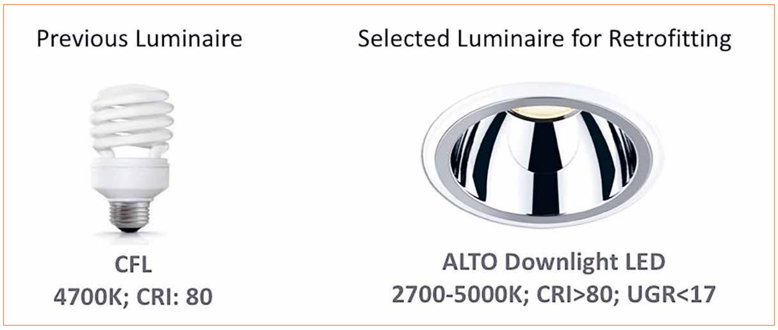


Figure 2: **The previous and selected luminaires for retrofitting**

How to translate the HCL concepts proven in laboratory studies into system implementation in real built environments, including hospitals and nursing homes, are still in the early stages and lack largely proven practices and strategies on an operational level [17,18]. There are a few past and ongoing pilot research and development efforts that have partially addressed certain aspects of the concerns of this current proposal. Such precedents include "Rigshospitalet, Psychiatric Centre Copenhagen: Research project on Ergonomic Circadian Lighting in psychiatry" [19], "Gateway-evaluating a trial LED Lighting System at the ACC Care Center in Sacramento, CA" [20], "Elderly Care Home in Solingen Germany" [21], and "Improved quality of life for resident dementia patients: St. Katharina research project in Vienna" [22]. In these projects, companies in lighting industry (e.g., OSRAM, Philips Lighting, Zumtobel) worked closely with the academia and healthcare institutes.

In this study, we aim to develop and implement a set of advanced human-centric lighting control strategies to improve the comfort and care of seniors, assist the nursing staff in their nightly rounds, and help residents navigate facility hallways via customizing light exposure scenarios for the residents and staffs.

Approach

Description of the case study area

This pilot study was conducted in a selected residence at level one of the Salvation Army Peacehaven Nursing Homes in Singapore. This residence is an entry-controlled area with natural ventilation, including 3 six-bedded rooms, 3 single-bedded rooms, 1 activity room, 8 toilets, and corridor (Figure 3). There are 21 senior residents with mild dementia residing in this home. In this residence, the lighting system will be retrofitted from conventional 24 W CFL lamps with fixed CCT level (i.e., 4700 K) to 10 W advanced tunable-white LED (2700 K to 5000 K; UGR<19; beam angle 40°) (Figure 3). In addition, the smart lighting control system has been installed to allow for individual luminaire control by mobile app via Bluetooth-based mesh network.

Pre-implementation assessment

This step includes pre-implementation user survey, on-site illuminance measurement of original lighting performance for the above-mentioned spaces, namely bedded rooms, corridor, activity room, and toilet. Nursing staff (14 females and 1 male, average age: 35.4 years, average working period of 8.11 years in this nursing home) were selected as participants to provide their feedback and investigate the residents' perception variables based on the observation from 15 March to 15 May 2017. The user survey with was conducted in from 15 to 30 May, 2017. Based on the above-mentioned assessments, the conceptual design of the control strategies together with user scenarios was developed. The questionnaires for pre-/post implementations was approved by the IRBs of Singapore Institute of technology and the Salvation Army Peacehaven Nursing Home. We selected 7 locations as reference points for the session of on-site measurements. Also, the illuminance meter (Gossen Mavolux 5032) was used to measure the illuminance in selected reference points.

Benchmarking of available strategies

This step addresses the benchmarking of available strategies in view of different space categories through the lighting simulation tool, ElumTools, as a plugin of Autodesk Revit. Such considered spaces include corridor, single/6-bedded rooms, and activity room. The preliminary simulations were conducted to compare the visual performances of the scenarios with existing CFL and the ones with selected tunable-white luminaires.

Human-centric lighting implementation and fine-tuning

This step includes the installation of the advanced tunable LED luminaire control system in the selected site. This system comprises IoT-based tunable LED luminaires with plug-and-play capability, user-friendly interface (involving embedded multiple control interface in smart devices and the re-use of wall switch), and advanced sensing technologies (e.g., human motion, movement direction, motionless occupancy, fallen human detection, high temperature). Also, preliminary human centric lighting strategies were implemented, tested, and commissioned (Figure 3). The installation and commissioning period was from 1 June to 15 August 2018. After this step, the settings with new control strategies were operated for two months, from 15 August to 15 October.

Post-implementation assessment

In this step, we verified and validated the performance of the human centric lighting strategies via post-implementation user surveys.

The previous-selected (total of 15) nursing staff, as participants, conducted the user surveys again to provide their feedback and investigate the residents' perception variables in view of visual comfort level of the residents and staff based on the observation during

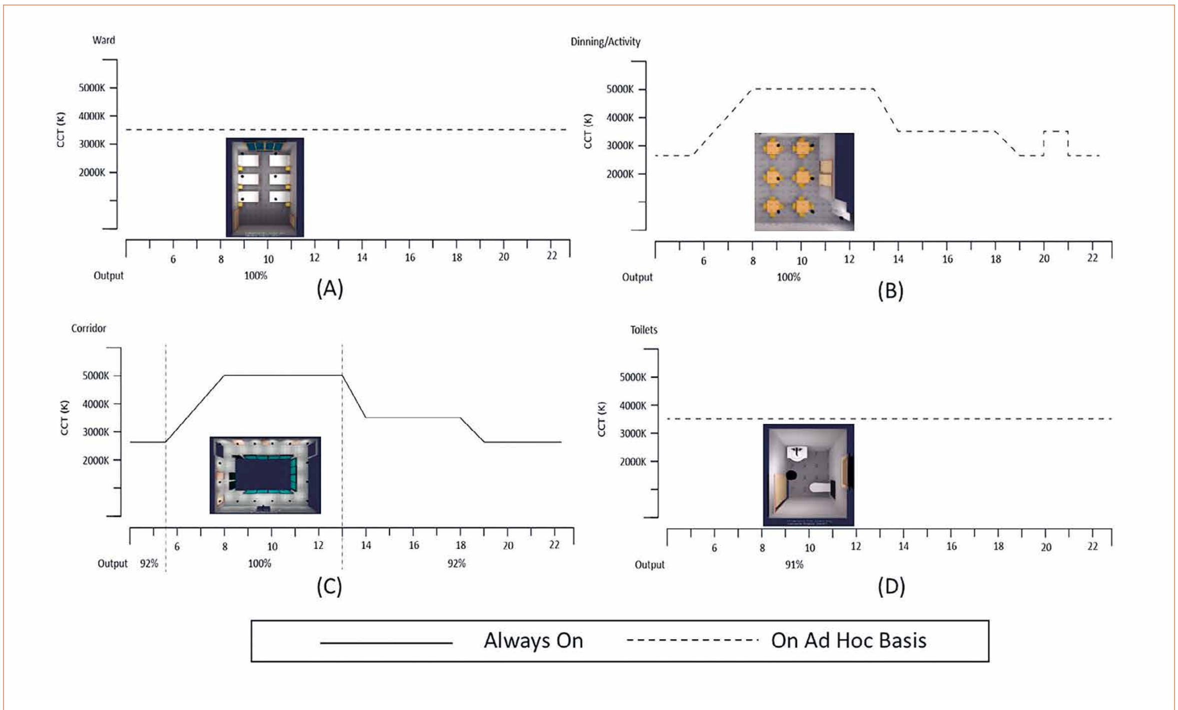


Figure 3: **The control scenarios involving luminance output and CCT appearance in the bedded rooms [A], the activity room [B], the corridor [C], and the toilets [D]**

the operation period. The user survey was conducted from 15 to 31 October, 2017. We also measured the illuminance level in 7 selected reference points via the illuminance meter (Gossen Mavolux 5032).

Data Analysis and Discussion

In this step, we analyzed the collected survey data and discussed the results.

Results

The data analysis involved:

- Preliminary simulation-based evaluation
- On-site illuminance comparison based on pre-/post retrofitting
- Data analysis based on pre-/post installations user questionnaires

Preliminary simulation-based evaluation

The BIM model of the selected residence was built in Autodesk Revit for carrying out a set of simulation with its advanced lighting plugin, ElumTools. Specifically, we evaluated the results of selected areas for further assessment, namely one six bedded room, one toilet, the corridor and activity room. Figures 4 and 5 illustrate an example of the simulation results pertaining to illuminance distributions of existing CFL luminaire and proposed retrofitted LED with four levels (i.e., 100, 50, 30, 10 percent) and CCT value 2700 K at the floor and reading levels (0 cm and 85 cm) in selected six-bedded room and the corridor. The results suggest that the proposed retrofitted tunable-white LED has a significant visual performance with higher uniformity compared with the pre-installation scenario.

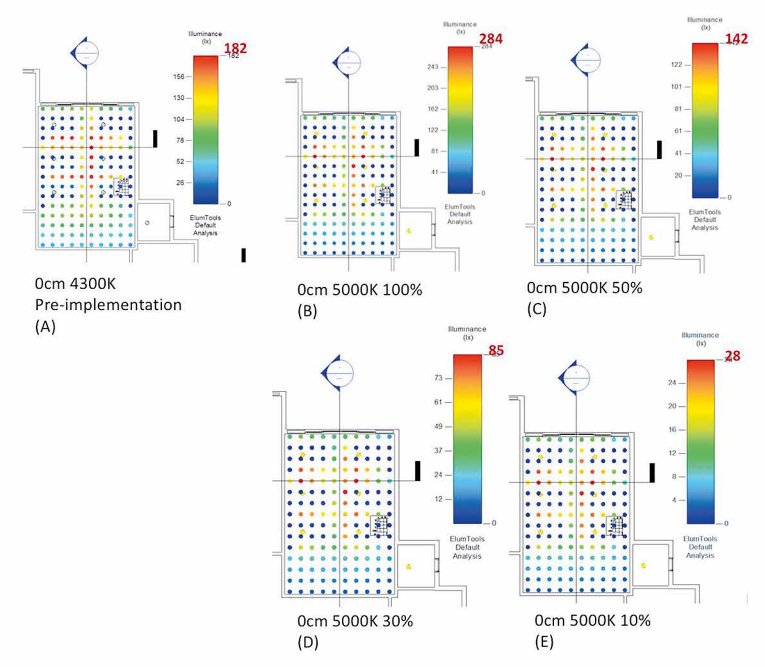


Figure 4: A set of simulation results involving the pre-implementation scenario [A] and four sets of post-implementation scenarios with four levels (i.e., 100, 50, 30, 10 percent) and CCT value 2700K at the floor level (0 cm), namely [B], [C], [D], [E]; unit: lx

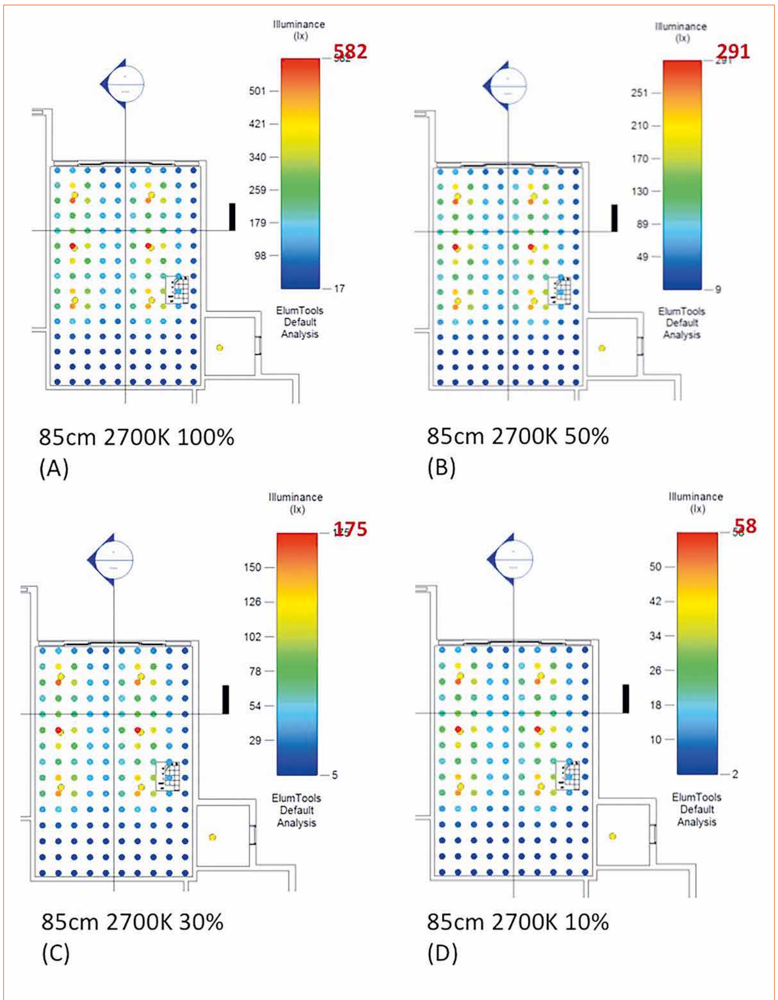
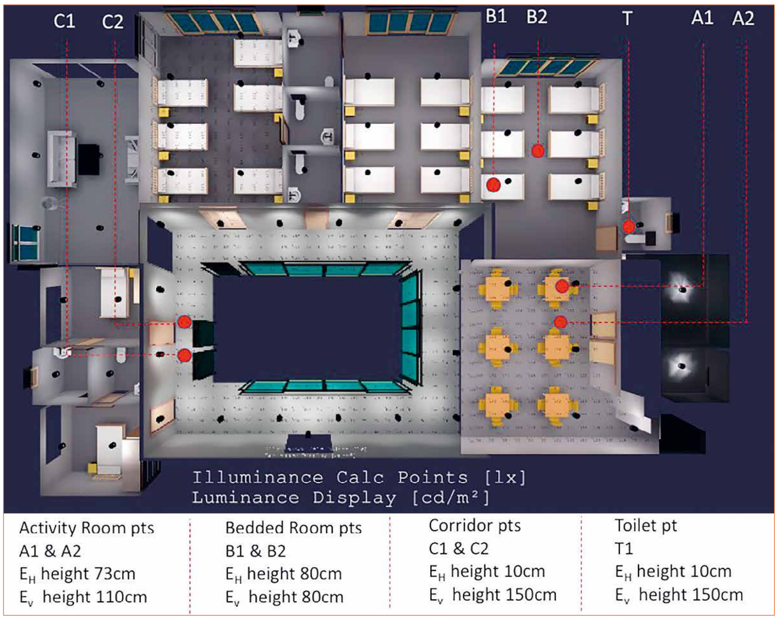


Figure 5: A set of simulation results involving four sets of post-implementation scenarios with four levels (i.e., 100, 50, 30, 10 percent) and CCT value 2700K at the reading level (85 cm), namely [A], [B], [C], [D]; unit: lx

On-site illuminance comparison

In this section, we compared the illuminance measurement data between pre/post- installation scenarios in this residence. As previously mentioned, we have selected two reference points in one six-bedded room (B1, B2), two points in the corridor (C1, C2), two points in the activity room (A1 and A2), and one point in the selected toilet (T1) (Figure 6). The comparison results are arranged in following tables in accordance with the previously described spaces, namely bedded

Figure 6:
The locations of the measurement points with height information



room, toilet (Table 1), corridor, and activity room (Table 2).

Data analysis

The results of the above-mentioned sessions (i.e., Section 5) involving 15 participants were analyzed in terms of three categories.

The categories pertain to:

- Lighting experiences
- Feedback
- Investigation of the residents' perception variables in temporal (i.e., day and night) and spatial (involving bedded room, corridor, toilet, and activity room) approach based on their observation

Thereby, the five-point qualitative Likert scale of the questionnaire was further converted to numerical values (from 1 to 5). Initial results of the analysis if these sessions are given in the following figures as mean values. In addition, we conducted a two-tailed t-test to better evaluate the significant difference between pre and post-retrofitting data. Figure 7 (mean values) compares the evaluation results regarding their lighting experiences in bedded rooms. As the results shown in figure 7 imply, HCL solution in our study provides the participants with significantly pleasant lighting experiences in a bedded room. HCL solution fairs better than CFL in terms of the categories of natural and bright lighting experiences. Figure 8 shows a comparison of theirs' and residents' (via observation) perceptual attitudes in bedded rooms. As the results shown in figure 8 imply, the residents are slightly easier to move around during the night. Also, the residents

Table 1 (right):
Measurement results in the bedded rooms and toilets; unit: lx

	Scenarios	Previous	Retrofitted
Ward/ bedded room	Period	Ad hoc basis	
	Output	100%	75%
	CCT	4700 K	3500 K
B1	Eh	21	26
	Ev	18	22
B2	Eh	25.8	18.7
	Ev	16	13.6

	Scenarios	Previous	Retrofitted
Toilets	Period	Ad hoc basis	
	Output	100%	91%
	CCT	4700 K	3500 K
T1	Eh	28.4	191
	Ev	56.1	107

Table 2 (below):
Measurement results in the corridor, and activity room; unit: lx

	Scenarios	Previous	Retrofitted			
Corridor	Period	0-24 h	08-13 h	14-18 h	17-5:30 h	
	Output	100%	100%	92%	92%	
	CCT	4700 K	5000 K	3500 K	2700 K	
C1	Eh	40	380	245	216	
	Ev	18	199	122	109	
C2	Eh	42	220	135	105	
	Ev	56	85	54	46	

	Scenarios	Previous	Retrofitted				
Dinning/ Activity Room	Period / Ad hoc basis	0-24 h	8-13 h	14-18 h	17-20 h	20-21 h	21-5:30 h
	Output	100%	110%	100%	100%	100%	100%
	CCT	4700 K	5000 K	3500 K	2700 K	3500 K	2700 K
A1	Eh	75	582	600	515	600	515
	Ev	33	111	115	92	115	92
A2	Eh	92.7	170	156	120	156	120
	Ev	28.8	73	69	52	69	52

slightly prefer warm white for the color appearance of the lighting in a bedded room during the night. The nursing staff are slightly more satisfied with the visual environment at night.

Figure 9 and figure 10 compare the results involving lighting experiences perceptual attitudes in the corridor while Figure 11 and Figure 12 do the same for the activity room. As the results shown in figure 9 imply, HCL solution in our study provides the participants with significantly natural and strong lighting experiences in the corridor.
HCL solution in our study provides more pleasant and bright lighting experiences in the corridor.
The results show that staff and residents both have AGREE ratings regarding the sufficient and uniformed brightness of the lighting during the day and night. As the results shown in figure 10 indicate, the residents and staffs significantly prefer cool white in the corridor during the day. Also, residents slightly prefer warm white during the night while the staff significantly prefer warm white during the night.
As the results shown in figure 11 imply, HCL solution provides the participants with significantly more monotonous lighting experiences in activity/dining room. HCL solution fairs better than CFL in terms of the categories of natural lighting experiences. As the results shown in figure 12 imply, the staff significantly prefer warm white for the color appearance of the lighting in the activity room during the night while the residents remain neutral. The residents are slightly more comfortable with light conditions in activity room throughout the whole day. The residents slightly prefer cooler white during the day.
No significant difference for task performance of residents during the day and caregivers during the night. Figure 13 related to the comparison of their and residents' (via observation) perceptual attitudes in the toilet.
The participants left AGREE ratings in terms of the clear path to the toilet due to the sufficient brightness of the HCL lamps throughout the whole day. The participants are with neutral rating in terms of warm white for the color appearance of the lighting in the toilet during the night. As the results shown in figure 13 portray, the residents significantly prefer cool white for the color appearance of the lighting in the toilet during the day. Also, the glare has been slightly restrained.

Figure 7:
Light experience in the bedded rooms (Mean values, N=15); *p<0.05

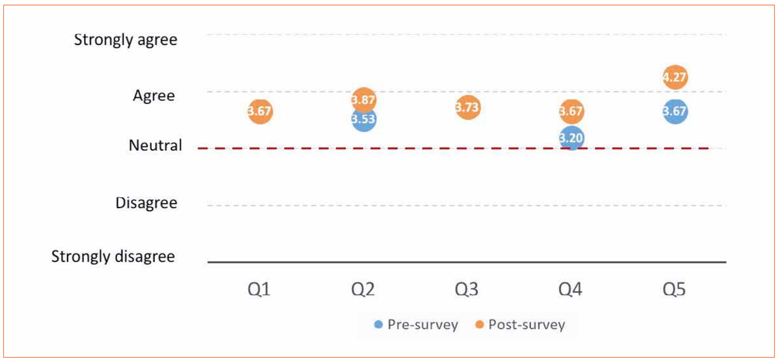


Figure 8:
Evaluation results related to the perceptual attitudes in the bedded rooms (Mean values, N=15)

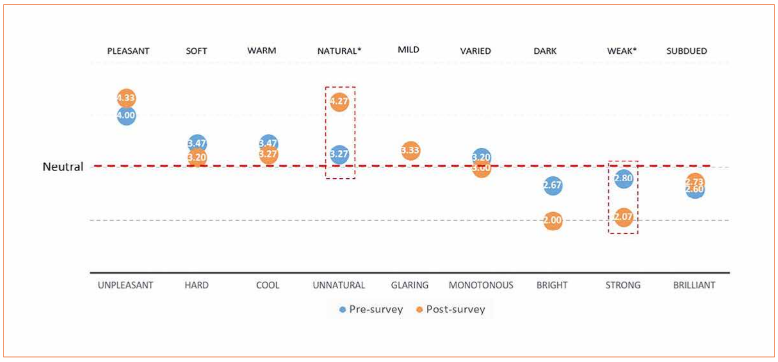


Figure 9:
Light experience in the corridor (Mean values, N=15); *p<0.05

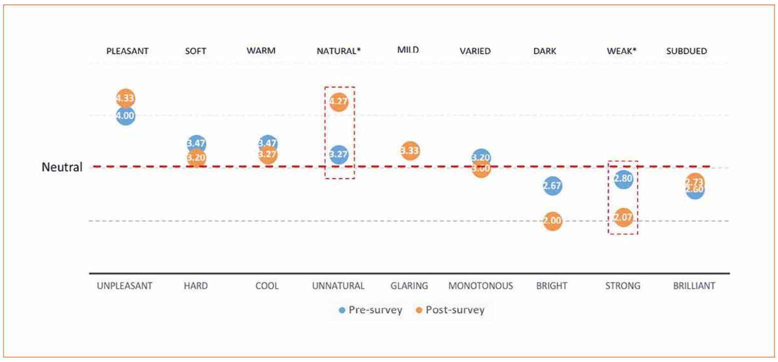


Figure 10:
Evaluation results related to the perceptual attitudes in the corridor (Mean values, N=15); *p<0.05

Limitations

In our research efforts, computational lighting simulations and empirical measurements were successfully applied for the comparative studies. However, the results could be further compared for all the spaces instead of selected rooms and reference points. Also, in order to better evaluate the impacts of HCL lighting, the supplementary data

Figure 11: Light experience in the activity room (Mean values, N=15); *p<0.05

Figure 12: Evaluation results related to the perceptual attitudes in the activity room (Mean values, N=15); *p<0.05

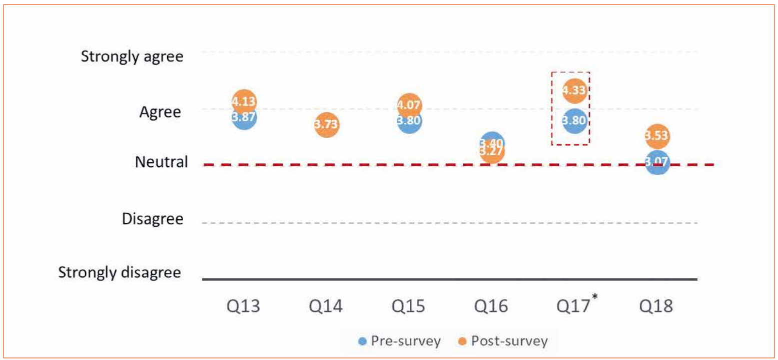


Figure 13: Evaluation results related to the perceptual attitudes in the toilet (Mean values, N=15); *p<0.05

(involving the body health) of the senior with mild dementia collected via FDA-approved wearable devices could be included in future studies.

Concluding Remarks

As the regular circadian rhythm is timely required for those seniors with mild dementia and nursing staff with long-term working hours, it is necessary to specify the circadian practices in the nursing homes based on our findings in previous sections, whereby two primary focus strategies are discussed below. Firstly, the effective methods to maintain the circadian rhythm should be further explored. Such an example includes the optimization of natural light levels with the replacement and/or supplement of electric lighting to artificially stimulate the human circadian system. Thus, the natural light and dark cycles are enhanced to facilitate sleep while natural light spectrum shift with the supplement of artificial lighting over the 24 hours are conducted. Potential applicable spaces in the nursing homes include ward bedded rooms, non-work related windowless environments, common areas, communal environments where relaxation is emphasized. In addition, for gloomy spaces with poor daylight penetration, advanced dynamic lighting control systems could be applied to artificially emulate a cycle of dynamic light with natural color shifts timed for circadian support. Also, it may be applied to provide tunable wavelengths of enhanced blue or white light for the purpose of enhancing performance and eliciting specific behavioral outcomes. Potential applicable spaces in nursing homes comprise nursing stations, dispensing pharmacy point, windowless office environments, night shift work areas, and residential settings for better sleep quality management.

These research efforts contributed to the above-mentioned two focus strategies. The presented paper demonstrated the preliminary study of a design strategy for HCL systems in nursing homes. Firstly, state of the art HCL and aging studies were discussed. We then captured the views to illustrate the preliminary HCL design strategies in a tropical nursing home, whereby the quantitative and qualitative approaches were considered.
The preliminary design strategies were developed and exemplified in a selected nursing home in Singapore. Also, pre-/post implementation user surveys together with quantitative evaluations (involving horizontal and corneal illuminance measurements) were conducted for assessing the performance of the HCL design strategies. These pilot study findings provide initial insight into HCL design-related knowledge and serve as the solid basis towards the HCL best practices in the environment of nursing home in Singapore.
For future phases of this research, we will try to further articulate current effort toward the implementation of HCL for a diversity of space and building types in the Tropics. ■

Acknowledgements:
The research presented in this paper is supported in part by in-kind contributions from Singapore Green Building Council (SGBC), Photizo Global Pte Ltd, and Singapore Institute of Technologies. Authors gratefully acknowledge the support of Prof. Tseng King Jet, Asscoc. Prof. Rosy Tay, Dr. Davy Cheung, and Mr. Christopher Lee toward the completion of this research efforts in this paper.

Appendix: Questions related to the perceptual attitudes in the questionnaire

Q1: The residents are able to fall asleep within 30 minutes in the bedded room during the night in the past month
Q2: The residents are able to move about with ease during the night
Q3: The residents feel safe to move about with the lighting levels during the night
Q4: The residents prefer warm white for the color appearance of the lighting in the bedded room during the night
Q5: You are able to work with ease attending to the residents with the lighting during the night
Q6: The residents can easily perform their tasks with the light conditions in the activity room during the day
Q7: The residents are comfortable with the light conditions in the activity room throughout the whole day
Q8: The residents prefer warm white for the color appearance of the lighting in the activity room during the night
Q9: The residents prefer cool white for the color appearance of the lighting in the activity room during the day
Q10: You are able to provide care to the residents in the activity room with current light condition during the night
Q11: You prefer warm white for the color appearance of the lighting in the activity room during the night
Q12: You prefer cool white for the color appearance of the lighting in the activity room during the day
Q13: The residents can see the path to the toilet during the night
Q14: The lamps provide sufficient and uniformed brightness for the residents in the toilets during the night
Q15: The lamps provide sufficient and uniformed brightness for the residents in the toilets during the day
Q16: The residents prefer warm white for the color appearance of the lighting in the toilet during the night
Q17: The residents prefer cool white for the color appearance of the lighting in the toilet during the day
Q18: The mirrors and tiles do not cause blinding glare (by reflection) throughout the whole day
Q19: The lamps provide sufficient and uniformed brightness for the residents in the corridor during the day
Q20: The residents prefer cool white for the color appearance of the lighting in the corridor during the day
Q21: The lamps provide sufficient and uniformed brightness for the residents in the corridor during the night
Q22: The residents prefer warm white for the color appearance of the lighting in the corridor during the night
Q23: The lamps provide sufficient and uniformed brightness for you in the corridor during the day
Q24: You prefer cool white for the color appearance of the lighting in the corridor during the day
Q25: The lamps provide sufficient and uniformed brightness for you in the corridor during the night
Q26: You prefer warm white for the color appearance of the lighting in the corridor during the night
Q27: There is little distracting reflection and glare is in the corridor

References:

[1] Rea M.S. and Figueiro M.G. (2016). "Light as a circadian stimulus for architectural lighting". Lighting Res. Technol. 2016;0:1-14
[2] Lucas R. J., Peirson S.N., Bersons D. M., Brownl T. M., Cooper H. M., Czeisler C.A., Figueiro M.G., Gamlin P.D., Lockley S. W., O'Hagan J.B., Price L.L. A., Provencio I., Skene D.J.,and Brainard G.C. (2014) "Measuring and using light in the melanopsin age", Trends Neurosci. 37(1): 1–9
[3] Cajochen C. (2007). "Alerting effects of light". Sleep Med Rev. 11(6):453–64
[4] Burkhalter, H.; Wirz-Justice, A.; Denhaerynck, K.; Fehr, T.; Steiger, J.; Venzin, R. M.; Cajochen, C.; Weaver, T. E.; Geest, S. De. (2015). "The effect of bright light therapy on sleep and circadian rhythms in renal transplant recipients: a pilot randomized, multicentre wait-list controlled trial", In Transpl Int., doi: 10.1111/tri.12443, volume 28(1), 2015
[5] Lewy, A. J., Sack, R. L. and Singer, C. L. (1984). "Assessment of treatment of chronobiologic disorders using plasma melatonin levels and bright light exposure: the clock-gate model and the phase response curve". Psychopharmacol. Bull., 20: 561–565
[6] Swaab D, Fliers E, Partiman T. The suprachiasmatic nucleus of the human brain in relation to sex, age and senile dementia. Brain Res. 1985;342:37–44
[7] Hofman MA, Swaab DF. Living by the clock: the circadian pacemaker in older people. Ageing Res Rev. 2006;5:33–51
[8] Skene DJ, Swaab DF. Melatonin rhythmicity: effect of age and Alzheimer's disease. Exp Gerontol. 2003;38:199–206
[9] Lieverse R1, Van Someren EJ, Nielen MM, Uitdehaag BM, Smit JH, Hoogendijk WJ. (2011). "Bright light treatment in elderly patients with nonseasonal major depressive disorder: a randomized placebo-controlled trial". Arch Gen Psychiatry. 68(1):61–70
[10] Hanforda N. and Figueiro M. (2013). "Light Therapy and Alzheimer's Disease and Related Dementia: Past, Present, and Future", J Alzheimers Dis. 33(4): 913–922
[11] Alessi CA, Martin JL, Webber AP, Cynthia Kim E, Josephson KR. Randomized, controlled trial of a nonpharmacological intervention to improve abnormal sleep/wake patterns in nursing home residents. J Am Geriatr Soc. 2005;53:803–810
[12] Ancoli-Israel S, Gehrman P, Martin JL, Shochat T, Marler M, Corey-Bloom J, Levi L. Increased light exposure consolidates sleep and strengthens circadian rhythms in severe Alzheimer's disease patients. Behav Sleep Med. 2003;1:22–36
[13] Burns A, Allen H, Tomenson B, Duignan D, Byrne J. Bright light therapy for agitation in dementia: a randomized controlled trial. Int Psychogeriatrics. 2007;21:711
[14] Lovell BB, Ancoli-Israel S, Gevirtz R. Effect of bright light treatment on agitated behavior in institutionalized elderly subjects. Psychiatry Res. 1995;57:7–12
[15] Hickman SE, Barrick AL, Williams CS, Zimmerman S, Connell BR, Preisser JS, Mitchell CM, Sloane PD. The effect of ambient bright light therapy on depressive symptoms in persons with dementia. J Am Geriatr Soc. 2007;55:1817–1824
[16] Figueiro MG, Gras LZ, Rea MS, Plitnick B, Rea MS. Lighting for improving balance in older adults with and without risk for falls. Age Ageing. 2012;41:392–395
[17] Halper M. (2016). "Human-centric lighting set to drastically improve workplace and individual performance". LEDs Magazine. (Oct 2016). 49–54
[18] Konis K. (2017). "A novel circadian daylight metric for building design and evaluation". Building and Environment. 113(2017). 22–38
[19] Chromaviso. Research in Circadian Lighting and user evidens. http://chromaviso.com/en/ergonomiccircadian- lighting/research-in-circadianlighting/ (20 April 2017, date last accessed)
[20] DOE. Gateway- evaluating a trial LED Lighting System at the ACC Care Center in Sacramento, CA. https://energy.gov/sites/prod/files/2016/ 09/f33/2016_gateway-acc.pdf. (20 April 2017, date last accessed)
[21] Philips Lighting. Elderly Care Home in Solingen Germany. http://www.lighting.philips.com.sg/ cases/cases/healthcare/elderly-care-home. (20 April 2017, date last accessed)
[22] Zumtobel. Improved quality of life for resident dementia patients: St. Katharina research project in Vienna. http://www.zumtobel.com/PDB/teaser/EN/Study_Health_and_Care_StKatharina.pdf. (20 April 2017, date last accessed)

Flex LED Based Smart Light System for Healing of Chronic Wounds

Chronic wounds are notoriously challenging to treat, because they do not follow the typical healing process or time-frame. The resulting burden is significant, affecting over 40 million patients. Blue light is known for its anti-microbial and anti-inflammatory effects in the initial stages of the healing process. David Kallweit, researcher at CSEM and Rolando Ferrini, Section Head at CSEM, report about the joint development of a chronic wound treatment device with their MEDILIGHT partners, URGO RID, University of Heidelberg, SignalGenerix, Microsemi, Technical University of Berlin, and Amires. He furthermore shows how it works and discusses future prospects.

As Blue light is already known for its anti-microbial and anti-inflammatory effects in the initial stages of the healing process and it does not damage tissue, in contrary to hazardous UV light, it is a preferred candidate for the treatment of chronic wounds. However, clear evidence of the beneficial effects of blue-light irradiation in the later stages of wound healing was still missing, thus hindering the development of effective solutions for complete therapy.

With its partners, CSEM developed a new thin and flexible LED based system which enables the treatment of such wounds with blue light. Thanks to this collaboration, it has been demonstrated that blue-light illumination can offer much more than just antibacterial effects. The anti-proliferative functionality has now been clearly proven, showing that blue light can prevent an overshooting epidermization in premature healing stages. The consortium has also shown for the first time that blue light can efficiently activate key cutaneous cells, i.e. keratinocytes and fibroblasts with another appropriate light dose and thereby accelerate the final wound-healing process.

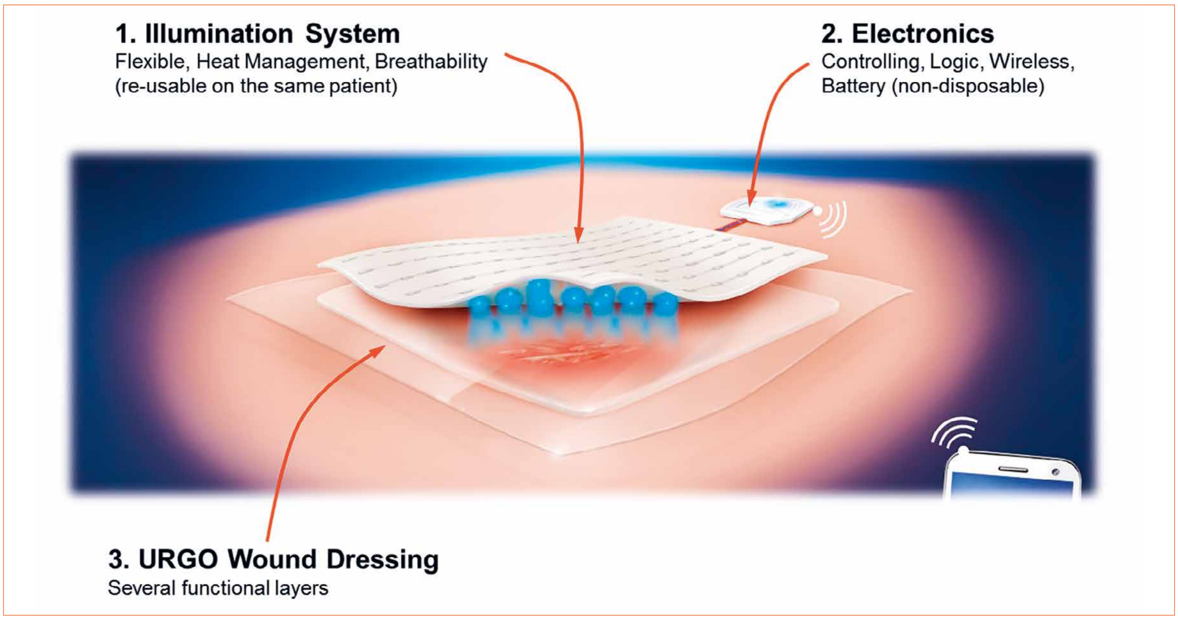


Figure 1:
Illustration of the MEDILIGHT illumination system

The Basics of Wound Treatment with Light

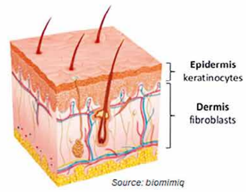
The key to the efficient wound treatment with the developed device lies in the mechanically flexible implementation of a very thin, energy-efficient and homogenous illumination system in combination with an elaborated lighting scheme which determines the applied optical power density and the duration of the treatment subject to the current phase of therapy, e.g. bacterial infection, cleansing, granulation of deeper skin cells (fibroblasts), and epidermization and closing of the wound (keratinocyte cells).

The system also includes sensors to spatially measure the blood oxygenation below the wound, as well as sensors to monitor the temperature. The latter is especially used to ensure that a defined maximum temperature level is not exceeded during the light treatment, thus avoiding the formation of an algesia with the patient. In order to reduce the generated heat to a minimum, a set of measures have been implemented like highly efficient LEDs and diffusor films, light harvesting and back reflection of misdirected light, very-low loss wound dressings, and structures for heat conduction and ventilation.

The whole system can be controlled via Bluetooth and a sophisticated mobile app. It not only allows to apply a certain illumination, but also to program personalized sets of light treatments which individually define point in time, duration, and light intensity, and can also monitor the temperature and blood oxygenation and thus provide a personal treatment history.

The Lighting System

The lighting system consists of two main parts: the controlling electronics and software and the mechanically flexible LED foil with light and heat management and the wound dressing optimized for minimal optical loss.



Healing stage	Infection (Bacteria)	Cleansing (Macrophages)	Granulation (Fibroblasts)	Epidermisation (Keratinocytes)
Purpose	• Limitation of cell proliferation • Inhibition of virulence • Formation of biofilm	• Modulation of macrophage activity (inflammation mediators) • Enhancement of granulation phase	• Proliferation • Migration • Dermis synthesis (collagen)	• Proliferation • Migration • Differentiation
Light Schedule	Confidential Data			
Device Application	Permanent	Permanent	Permanent	Permanent
Sensors	Temperature O_2	Temperature O_2	O_2	O_2

Figure 2:
Different wound healing stages

Figure 3:
Fully functional prototype

Figure 4:
Illustration of the system and its application

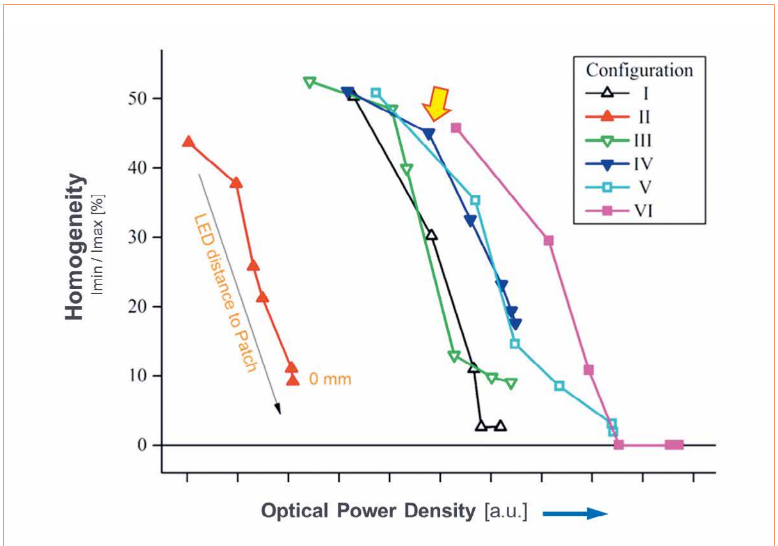


Figure 5:
Summary of the different diffusors being tested

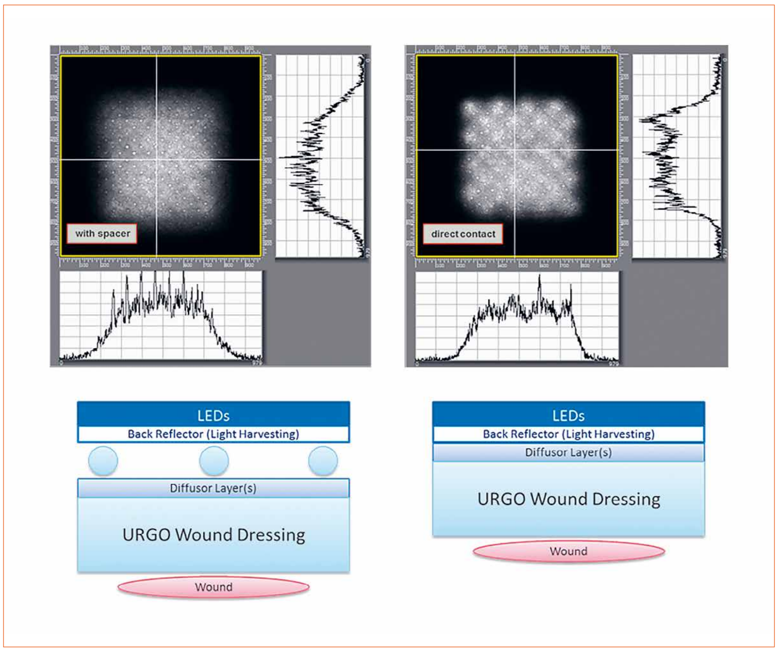


Figure 6:
Illustration of the two optical setups and the corresponding illumination profiles

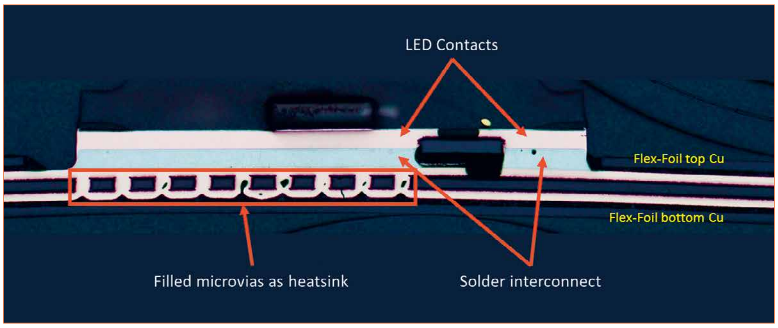


Figure 7:
Cross section through mounted LED on flex foil

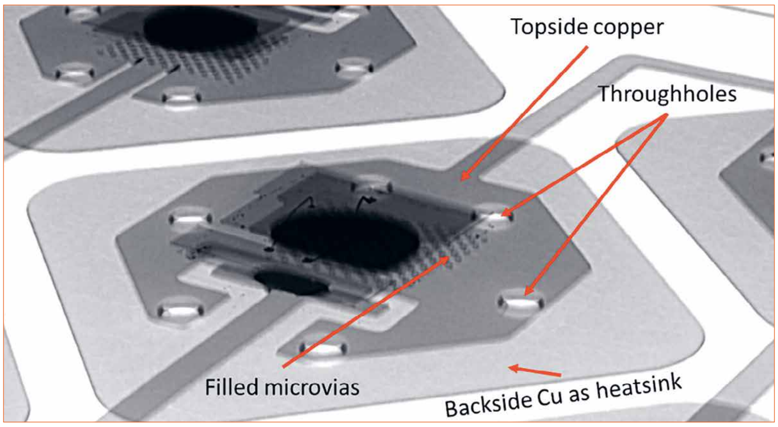


Figure 8:
X-Ray image of a mounted LED

In order to find the best compromise between high illumination homogeneity, but also minimal power loss different diffusor design were built and put under test. The diffusors were placed first in direct contact and then at increasing distances from the LED foil. At each position the intensity distribution was measured and a measure for the homogeneity was calculated. The result is shown in figure 5.

As one can see, and would have expected, the illumination homogeneity increases with increasing distance to the LEDs. On the other hand, the transmitted optical power is also reduced and thus the efficacy of the illumination system is reduced. Finally diffusors "IV" was selected, as it provided quite good homogeneity together with an acceptable efficacy of about 75% (specifications of diffusor and used light intensity is confidential due to possible patent application).

The light for the device is generated by a flex LED foil which is combined with a thin combination of diffusor foils. In order to improve the overall energy efficiency the flex LED foil is equipped with another back reflector foil, which collects the light that is accidentally reflected at the diffusor layer and redirects it towards the wound. Finally, two optical designs were found where he diffusor can be either placed at a certain distance in order to gain a higher illumination homogeneity, or it can even be placed in direct contact to the LED foil, yet providing enough homogeneity of illumination for the biological effects of killing of bacteria and proliferation of skin cells to be effective. Figure 6 shows the two possible optical setups (diffusor with spacer and in direct contact). The corresponding measured illumination profiles are shown on top. The illuminated area shown is 4x4 cm.

In order to reduce the heat generated by the LEDs the flex LED foil, some air vents and copper heat sinks have been implemented in the flex LED foil.

For safety reasons (to avoid overheating and damage to the patient) 5 sensors continuously monitor the temperature. One is located in the center of the illumination area and the other at the four corners. If the temperature threshold of (currently) 40°C threshold is reached the illumination is stopped until, through passive cooling (blood circulation, copper heat sinks, and air vents) the lower threshold of (currently), 37°C is reached again. Then the illumination is started again.

In order to reduce the heat generated by the LEDs they are also driven in pulsed mode. By correspondingly increasing the total duration of the illumination, it is made sure that the total required energy budget is delivered to the wound, which is needed to allow the desired biological effect to kick in.

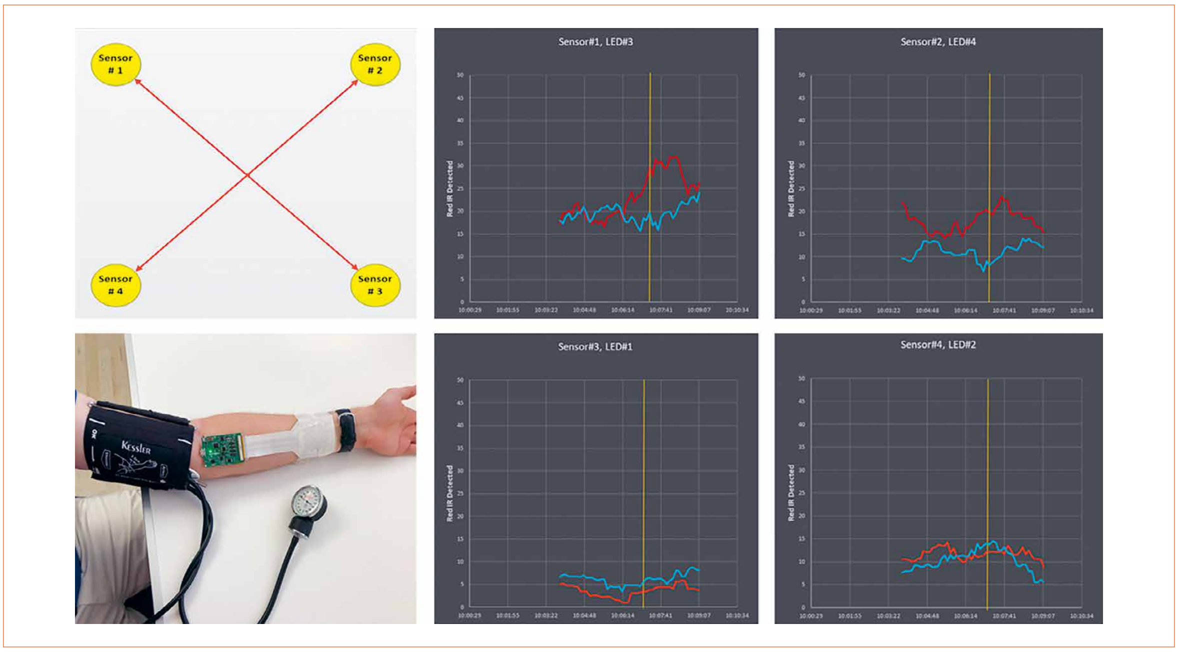
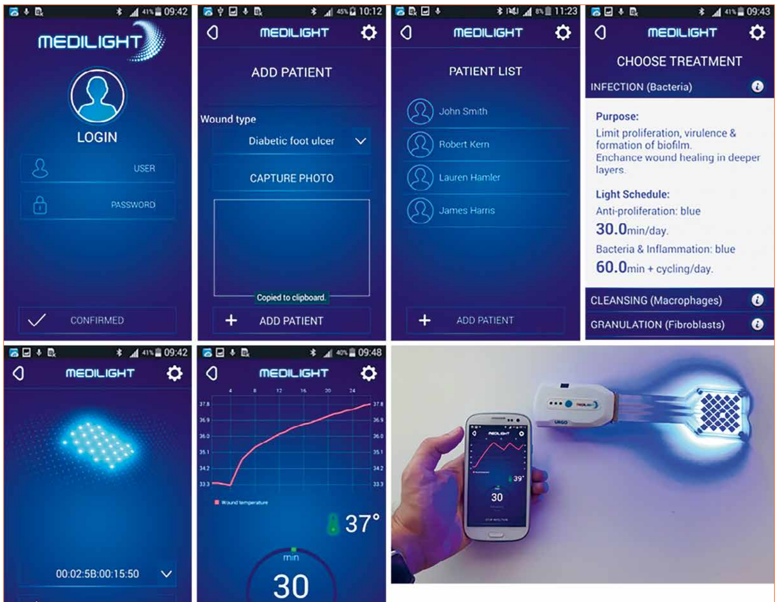


Figure 9: Flex-foil with mounted components

Finally the flex LED foil is also equipped with a sensor system, which allows for the measurement of local blood oxygenation as well as a mapping of the oxygenation of the muscle (across the wound area). Therefore, 4 pairs of red and infrared LEDs and photodiodes are placed in each corner of the wound dressing. By measuring the emitted light within sensor 1 only, one measures the local blood oxygenation. By measuring the light emitted from the opposing LEDs one can also measure the oxygenation of the muscle below the wound area.



Screenshots of the mobile app for controlling the MEDILIGHT device. Personalized light treatment schemes can be set and the temperature is monitored to avoid provoking algesia. The MEDILIGHT device can be controlled wireless.

Figure 10: Implemented sensor for measuring the blood oxygenation at the wound. On the left the mapping across the wound area is shown. On the right the measurement signals for the received red and infrared light that is received from the opposing LEDs is shown

The illumination system is controlled by a small box which can be easily attached to a shoe. Via a mobile app which communicated with the electronic box it is possible to control and program the illumination system. The app also allows to administer a list of devices and patients, which can be individually selected. Thus, subject to the current wound healing status of the respective patient, the doctor can chose and setup the corresponding treatment (illumination) procedure (infection, cleansing, granulation, and epidermization) individually.

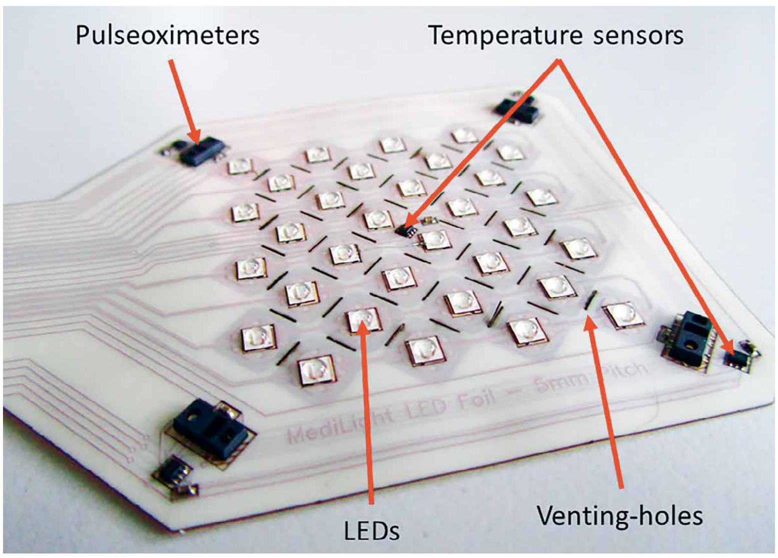


Figure 11: Screenshots of the developed mobile app which allows to control the illumination device

Besides setting the light treatment the app also allows monitoring the temperature situation and history as well as the measurement of the blood oxygen – which takes place

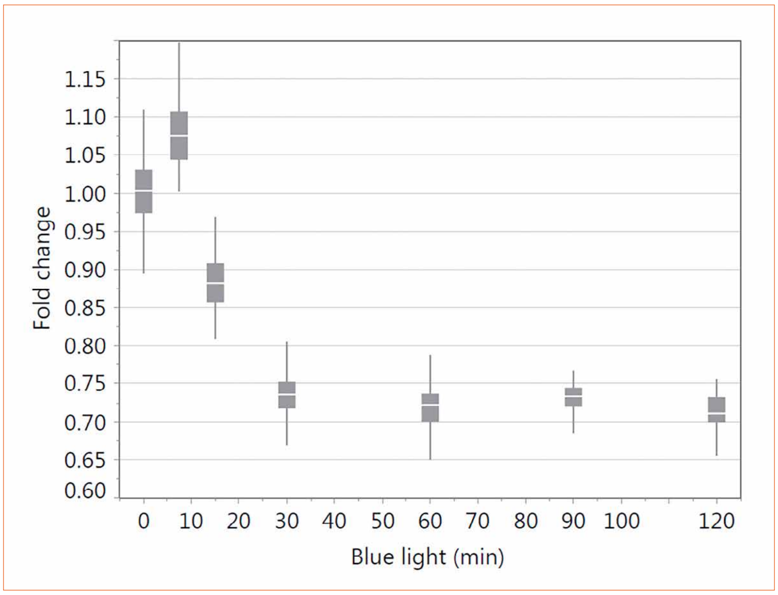


Figure 12:
XTT test results for keratinocytes irradiated with different blue light exposure times (0, 7.5, 15, 30, 60, 90 and 120 min) tested 24 h following light stimulation. Data were normalized using the no light control. The box-and-whisker plots represent the distribution of XTT data values. These are ranked into quartiles, which divide the data set into a box of four equal groups; the band inside the box reflects the median. The whiskers extend from the ends of the box to the outermost data point that falls within the distances calculated as follows: 3rd quartile +1.5* (interquartile range) and 1st quartile -1.5* (interquartile range) (modified from6)

when then wound illumination is switched off. All the light treatments and measurements can be organized and pre-programmed based on an individual schedule. The collected data is stored and can be read and transferred to a secured data server / cloud service.

Biological Effects

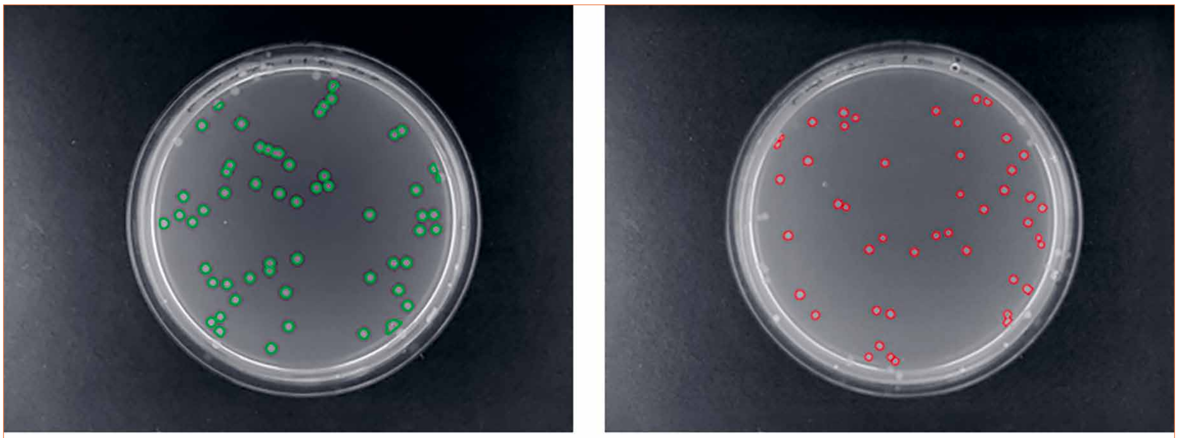
According to the literature, light therapy can be applied for a variety of medical conditions, especially for skin disorders along with tissue regeneration. Non-healing, chronic wounds are characterized by recurrent inflammatory processes, impaired cell function and molecular deficiencies within their microenvironment [1]. The anti-microbial and anti-proliferative effects of blue light are well known and explicitly described in literature [2,3]. In order to improve the wound healing process, MEDILIGHT proposed the use of blue light in early wound healing stages in order to inhibit or even abandon bacterial growth. In addition, it is important to prevent an overshooting epidermization by keratinocytes at the wound surface leading to a premature closure of the trauma. Contrary, red light is supposed to stimulate cell proliferation, migration and differentiation [4], which is decisive in later healing stages leading to a closure starting from the wound bed.

Light schedules using different wavelengths and dosages were at first tested and identified using skin cell types such as keratinocytes and fibroblasts as well as various bacterial strains like Staphylococcus aureus and Pseudomonas aeruginosa, which are the most prominent strains in chronic wounds [5]. The impact of the chosen irradiation schedule was further tested using healthy and diabetic rats to prove the transfer from in vitro to in vivo.

In vitro studies using infra-/red light have not shown the desired effects in keratinocytes and fibroblasts, which is not in agreement with most of the studies published (data not shown). However, lower doses with a defined energy of blue light were found to stimulate cell activity and proliferation. In contrast, higher doses, with a maximum at an irradiation time of 30 min of blue light, slow down cell metabolism (Figure 12) as well as proliferation confirming the anti-proliferative effect without leading to apoptosis [6,7].

Directly following irradiation, levels of reactive oxygen species (ROS) got highly increased leading to the activation of several signaling pathways and downstream processes identifying the aryl hydrocarbon receptor as a possible target for photobiomodulation with blue light [7].

In vitro tests studying the effect of blue light on bacterial strains, revealed promising results with respect to colony count and size analyzed with AutoCellSeg, which is a software analyzing colony counts automatically by adaptive image segmentation and giving room for post-editing [8] (Figures 12a&b).



(A) Untreated bacteria (B) Light-treated bacteria

Figure 13:
Image analysis of plated bacteria, either (A) untreated or (B) light-treated following blue light treatment

Thus, with blue light both issues were solved: On the one hand, bacterial growth and an accelerated epidermization can be blocked with higher doses of blue light, whereas on the other hand, low doses give rise to cell activation and stimulation of proliferation. Both findings help to improve wound management of chronic lesions, which was started to be verified in vivo showing first promising results confirming the outcomes found in vitro.

Outlook

The developed prototype is an ideal solution for a smart, wearable system for blue-light treatment of chronic wounds, such as diabetic ulcers. It further paves the way for the potential future commercialization of devices based on light therapy for monitoring wound healing. The application here is just one example of the many other imaginable applications enabled by the project, as the approach could also target other medical issues in the future.

The discovery and demonstration of the efficacy of blue light in both antibacterial functions and the activation of key cutaneous cells allowed to file two fundamental patents. The results also open the way for other important application opportunities that will address unmet needs, such as the disinfection of medical instruments and operating environments. It is important to note that MEDILIGHT was initially a human adventure. Several teams, several countries, and several skill-sets have joined forces to achieve a single goal: to create innovative healthcare solutions for tomorrow. ■

Acknowledgements:
MEDILIGHT is a European consortium funded within the H2020 Framework Program (grant agreement No. 644267) with an EU contribution of EUR 3.2 million started in February 2015, the project will come to an end in July 2018. The consortium builds on the competencies of the following seven partners: Technische Universität Berlin (TUB), Germany; URGO RID, France; Ruprecht-Karls-Universität Heidelberg, Germany; Centre Suisse d'Electronique et de Microtechnique SA (CSEM), Switzerland; SignalGeneriX Ltd, Cyprus; Microsemi Semiconductor Limited, United Kingdom; and AMIRES s.r.o., Czech Republic.

References:
[1] Frykberg, RG, Banks, J: Challenges in the Treatment of Chronic Wounds. Advances in wound care, 4: 560-582, 2015
[2] Mamalis, A, Garcha, M, Jagdeo, J: Light emitting diode-generated blue light modulates fibrosis characteristics: fibroblast proliferation, migration speed, and reactive oxygen species generation. Lasers in surgery and medicine, 47: 210-215, 2015
[3] Dai, T, Gupta, A, Murray, CK, Vrahas, MS, Tegos, GP, Hamblin, MR: Blue light for infectious diseases: Propionibacterium acnes, Helicobacter pylori, and beyond? Drug resistance updates : reviews and commentaries in antimicrobial and anticancer chemotherapy, 15: 223-236, 2012
[4] Moore, P, Ridgway, TD, Higbee, RG, Howard, EW, Lucroy, MD: Effect of wavelength on low-intensity laser irradiation-stimulated cell proliferation in vitro. Lasers in surgery and medicine, 36: 8-12, 2005
[5] Gjodsbol, K, Christensen, JJ, Karlsmark, T, Jorgensen, B, Klein, BM, Krogfelt, KA: Multiple bacterial species reside in chronic wounds: a longitudinal study. International wound journal, 3: 225-231, 2006
[6] Becker, A, Sticht, C, Dweep, H, van Abeelen, FA, Gretz, N, Oversluizen, G: Impact of blue LED irradiation on proliferation and gene expression of cultured human keratinocytes. SPIE (Ed) SPIE BiOS San Francisco, International Society for Optics and Photonics, 2015
[7] Becker, A, Klapczynski, A, Kuch, N, Arpino, F, Simon-Keller, K, De La Torre, C, Sticht, C, van Abeelen, FA, Oversluizen, G, Gretz, N: Gene expression profiling reveals aryl hydrocarbon receptor as a possible target for photobiomodulation when using blue light. Scientific reports, 6: 33847, 2016
[8] Khan, AUM, Torelli, A, Wolf, I, Gretz, N: AutoCellSeg: robust automatic colony forming unit (CFU)/cell analysis using adaptive image segmentation and easy-to-use post-editing techniques. Scientific reports, 8: 7302,

Voice Controlled Lighting that Protects Privacy and Data

Intelligent lighting systems undoubtedly offer high comfort and energy efficiency. But conventional voice control systems like Amazon Alexa, Apple Siri or OK Google that have connected lamps and lighting fixtures, are becoming targets for uninvited guests. The benefits and technology of a new approach offering local voice control and artificial intelligence will be explained by Genia Shipova, Director Global Communications at Snips.

Intelligent lighting systems undoubtedly offer high comfort and energy efficiency. But connected lamps and lighting fixtures are also becoming targets for uninvited guests. Like many connected devices, the smart lights potentially open a gateway for cyber-attacks or a backdoor to information that should better remain within users' homes or offices. The problem becomes even more pressing when lights are not only 'smart' but also voice-controlled, since voice data is a biometric identifier and is as unique to users as their fingerprints. As more homes and offices are connected with voice-controlled lighting installations, the threat of breaches only increases. Yet this does not have to be the case. Lighting can also be controlled locally, on-device using voice and in compliance with European regulations and while protecting privacy.

With the enforcement of the European General Data Protection Regulation (GDPR) coming into effect this year, security and privacy must also be taken into consideration for intelligent lighting devices. Proactive measures are required to avert damage to companies and their customers. While the introduction of voice-controlled lighting undoubtedly offers new experiences for end users, companies must take proactive steps to protect their customers in the wake of this new legislation.

Companies have traditionally approached adding voice to products by leveraging cloud servers to perform machine learning and process voice data. This offered high-performance voice recognition but is potentially jeopardizing security and privacy.

Process Speech Locally

The AI voice specialist Snips, is committed to protecting privacy when using voice to control lights, lighting fixtures and many other connected devices. The company's approach is impressively simple, but the solution is anything but trivial because the necessary know-how is based on the use of mechanisms of artificial intelligence and machine learning.

The voice interface is based on the idea of completely local language processing and control. This means that the private user data never leaves the local installation. Accordingly, the system is private by design and compliant with even the strictest data protection regulation.

This approach has significant implications for smart lighting companies. First of all, there is the question of effort: Why should the cloud be used to manage such a simple procedure as switching on the light? Secondly, there is the question of accessibility: why should switching on or dimming the light depend on whether the Internet is available? If the Internet fails or the router is defective, customers could literally be caught in the dark.

Simple requirements call for simple solutions. Switching on the light is based on very few voice commands. There is no need to send a command like “turn on the light” or “dim the lights in the kitchen by 30%” to the cloud for processing. OEMs can also embed voice interfaces on microcontrollers that work offline and are also tailored to the product and brand. This is both cost-efficient and helps to calculate profitability because no costs are incurred for the actual use.

Embedded Solutions for OEMs

Companies like Alexa and Google force the OEMs who integrate with their platforms to sacrifice a degree of their brand identity and customer relationships. For lighting OEMs, utilizing an embedded voice platform allows them to decouple their offers from aggressive third parties who might market competing offers or release their own offer and take more control of their customer’s voice experience.

The architecture is designed to enable OEMs to design and build customized voice solutions by manufacturers of virtually any device, but can also be easily used by developers and makers. For this purpose, parts of the technology stack are open to the public, making it possible for everybody to set up a low-cost voice-controlled lighting system.

Selecting the Fitting Hardware

The hardware set-up to create a functional solution depends on the level of sophistication of the intended use case. It is important to understand that all hardware components must be matched in their performance to each other in order to enable the desired functionality. This is, at the end of the day, a question of finding a consistent set-up to balance the intended level of functionality, comfort and pricing.

The choice of the appropriate microphone, for example, shows the complexity combined with the development of merchantable products that meet the customers’ expectations. Many of the devices used for voice control purposes (e.g. home assistants, speakers, entertainment hubs, coffee machines, lighting control) typically sit somewhere in a room, at a certain distance away from the speaker. And just like the remote control allows to switch TV channel while staying in the couch, it is important to enable voice-controlled devices to understand what is said without having to walk up close to them and start shouting. Furthermore, we don’t want the devices to start triggering commands when we are not explicitly asking for them to do so, so we expect some tolerance to noise, music or conversations others might be having in the room.

Summing up, a good microphone for that purposes would:

- Allow the user to speak anywhere in the room, that is, from long distances, and from any angle
- Be resistant to various kinds of noise (music, conversations, random sounds)

Finding a microphone matching these criteria is a bit of a challenge. Cheap, generic USB microphones turn out to be unsuited for the task. They only capture sound coming from up close, and from a specific direction. The microphone arrays themselves do not solve the problem of understanding what we are saying to the devices, but they certainly are an essential component.

Many of today’s voice-enabled devices work in the following way: they remain passive until the user pronounces a special wake word, or hotword, such as “Alexa”, “OK Google”, “Hey Snips”, which tells the device to start listening carefully for what the user is saying. Once in active listening mode, it attempts to transcribe the audio signal into text, performing so called Automatic Speech Recognition [1] (or ASR for short), the goal being to subsequently understand what the user is asking for, and act accordingly.

Hotword Detection and Automatic Speech Recognition

Hotword detection and ASR are two distinct problems, and they are usually treated independently. Good hotword detection software must have high recall and high precision: it should always detect a hotword when it is spoken, and it should absolutely not detect a hotword when it has not been spoken. Indeed, we don’t want to have to repeat ourselves when triggering an interaction, and we don’t want the device to start listening when it hasn’t been asked to.

Similarly, the ASR processes the audio signal and translates it into the corresponding words. A spoken sentence is nothing more than a sequence of phonemes [2]. Therefore, a fair bit of the complexity lies in capturing a reasonably good audio signal so that the ASR can differentiate between phonemes and construct the most accurate text sentence. If noise levels are too high and the audio saturates, the ASR could misunderstand a word.

There are various factors which affect the quality of hotword detection and ASR. Some words are simply not suitable as hotwords, for instance if they are difficult to pronounce (“rural”) and hence difficult to detect, or if they are too close to words you would commonly use (“hey”), as they would constantly trigger the device when you are having a conversation nearby. Good acoustic models are trained so as to be robust to ambient noise, sound levels, variation in pronunciations and more. However, if the microphone can consistently provide a clean audio signal regardless of the situation, it will drastically improve the performance of hotword detection and ASR, and hence of the end user experience. That is why microphone arrays usually feature a dedicated chip, a Digital Signal Processor (DSP), for performing things like noise reduction, echo cancellation and beamforming.

The example shows the interdependencies between the quality used hardware components and the desired comfort and performance of the whole solution. Objectively benchmarking microphone arrays is not straightforward, as results will of course depend on the underlying acoustic models.

Complex Language Training

Although the majority of voice-controlled lighting requirements may be limited for the moment, this approach is still at the forefront of voice adoption and additional use cases will develop over time. For example, voice-controlled lighting setups shouldn't just control lighting in one room, but rather in the entire house or office.

Most cloud-based voice platforms introduce additional use cases by analyzing how people are using their assistants with machine learning. Yet this often ends up delivering an inferior user experience that is often referred to as the "cold start" problem. Essentially, voice assistants frequently aren't very good right away when a user turns them on. This problem is solved by performing machine learning before it gets in the hands of the user. Therefore, it is inevitable to working together with the respective manufacturers to train their assistants directly to a use case and brand.

The Ecosystem

The ecosystem comprises a web console to build voice assistants and train the corresponding Spoken Language Understanding (SLU) engine, made of an Automatic Speech Recognition (ASR) engine and a Natural Language Understanding (NLU) engine. The console can be used as a self-service development environment by businesses or individuals, or through professional services.

The Platform is free for non-commercial use. Since its launch in the summer of 2017 over 23,000 voice assistants have been created by over 13,000 developers. The currently supported languages are English, French and German, with additional NLU support for Spanish and Korean. More languages are added regularly.

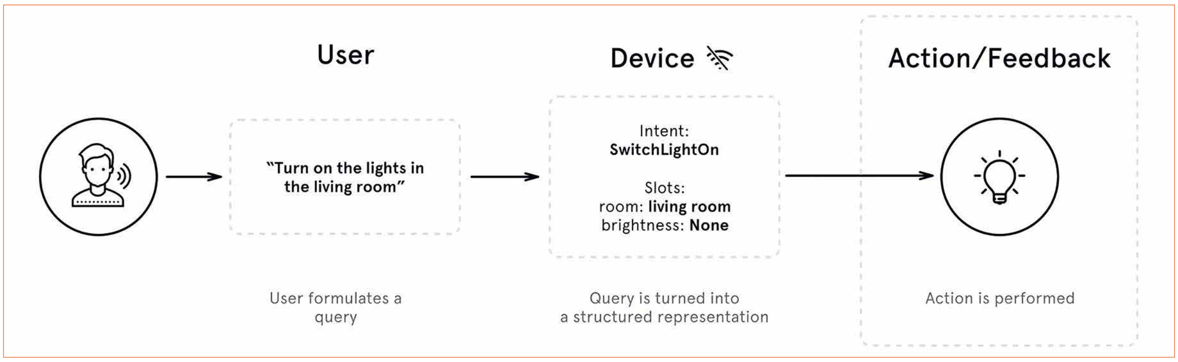
An assistant is composed of a set of skills - e.g. SmartLights, SmartThermostat, or SmartOven skills for a SmartHome assistant - that may be either selected from preexisting ones in a skill store or created from scratch on the web console. A given skill may contain several intents, or user intention - e.g. SwitchLightOn and SwitchLightOff for a SmartLights skill. Finally, a given intent is bound to a list of entities that must be extracted from the user's query - e.g. room for the SwitchLightOn intent. When a user speaks to the assistant, the SLU engine trained on the different skills will handle the request by successively converting speech into text, classifying the user's intent, and extracting the relevant slots.

Once the user's request has been processed and based on the information that has been extracted from the query and fed to the device, a dialog management component is responsible for providing a feedback to the user, or performing an action. It may take multiple forms, such as an audio response via speech synthesis or a direct action on a connected device - e.g. actually turning on the lights for a SmartLights skill. Figure 1 illustrates the typical interaction flow.

The language modeling component of the platform is responsible for the extraction of the intent and slots from the output of the acoustic model. This component is made up of two closely-interacting parts. The first is the language model (LM), that turns the predictions of the acoustic model into likely sentences, considering the probability of co-occurrence of words. The second is the Natural Language Understanding (NLU) model, that extracts intent and slots from the prediction of the Automatic Speech Recognition (ASR) engine.

In typical commercial large vocabulary speech recognition systems, the LM component is usually the largest in size, and can take terabytes of storage. Indeed, to account for the high variability of general spoken language, large vocabulary language models need to be trained on very large text corpora. The size of these models also has an impact on decoding performance: the search space of the ASR is expanded, making speech recognition harder and more computationally demanding. Additionally, the performance of an ASR engine on a given domain will strongly depend on the perplexity of its LM on queries from this domain, making the choice of the training

Figure 1:
Interaction Flow



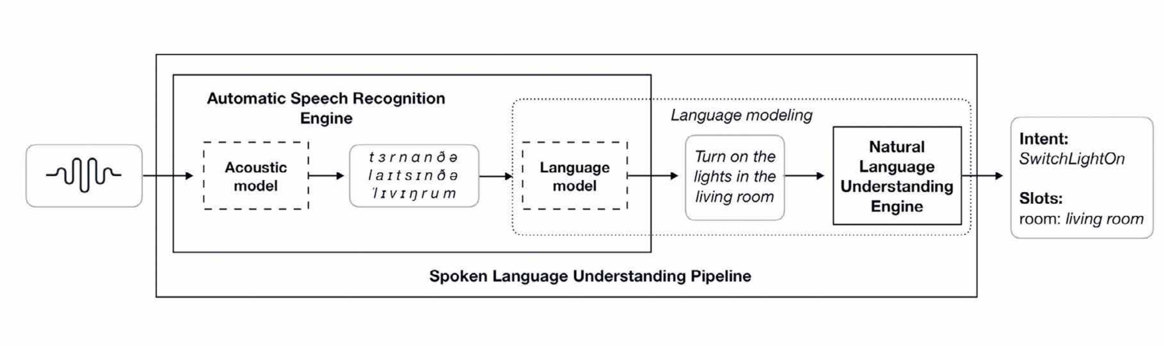


Figure 2: Spoken Language Understanding Pipeline

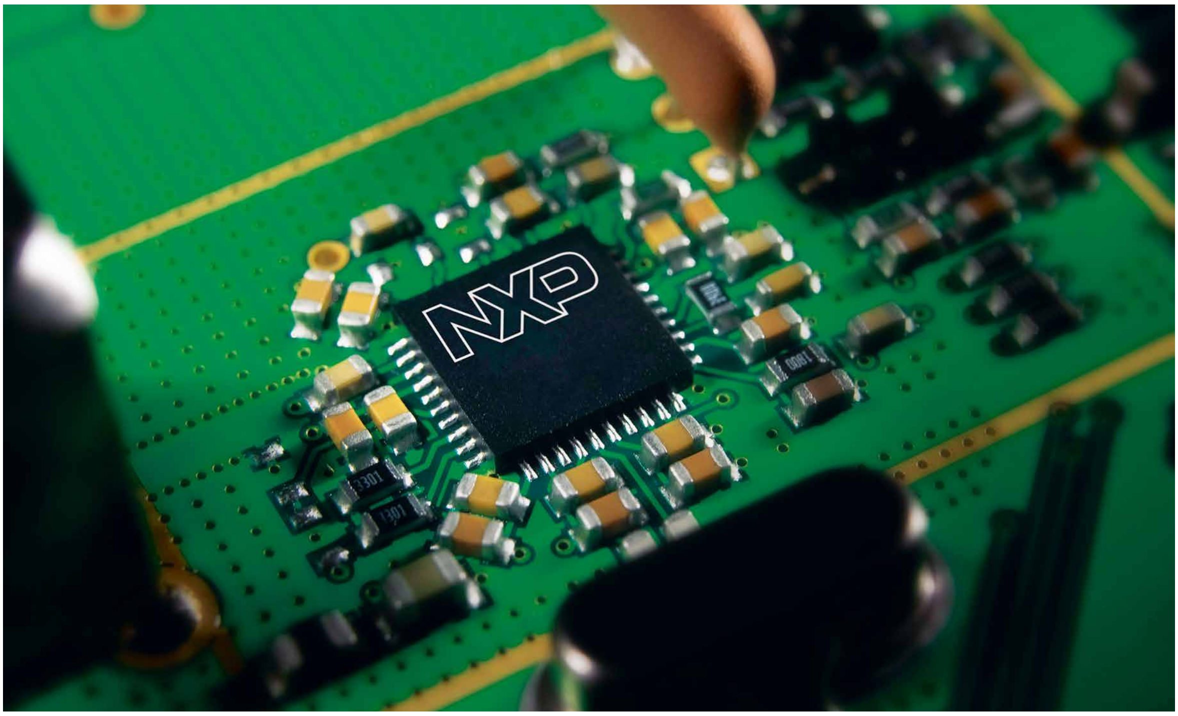


Figure 3: The processor capacity is defined by the intended use case

text corpus critical. This question is sometimes addressed through massive use of users' private data.

One option to overcome these challenges is to specialize the language model of the assistant to a certain domain, e.g. by restricting its vocabulary as well as the variety of the queries it should model. In fact, while the performance of an ASR engine alone can be measured using e.g. the word error rate, Snips assess the performance of the SLU system through its end-to-end, speech-to-meaning accuracy, i.e. its ability to correctly predict the intent and slots of a spoken utterance. As a consequence, it is sufficient for the LM to correctly model the sentences that are in the domain that the NLU supports.

Conclusion

The system is well prepared for future tasks and probably the key element for this is the design of the language model: The size of the language model is thus greatly reduced, and the decoding speed increases. The resulting ASR is particularly robust within the use case, with an accuracy unreachable under the hardware constraints for an all-purpose, general ASR model. This design principle makes it possible to run this SLU component efficiently on small devices with high accuracy as requested for e.g. for smart lighting use cases.

References:

[1] Automatic Speech Recognition: https://en.wikipedia.org/wiki/Speech_recognition
[2] Phonemes: https://en.wikipedia.org/wiki/Phoneme
[3] Digital Signal Processor (DSP): https://en.wikipedia.org/wiki/Digital_signal_processor
[4] Beamforming: https://en.wikipedia.org/wiki/Beamforming

Circadian-Friendly Light Emitters: From CCT-Tuning to Blue-Free Technology

Common levels of blue radiation are sufficient to disrupt the circadian cycle, calling for blue-depleted emitters in the evening. Most current solutions employ low-CCT and suffer from poor light quality. Aurelien David, chief scientist at Soraa explains the melanopic lumen and its possible sources of inaccuracy related to the uncertainty in assessing the circadian action spectrum. He also discusses the concept of a blue-free emitter with minimal melanopic lumen at very low CCT, and how such a spectrum providing good light quality can be optimized.

The last two decades of research have revealed a significant effect of blue radiation on our circadian cycle, calling for suitable light emitters. The basics of these physiological effects of blue light are first reviewed. Metrics to measure these effects are introduced, and variations in the estimated circadian action spectrum are illustrated. Strategies to influence circadian entrainment are discussed, including CCT-tuning and more advanced spectral engineering. Finally, the specific challenge of offering low-entrainment light emitters is highlighted; a solution based on the novel blue-free technology is presented, and shown to break the trade-off between light quality and circadian entrainment plaguing conventional LED sources, with applications in general lighting and displays.

Light and Sleep – Scientific Foundations

Light has long been known to influence the circadian cycle through non-visual channels. In the early 2000's, significant progress in understanding was achieved when the specific vector for this stimulus was discovered [1,2]: besides the four visual cells, the human retina comprises a non-visual cell type, the intrinsically photosensitive retinal ganglion cell (ipRGC).

The study of the circadian effects of light is a still-evolving field. However, a few results are well accepted.

The ipRGCs are maximally-sensitive to blue-cyan light, with a peak around 460-490 nm. ipRGC stimulation causes direct non-visual physiological signals – inducing the suppression of melatonin and other hormones – and has a direct influence on our circadian cycle [3,4]. This stimulation is governed by the total dose of stimulating radiation reaching the ipRGCs (i.e. the amount of radiation, weighed by the ipRGC sensitivity) [5]. From an evolution standpoint, this sensitivity is understandable: morning daylight is bright and rich in blue radiation, providing a natural synchronization signal.

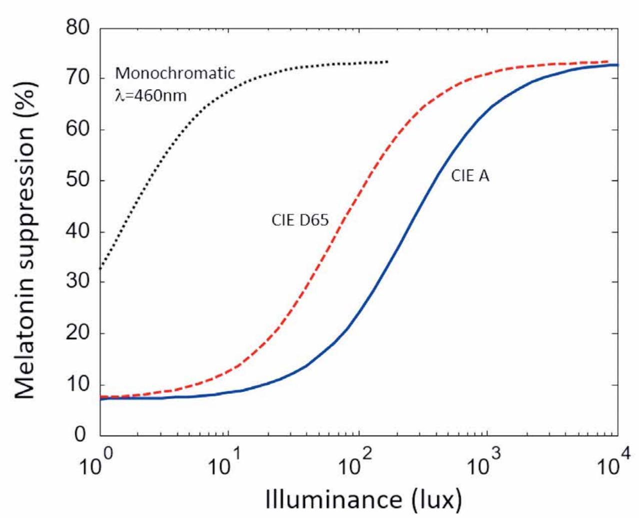


Figure 1: Melatonin suppression (after two hours of light exposure) versus illuminance, for various light sources

Figure 1 shows the melatonin suppression (after two hours of light exposure) versus illuminance, for various light sources. The dashed curve is after the experimental data of [6] and shows the response to monochromatic blue light. The other two curves are derived from this data and show the response for two white-light reference illuminants: respectively CIE A (2,800 K) and CID D65 (6,500K). In each case the curve has a so-called sigmoidal shape: it saturates for very low and high retinal illuminance levels. Note the logarithmic scale of the x-axis indicating that, in the sensitivity region, a large-enough change in illuminance (typically a factor of two to ten) is required to significantly affect melatonin suppression

The effect of blue radiation on our sleep cycle is a form of circadian entrainment. Entrainment is often evaluated experimentally by measuring the suppression of melatonin in saliva after exposure to light. Melatonin suppression only has an indirect relationship to sleep (contrary to common belief, melatonin does not cause sleep per se, and instead indicates exposure to obscurity). However, because melatonin is much easier to measure than quality of sleep in experiments, it constitutes a convenient proxy for discussions of light and circadian effects.

Crucially, melatonin suppression exhibits a non-linear response to the total dose of stimulating light, as illustrated in figure 1. Foundational research on the circadian impact of light was first conducted with monochromatic blue radiation [6], for which the relationship between dose and melatonin suppression was directly measured. From these measurements, equivalent curves can be derived for white light sources by considering the amount of blue radiation in their spectra. As seen in figure 1, melatonin suppression depends strongly on illuminance: low light levels cause negligible suppression, whereas at high levels the suppression happens over a short time scale and saturates at longer times.

Importantly, it has been shown that regular amounts of indoor artificial light are also sufficient to cause circadian stimulation [7,8].

Given this medical understanding, the lighting industry has been trying for the last few years to develop products which respect or influence our circadian cycle – an approach often described under the umbrella term “human-centric lighting”. Two essential aspirations of human-centric lighting are to offer high circadian stimulation in the morning (to help synchronize our internal clocks) and limited stimulation in the hours before bedtime (to avoid sleep disruption). This has proven to be a challenging task, in part because the underlying scientific understanding is only partial, making it difficult to ensure that products indeed provide the benefits they claim.

Quantifying Circadian Entrainment – Methods and Uncertainties

A central challenge is to translate the general concepts described above into simple quantities, enabling engineers to develop a light source. The main approach retained today is to compute an effective amount of circadian stimulation by weighing the SPD of a light source with a so-called circadian action spectrum (an estimate of the wavelength-sensitivity of our circadian system). The result of this calculation is sometimes called the melanopic lux: a quantity derived in analogy with the well-known lux, but where the photopic sensitivity curve V(λ) is replaced by the circadian action spectrum. Given two sources of same illuminance, the melanopic lux compares their relative potential for entrainment.

The concept of melanopic lux implies significant simplifications. For instance, it ignores the dynamic aspects of circadian response – including the fact that the impact of a light source depends strongly on the history of prior light exposure during the day [5]. Further, it assumes that only the ipRGCs influence the circadian system, whereas it is known that visual receptors also have an influence. These simplifications, although significant, appear necessary given our state of knowledge to enable engineering applications.

Another source of uncertainty comes from the estimation of the circadian action spectrum itself, which isn't an easy task. It took decades of careful work for color scientists to determine the spectral sensitivity of the corneal cones, which dictate our color vision – and similar research regarding the ipRGCs is ongoing. The current estimates all agree that the spectral

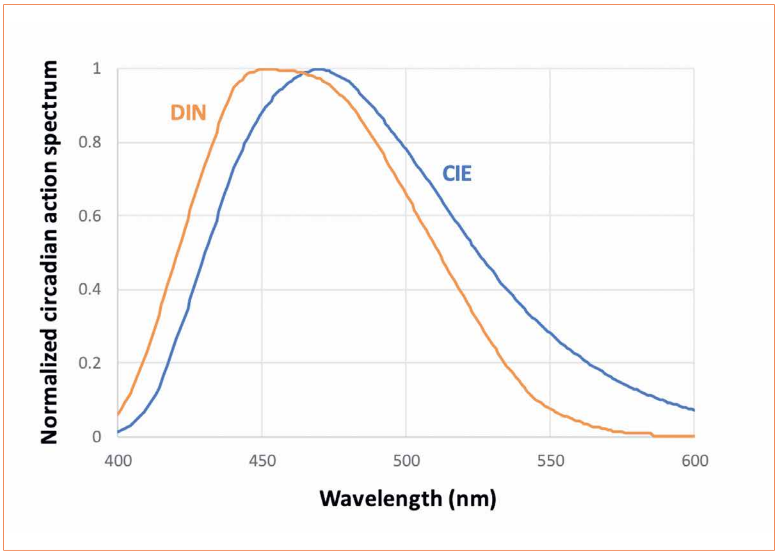


Figure 2: Examples of circadian action spectra, proposed by the CIE and the DIN

sensitivity is maximal around 460-490nm, but they differ in the shape of their short- and long-wavelength tails.

Figure 2 shows two action spectra retained by standard-setting entities: the International Lighting Commission (CIE) and the German Institute of Standards (DIN), illustrating such differences in sensitivity at short and long wavelength. Yet other estimates in literature suggest the action spectrum may be narrower.

The CIE action spectrum in particular has garnered some consideration. It is the basis for the melanopic lux calculation in the software toolbox of reference [9] – which will be used in this Article. It forms the basis for human-centric specification in the recent WELL building standard.

Spectral Engineering for Circadian Entrainment

These calculations enable the engineering of a spectral power distribution (SPD) for increased or decreased circadian stimulation, an opportunity which has garnered much attention in the lighting community. In the following, various approaches are reviewed.

CCT tuning

Given the maximal sensitivity of the action spectrum to blue radiation, one naturally expects that emitters of higher correlated color temperature (CCT), which emit more short-wavelength radiation, should cause more entrainment. This is indeed the case, as illustrated on figure 3a, which shows the fraction of blue light and the melanopic lumen for blackbody radiators of various temperatures: the melanopic lux roughly increases between 2,500 K and 5,000 K.

Figure 3a shows the melanopic lux for a series of blackbody radiator emitters of varying CCTs, each with an illuminance of 100 lux. The higher amount of blue radiation at higher CCT translates into a higher melanopic lux. Figure 3 b shows a comparison of two LED SPDs with a same CCT of 5,000 K. Deep blue curve: conventional white LED with a blue-pump LED having a peak wavelength 440 nm (CRI Ra=80 / R9 = 0, melanopic lux = 75). Light blue curve: LED with blue-cyan pump LED and modified phosphors (CRI Ra = 70 / R9 = 0, melanopic lux = 105)

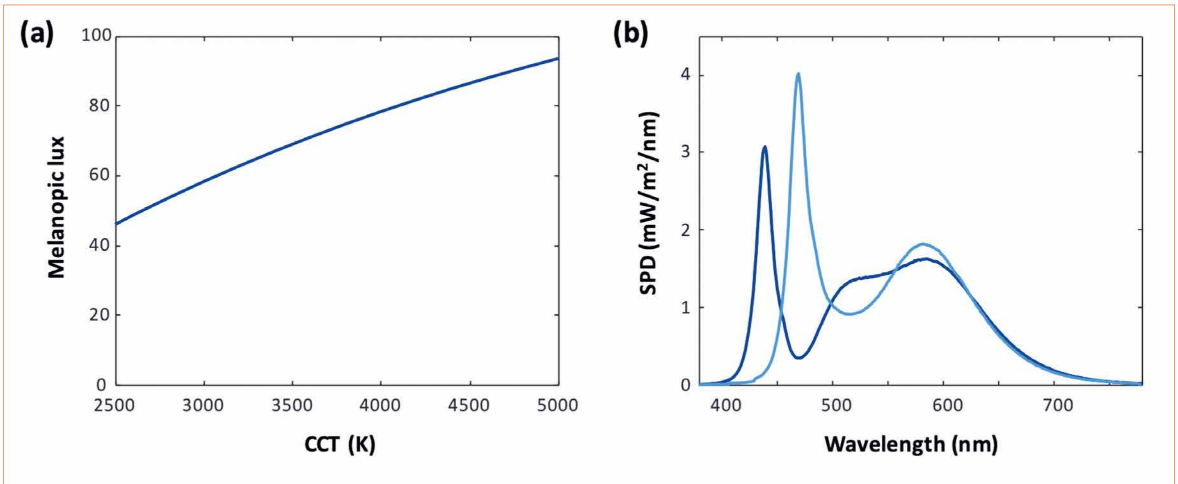
It should be kept in mind, however, that CCT tuning must be considered together with illuminance levels to have a meaningful effect on circadian entrainment, because circadian response saturates at low and high light levels. This is seen in figure 1. Comparing the melatonin suppression of an A-lamp (2,800 K) and a cool white emitter (6,500 K), the difference is sizable at moderate illuminance levels (around 100 lux), but small or even negligible at low and high illuminance (below 10 lux or above 1,000 lux).

Therefore, CCT-tuning can indeed be impactful, provided it is combined with an appropriate level of light – i.e. a few hundred lux, where our circadian system is most sensitive. Fortunately, such lighting levels are in fact typical of indoor lighting. The effect of CCT-tuning in indoors lighting has been documented in studies [10].

Blue-enriched spectra for increased stimulation

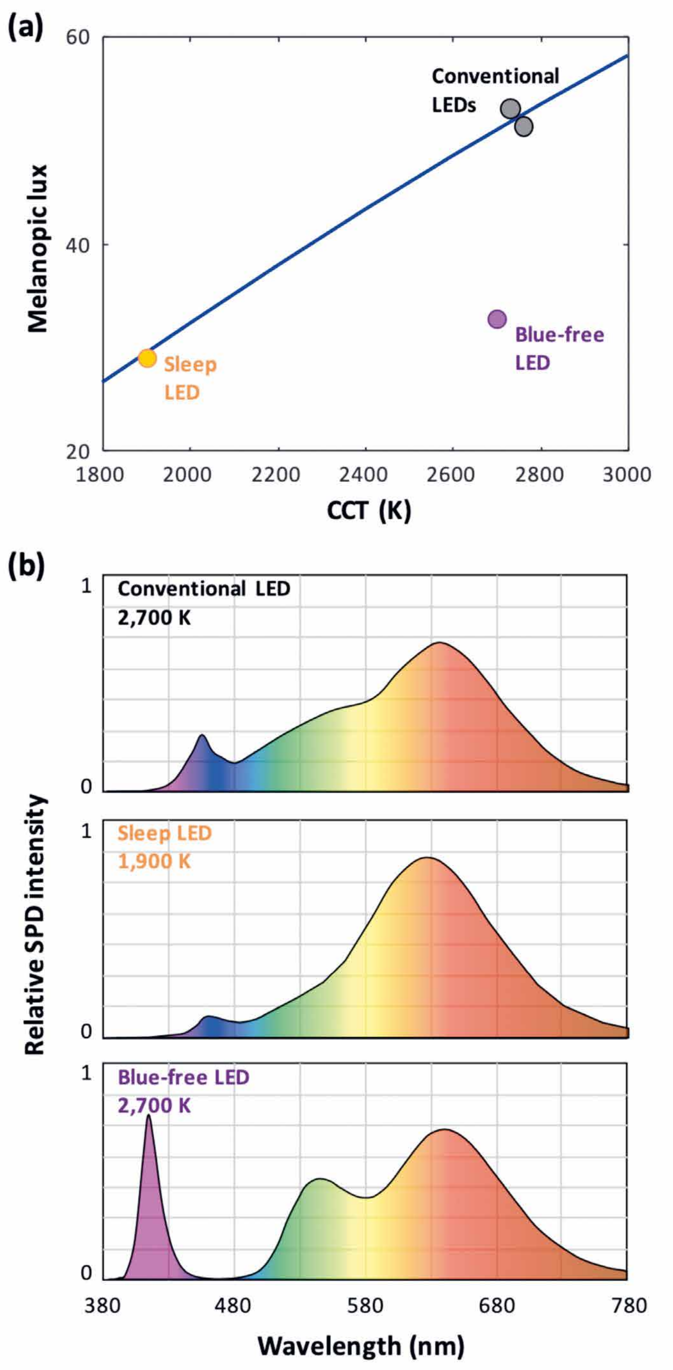
Beyond the CCT trend discussed above, lighting manufacturers are seeking to engineer SPDs in order to further influence entrainment for a given CCT. For LED emitters, this can be achieved by selecting proper wavelengths for the pump LEDs and phosphors, to manipulate the detailed shape of the SPD.

A well-known example is that of "blue-enriched" SPDs. Given the objective to maximize entrainment in the morning, the first step is to use a high CCT as just discussed, but the lighting designer may decide that there is a maximum acceptable value – say 5,000K. Given this CCT, the SPD can be optimized to increase melanopic lux. Figure 3b shows an example, where a conventional blue-pump LED (λ = 440 nm) is replaced with a blue-cyan LED (λ = 470 nm), resulting in a 40% relative increase in melanopic lumens. This comes at a cost on color rendition however, since in this example the CRI drops from 80 to 70 – these specific values aren't fundamental, yet they



Figures 3a&b: Melanopic lux for a series of blackbody radiator emitters of varying CCTs (a) and SPDs for two LEDs at CCT 5000 K (b) illustrate the existence of a trade-off between circadian entrainment and color rendition.

Blue-enriched SPDs can of course be used in more complex lighting systems, where they are combined with a tunable CCT and a tunable illuminance, in order to deliver maximal stimulation at the proper time of the day. Some research supports the validity of such a "daylight-simulating" approach [11].



Figures 4a&b: Blue-depleted SPDs for reduced entrainment. CCT vs. melanopic lux comparison (a) and SPDs (b) of a conventional (blue-pumped) white LED, a blue-pumped "sleep" LED, and a violet-pumped blue-free LED

Blue-depleted spectra for decreased entrainment

The converse problem – that of minimizing stimulation in the evening, especially in the two hours before bedtime – poses more significant conceptual challenges. Fundamentally, this is because nearly-all LED technology today is predicated on the use of blue pump LEDs with peak wavelengths most commonly in the range 440-460 nm, making it impossible to completely remove blue radiation.

Figures 4 show blue-depleted SPDs for reduced entrainment. All emitters have the same illuminance (100 lux). Figure 4a demonstrates the relationship between CCT and melanopic lux for blackbody emitters (line), and various LEDs (dots). Blue-pumped LEDs (whether they are conventional or "sleep-friendly") closely follow the behavior of Blackbody emitters. In contrast, blue-free LEDs break this trade-off and offer a conventional CCT (here, 2,700 K) together with a low melanopic lux. Figures 4b show representative SPDs of a conventional (blue-pumped) white LED, a blue-pumped "sleep" LED, and a violet-pumped blue-free LED.

Conventional white LEDs, with blue-pump LEDs peaking around 450 nm, display a melanopic lux very close to the curve from figure 4a, with small variations depending on the specific phosphor used – showing that in this case, standard spectral engineering isn't a sufficient tool to reduce the circadian lux.

In past years, the lighting industry has tried to address this issue by offering blue-depleted LEDs. However, this can only be obtained by reducing the CCT of the emitter. This is because blue is an essential part of the SPD of a white LED, required to color-balance it for a given CCT: when forcing a lower blue peak, the CCT must also be reduced.

Therefore, the resulting "sleep-friendly" LEDs merely show a melanopic lux compatible with their reduced CCT, nearly identical to a low-CCT blackbody radiator. In practice, such low CCTs (around 2,000 K) are practically equivalent to candle light and display a pronounced yellow cast, which is unacceptable in most lighting applications – let alone to light up a whole home for extended hours before bedtime.

In summary, conventional blue-based LEDs suffer from a fundamental trade-off whereby low circadian stimulation is tied to low CCT.

Blue-free emitters: a fundamental solution for low circadian entrainment

In past years, efficient white lighting based on violet pump LEDs has emerged as a viable alternative to the conventional blue-pump LED scheme. This was in large part enabled by the development of ultra-high efficiency violet LEDs. So far, violet-pumped white LEDs have mostly shown an advantage in applications where high quality of light is sought – in this case, they are combined with three phosphors (including a blue phosphor) to produce a full-spectrum with wide wavelength coverage.

However, violet-pump LEDs also offer a unique advantage for circadian-friendly lighting. Indeed, by omitting the blue phosphor and selecting the other phosphors appropriately, they enable white light where blue radiation is virtually absent, as shown on figure 4b [12]. Despite this, a desired CCT (in this case, standard warm-white at 2,700 K) can be achieved by retaining a sufficient amount of violet in the SPD. As seen in figure 4a, this source nonetheless offers a melanopic lux similar to a 2,000 K conventional source.

Therefore, such blue-free SPDs break the trade-off between blue radiation and CCT described earlier, enabling low circadian entrainment without compromising the color of the light itself. Perhaps more surprisingly, the SPD if figure 4b also displays excellent color metrics (CRI Ra = 80, R9 = 90) – making it acceptable for widespread use in residential and hospitality settings.

From Lighting to Displays?

Concerns about blue light and circadian disruption are not limited to architectural lighting – electronic displays also cause the same effects. Conventional displays, with a CCT of about 6,500 K and a large blue peak, naturally provide high circadian entrainment, and there is little desire to further increase it. Rather, there is interest in reducing entrainment. Indeed, studies have confirmed that the use of displays at night could have a disruptive impact on sleep [13].

The previous discussion, while aimed at lighting applications, is also directly relevant for displays. Today, the approach retained in the industry is to reduce the display's CCT at night. This function is offered by the well-known software utility f.lux, and has been integrated in smartphones (e.g. Apple's Nightshift mode). However, just as in lighting, reducing CCT can only be taken so far before the color of the screen appears too warm. A low-point of 3,500 K is often proposed in this approach.

Here again, blue-free technology offers a path by enabling reduced circadian entrainment (on the order of 50%), even for high-CCT. Importantly, with proper engineering of color filters, this can be obtained while retaining the display's color quality: for instance, a DCI-P3 color gamut can be obtained and, contrary to common expectations, a saturated-blue primary can be achieved despite the absence of blue radiation in the SPD.

Conclusions

Given the significant effects of light on the circadian cycle, there is little doubt that human-centric lighting will proliferate in coming years. Ever-increasing scientific understanding will enable more relevant solutions. As it stands, the main challenge for the lighting industry is to offer dynamic lighting systems that can modulate circadian entrainment – at a minimum by tuning CCT, and beyond this with advanced spectral engineering. For years, the lighting industry has been able to offer a good solution to one half of this problem, by combining high illuminance and a blue-enriched SPD. With the advent of blue-free technology, enabled by highly-efficient violet pump LEDs, it is now possible to tackle the other half of this challenge and provide architectural-grade lighting with reduced circadian entrainment. ■

References:

[1] D. M. Berson, "Phototransduction by Retinal Ganglion Cells That Set the Circadian Clock," Science (80-)., vol. 295, no. 5557, pp. 1070–1073, 2002
[2] S. Hattar, H. W. Liao, M. Takao, D. M. Berson, and K. W. Yau, "Melanopsin-containing retinal ganglion cells: architecture, projections, and intrinsic photosensitivity.," Science, vol. 295, no. 5557, pp. 1065–70, Feb. 2002
[3] C. Dibner, U. Schibler, and U. Albrecht, "The Mammalian Circadian Timing System: Organization and Coordination of Central and Peripheral Clocks," Annu. Rev. Physiol., vol. 72, no. 1, pp. 517–549, Mar. 2010
[4] T. A. LeGates, D. C. Fernandez, and S. Hattar, "Light as a central modulator of circadian rhythms, sleep and affect," Nat. Rev. Neurosci., vol. 15, no. 7, pp. 443–454, Jul. 2014
[5] J. J. Gooley, S. M. W. Rajaratnam, G. C. Brainard, R. E. Kronauer, C. A. Czeisler, and S. W. Lockley, "Spectral Responses of the Human Circadian System Depend on the Irradiance and Duration of Exposure to Light," Sci. Transl. Med., vol. 2, no. 31, p. 31ra33-31ra33, May 2010
[6] G. C. Brainard and J. P. Hanifin, "Action Spectrum for Melatonin Suppression: Evidence for a Novel Circadian Photoreceptor in the Human Eye," in Biologic Effects of Light 2001, Boston, MA: Springer US, 2002, pp. 463–474
[7] J. J. Gooley, K. Chamberlain, K. A. Smith, S. B. S. Khalsa, S. M. W. Rajaratnam, E. Van Reen, J. M. Zeitzer, C. A. Czeisler, and S. W. Lockley, "Exposure to Room Light before Bedtime Suppresses Melatonin Onset and Shortens Melatonin Duration in Humans," J. Clin. Endocrinol. Metab., vol. 96, no. 3, pp. E463–E472, Mar. 2011
[8] R. G. Stevens and Y. Zhu, "Electric light, particularly at night, disrupts human circadian rhythmicity: is that a problem?," Philos. Trans. R. Soc. B Biol. Sci., vol. 370, no. 1667, pp. 20140120–20140120, Mar. 2015
[9] R. J. Lucas, S. N. Peirson, D. M. Berson, T. M. Brown, H. M. Cooper, C. A. Czeisler, M. G. Figueiro, P. D. Gamlin, S. W. Lockley, J. B. O'Hagan, L. L. A. Price, I. Provencio, D. J. Skene, and G. C. Brainard, "Measuring and using light in the melanopsin age," Trends Neurosci., vol. 37, no. 1, pp. 1–9, Apr. 2014
[10] S. A. Rahman, M. A. St. Hilaire, and S. W. Lockley, "The effects of spectral tuning of evening ambient light on melatonin suppression, alertness and sleep," Physiol. Behav., vol. 177, pp. 221–229, Aug. 2017
[11] V. Gabel, M. Maire, C. F. Reichert, S. L. Chellappa, C. Schmidt, V. Hommes, A. U. Viola, and C. Cajochen, "Effects of Artificial Dawn and Morning Blue Light on Daytime Cognitive Performance, Well-being, Cortisol and Melatonin Levels," Chronobiol. Int., vol. 30, no. 8, pp. 988–997, Oct. 2013
[12] M. R. Krames and A. David, "US9410664B2 - Circadian friendly LED light source," US9410664B2, 09-Aug-2016
[13] A.-M. Chang, D. Aeschbach, J. F. Duffy, and C. A. Czeisler, "Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness.," Proc. Natl. Acad. Sci. U. S. A., vol. 112, no. 4, pp. 1232–7, Jan. 2015

Technical Progress Improves Efficacy of Green LEDs by 40%

Wasted light yield and high forward voltage are the result of the "green gap" phenomenon, seen in green LEDs, which create efficiency problems and high costs for applications utilizing green LED technology. Developers at Osram Opto Semiconductors recently succeeded in dramatically lowering conventional forward biases by 600 mV during the production of green indium gallium nitride (InGaN) based LEDs. Dr. Jan-Philipp Ahl, technical expert and Dr. Adam Bauer, project manager, explain how this innovation increases the luminous output and how customers can benefit from improved efficiency of up to 40 percent in comparison with previous products. They demonstrate that the new development is particularly advantageous for applications involving the combined use of red, blue, and green LEDs but also for mobile applications where battery lifetime is important. They explain that crucial factors contributing to this increased efficiency were improved charge-carrier transport and optimized quality for materials to be used in the epitaxial layers, and how this has been achieved.

Like other LED manufacturers, Osram has been developing multiple approaches to generating green light for many years. These technologies can be assigned to two categories. Direct green LEDs create green light "directly" from the electrical energy used (Figure 1: approaches 1 and 4). On the other hand, converted green LEDs first create light with a shorter wavelength, which is then converted into green (Figure 1: approaches 2 and 3).
Direct LEDs offer certain advantages: Compared to converted approaches, they are simpler because no second component is needed. Phosphor based solutions (approach no. 2) also have much higher spectral widths, which do not meet the high color rendering requirements of the latest display technologies. Sample spectra are shown in figure 2. In order to surpass the higher spectral width of converted solutions, a special converter has been developed in the government funded research project "Hi-Q-LED" (approach no. 3) [1]. While achieving high spectral quality, LED efficiency could not reach the values of phosphor converter solutions. The latter was therefore preferred especially in applications with high luminous flux. In general, these converted approaches have shown even higher luminous efficiency in the past, which has made them a viable alternative to the direct approach.

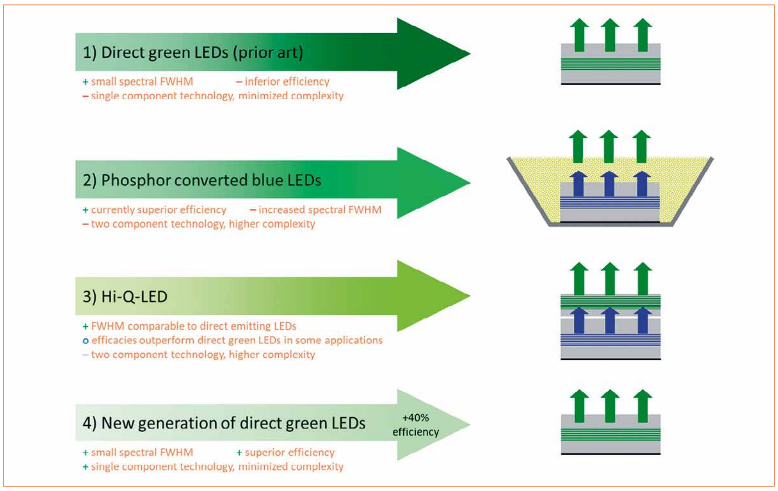


Figure 1: History of green LED development

Approach no. 4, presented in this article, has now raised the performance of direct green LEDs to a level previously achieved only through conversion technologies. At the same time, they still keep the advantages of direct LED, i.e. single component technology and superior spectral width. Therefore, the improved direct LED now combines all benefits in one single and simple solution: High luminous efficiency, lowest spectral width, high absolute output power, simple design and low cost. Thus, this approach bares the potential to make conversion technologies obsolete in most applications.

A Technical Challenge

InGaN-based LEDs suffer from a loss of efficiency when their color changes from blue to green (in other words, when their wavelength is increased correspondingly). Aluminum indium gallium phosphide LEDs on the other hand are likewise much less efficient when their wavelengths shift from the red to the green spectral range. Within the industry, this process is known as the “green gap phenomenon” and has been a challenge for developers for years now. But what causes the loss of efficiency for InGaN-based LEDs?

On the one hand, the internal quantum efficiency decreases on account of the necessary changes in the material composition of the illuminating layers within the LED. These layers – quantum wells – transform a larger portion of the electrical current into warmth instead of light when their level of indium rises as wavelength increases. The phenomenon is intrinsic in nature and, to a certain extent, cannot be controlled.

Furthermore, it has never been possible until now to lower the unusually high forward biases of green LEDs being significantly higher than the theoretically attainable value of the illuminating layers’ bandgap. The bandgap for green-emitting quantum wells is approximately 2.3 electron volts (eV). Nonetheless, around 3.2 volts (V) (at minimum) have been required to operate to green light diodes at the current densities typical for applications. This results in a difference of up to one volt from the theoretically attainable forward bias.

The main reason behind this is the distribution of charge carriers across the various illuminating layers in the LED, which has been inadequate up until now. In their efforts to develop improvements, the engineers focused their energies on this issue.

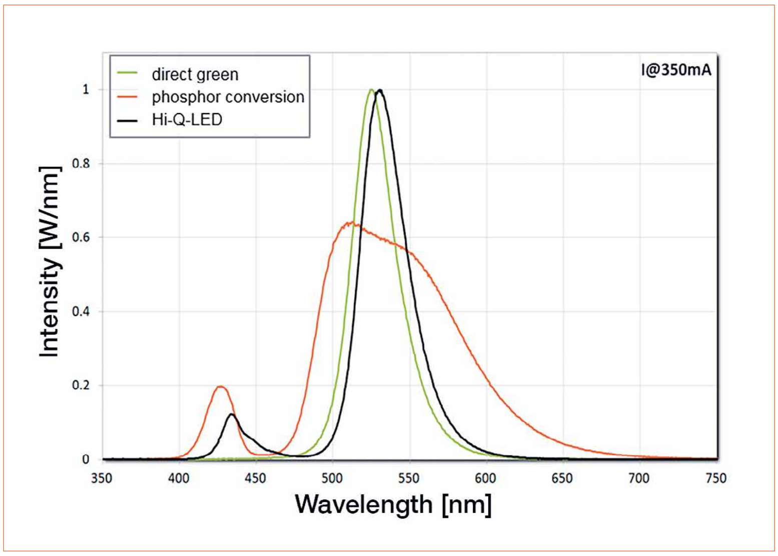


Figure 2: Spectral comparison of different green emitters

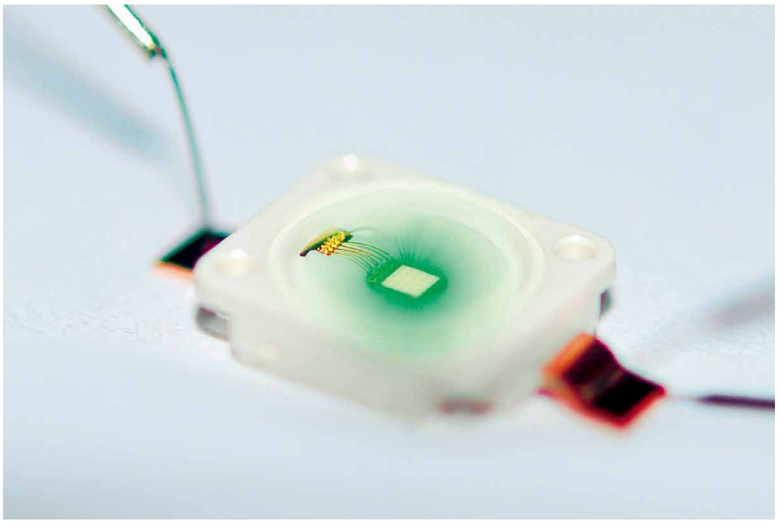


Figure 3: Reducing the conventional forward bias in green LEDs is the key to improve efficiency

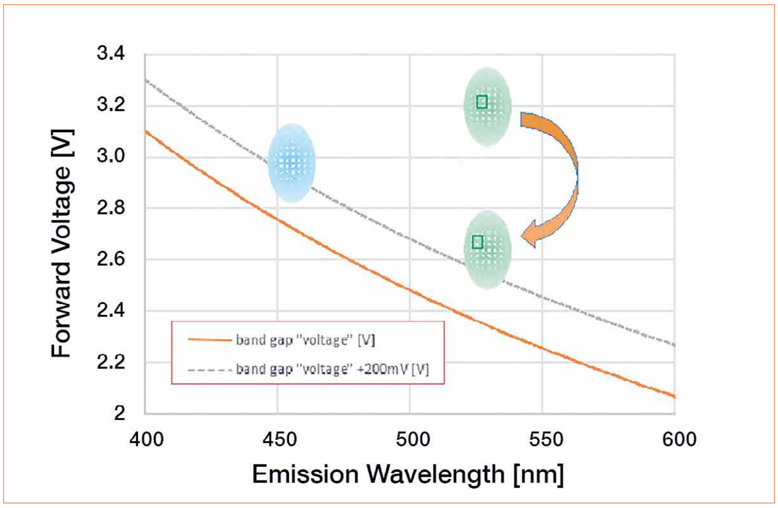


Figure 4: Reduction in the forward bias: The improvement has achieved voltages just barely above the theoretical minimal voltage, as is already the case for blue LEDs. The theoretically achievable values are displayed in orange and are limited by the InGaN bandgap voltage

Solving the Challenge

The high-tech company’s development team in Regensburg was successful in eliminating some of these limitations. They were able to lower the forward bias from 3.2 V to 2.6 V at a current density of 45 A/cm^2 (Figure 4). This is the world’s lowest value for direct-emission green LEDs achieved to date. The accomplishment can be credited in part to the improvement in charge-carrier transport through the light-emitting area of the semiconductor layers.

Prior to the recent breakthrough carriers were unevenly distributed among the light emitting layers in green GaN-based LEDs. The reason for this problematic layout was that the barrier layers between the light emitting quantum wells were generally too thick. A certain barrier thickness is however required – especially for green LEDs – in order to maintain a sufficient epitaxial quality throughout the entire active region. In comparison blue InGaN-based LEDs can make use of thin barriers granting better charge carrier distribution.

Another important factor is that green quantum wells also have to be energetically deeper in order to emit light at the desired longer wavelength. This however makes the transport of carriers even more difficult. The described issues do not only decrease the lumen output, but also lead to an increased forward voltage residing way above the band gap voltage.

Why is such an uneven carrier distribution detrimental for the performance of LEDs?

A higher carrier density in a single or a few quantum wells decreases the lumen output of LEDs due to increased so-called non-radiative Auger recombination [2].

These Auger processes are scaling cubically with the charged carrier density n, whereas radiative re-combinations, which contribute to the lumen output only scale quadratically with n. in order to enhance the performance the goal is therefore to distribute a fixed number of charge carriers in an LED to as many quantum wells as possible.

Based on this knowledge, the engineers concentrated on obtaining a more even distribution of charged carriers in-between the quantum well layers within the development activities. This was achieved by careful tailoring of doping profiles in the green LED. The doping profile affects the electronical band structure leading to an improved injection of charged carriers in all quantum wells. Another positive result of this development progress is that it eliminates the issue of high forward voltages almost entirely.

Additional levers in progress to achieve e higher efficiency were a thorough tailoring of layer thicknesses and stoichiometry in the optically active region. Furthermore, an increased material quality of the epitaxial stack lowered point and threading dislocation density was applied. This contributed to the efficiency increase by a reduction of non-radiative Shockley-Read-Hall recombination rate.

Record-Breaking Development

The improvement in efficiency corresponds to a 20-percent reduction in the forward bias, which is a major milestone for green-LED development. At the same time, the developers succeeded in significantly improving light yield at a fixed current:
The team achieved a 12-percent increase in luminous flux at a current density of 45 A/cm another highlight in green-LED development.
The absolute light output – more than 300 lm for 1 A pumping electricity – opens up a world of new possibilities for customers' applications (Figure 5).

Considered as a whole, these advancements correspond to an increase in efficiency of 40 percent for the entire green UX:3 portfolio. At 350 mA, 1-mm^2 UX:3 chips that use the new technology can achieve efficiency values of well above 175 lm/W at 530-nm wavelengths. Even larger gains in efficiency have been observed at smaller current densities (Figure 5). When the technology is applied to 1-mm^2 UX:3 chips, efficiency values above 300 lm/W can be achieved at currents of around 40 mA.

These results enable entirely new ranges of efficiency which had previously only been possible with phosphide-converted emitters and considerably reduced spectral quality. The idea of adapting the technology therefore appeals to many additional areas of application.

Areas of Application

The increase in efficiency of around 40 percent for present nominal current densities makes it possible to achieve considerably longer-lived batteries for mobile devices, for example. Green light-emitting diodes in products such as fitness trackers and smartwatches record biometric information like the wearer's pulse (Figure 6).
Further research is already underway to discover new application possibilities: Stanford University is currently conducting a major study on heart-disease detection using pulse measurements taken with green LEDs [3].

As mentioned above, the most recent technological development is

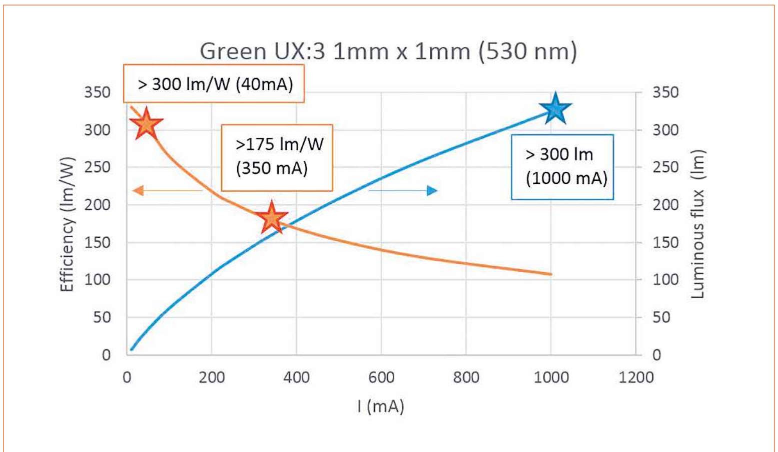


Figure 3: Efficiency and luminous flux compared to electrical current in a green UX:3-based LED with an edge length of 1 mm and wavelength of 530 nm

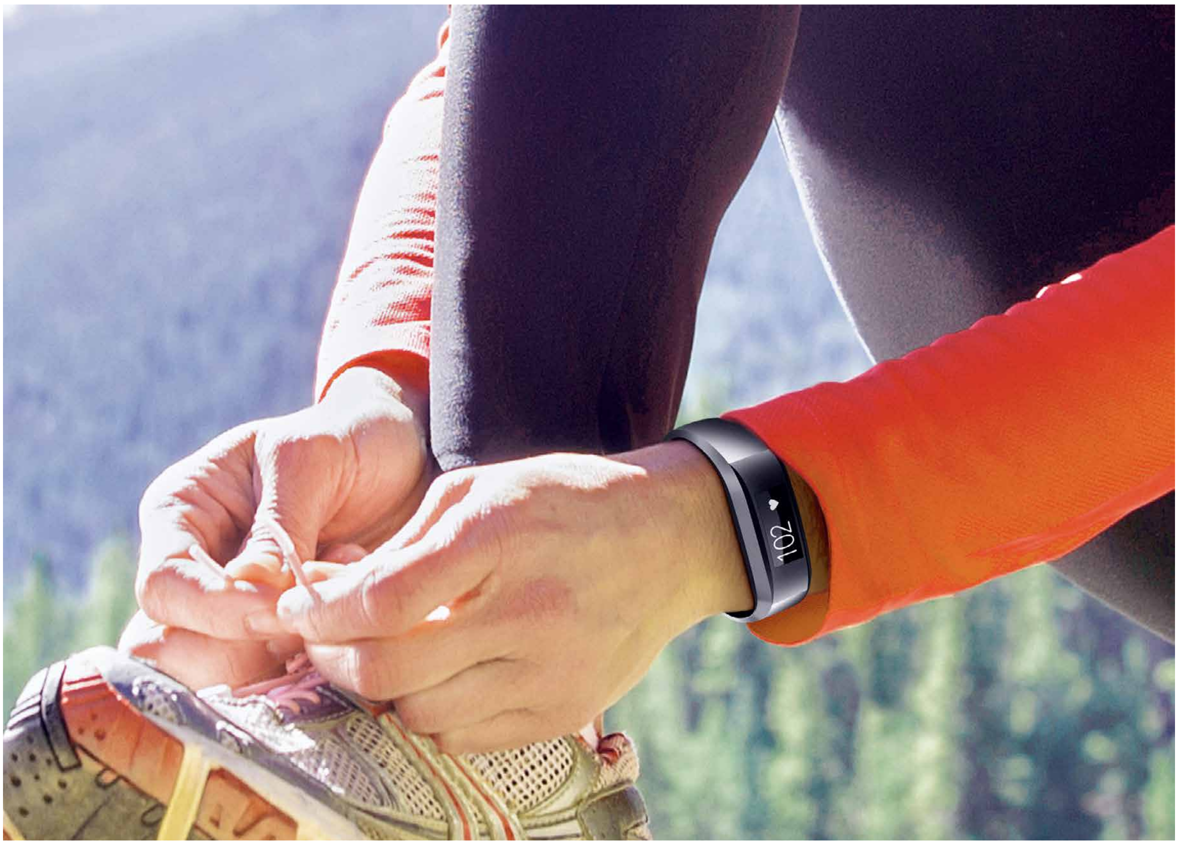


Figure 4:
The 40% gain in efficiency helps improve the battery life time of mobile devices such as fitness trackers

particularly advantageous for applications involving the combined use of red, blue, and green LEDs. Because all three colors now exhibit a voltage of below 3 V, drivers which have previously been designed for higher maximum voltages can be downsized.
Not only does this reduce what is known as "dissipative loss output" and, to a certain extent, lower costs, it also facilitates customers' design processes for future products thanks to the space saved.
For instance, RBG solutions such as this are increasingly built into video walls.

The developers are currently working on other improvements whose potential has been revealed by the recent findings.

References:

[1] https://www.osram-group.de/media/press-releases/pr-2014/06-11-2014 The "Hi-Q-LED" project funded by the German Federal Ministry of Education and Research (BMBF) has made pioneering progress with green light-emitting diodes.

[2] https://aip.scitation.org/doi/abs/10.1063/1.4754688 Influence of indium content and temperature on Auger-like recombination in InGaN quantum wells grown on (111) silicon substrates (B. Galler et. al)

[3] Stanford study: https://www.ledinside.com/news/2017/12/apple_stanford_collaborate_on_heart_study_using_green_led_to_measure_heart_rate

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.

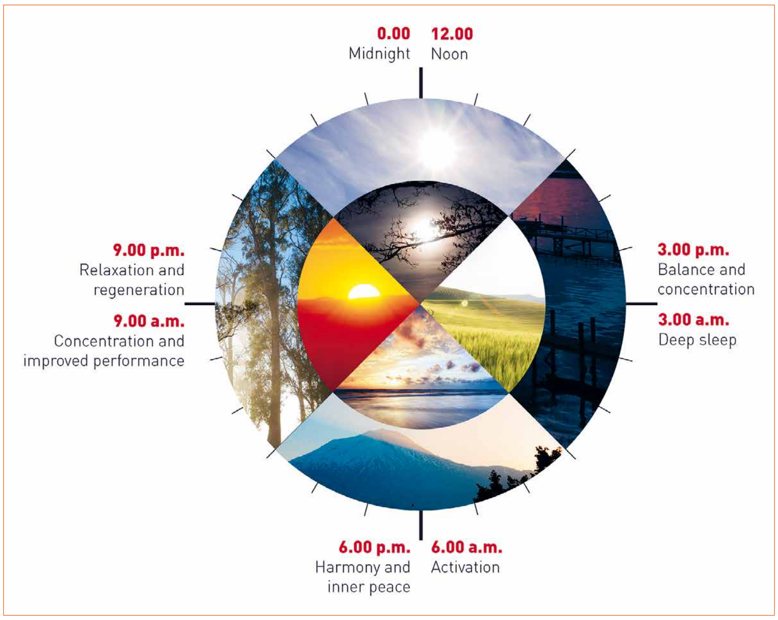


Figure 1:
In rhythm with the biological clock [7]

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]

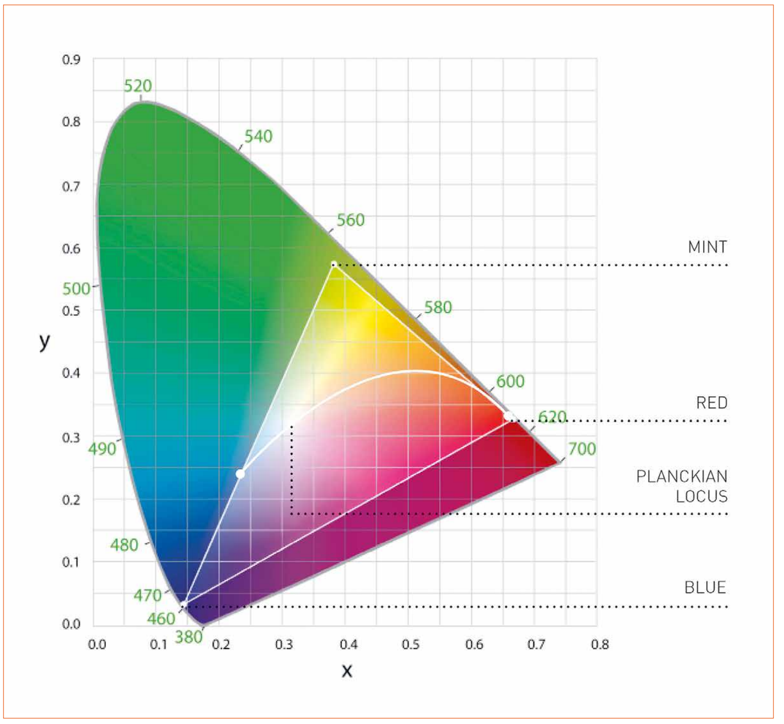


Table 1:
Example of stating the melanopic action factor [7]

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

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.

Figure 4:
Example for mimicking horizon [7]

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.

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.

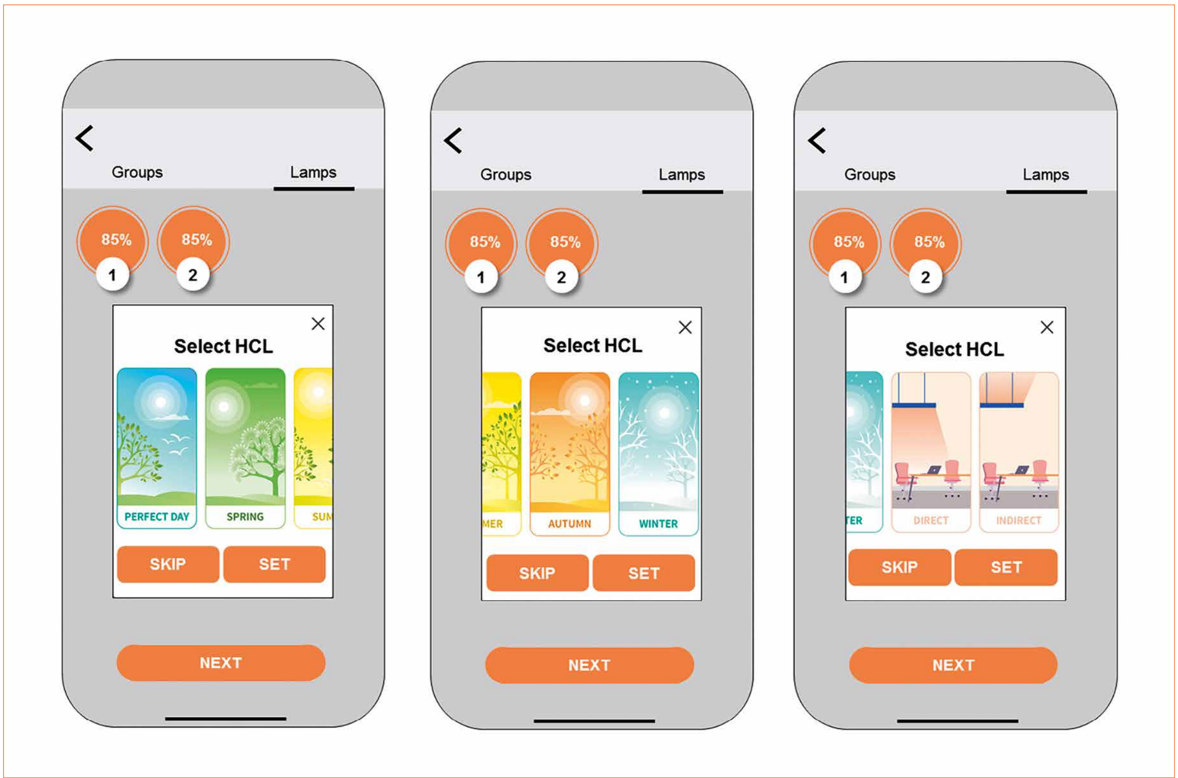


Figure 5:
Example for control [7]

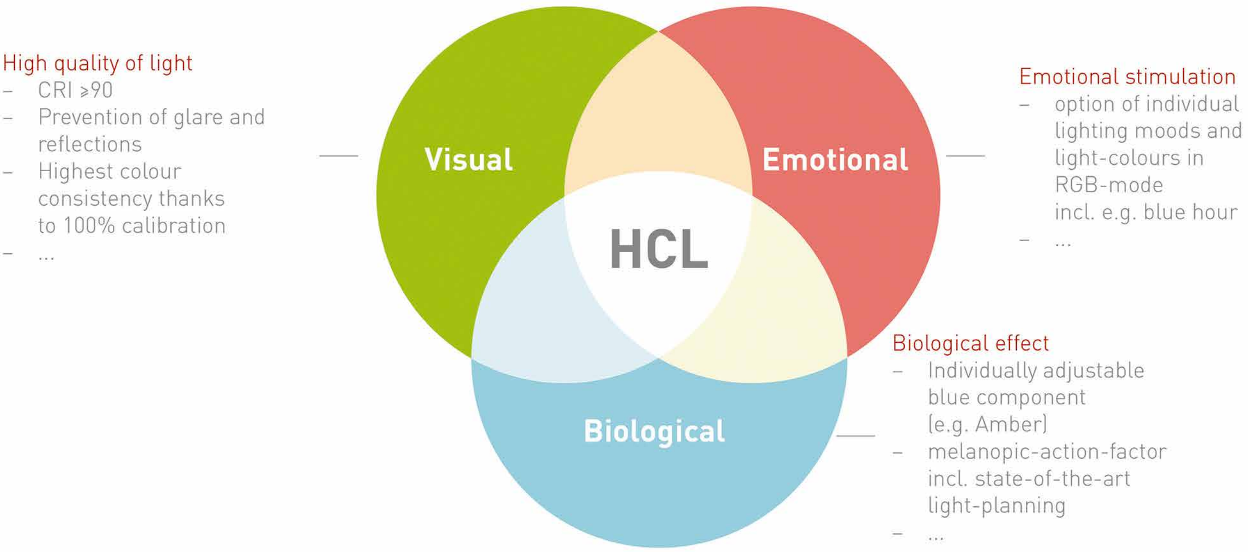


Figure 6:
Three pillars of Human Centric Lighting [7]

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. ■

References:

[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
[2] Human Centric Lighting: Going Beyond Energy Efficiency, ZVEI July 2013
[3] Global Human Centric Lighting and Environmental Lighting, Market Research Report 2018
[4] Octavio PEREZ, PhD Mount Sinai Hospital NYC LpR Nov/Dec 2018 Issue 70 p. 38
[5] AS/NZS 1680.2.5:1997
[6] Prof. Dr. med. Dipl.-Ing. Herbert Plischke www.lichtnet.de
[7] Image Sources: Kiteo / Lumitech / DARA / licht.de

Melanopic Green - The Other Side of Blue

For years now, there has been a controversial discussion about the amount of blue light in LEDs. Medical studies have shown that, depending on the amount, blue light at night disrupts the circadian rhythm. As a result, warm white (<3000 K) light sources are often touted as a solution for street lighting as well. Ian Ashdown, P. Eng. (Ret.), FIES Senior Scientist at SunTracker Technologies discusses whether or not it is sufficient to only look at the CDT or if other wavelengths and aspects should be considered.

Numerous medical studies have shown that exposure to blue light at night suppresses the production of melatonin by the pineal gland in our brains and so disrupts our circadian rhythms. As a result, we may have difficulty sleeping. It is therefore only common sense that we should specify warm white (3000 K) light sources wherever possible, especially for street lighting. - True or false?

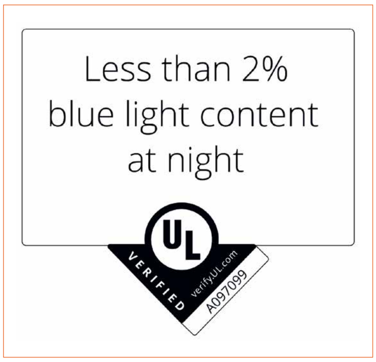


Figure 1:
UL Verified Mark example

About Blue Light and a Common Understanding

To answer the question from above, we first need to define what we mean by "blue light." Neither the Illuminating Engineering Society (IES) nor the Commission Internationale d'Eclairage (CIE) define the term in their online vocabularies. However, UL (formerly Underwriters Laboratories Inc.) has recently introduced its UL Verified Mark, a "third-party product claims verification program." One such Verified Mark is shown in figure 1.

The verification process for this mark is described thus:
"In accordance with LM-79-08, Section 9.1, measure the radiation emitted by the product across the visible spectrum of 380 – 780 nm. From the visible spectrum radiation measurement, determine the amount of 'blue light' radiation emitted between 440 – 490 nm. To calculate the percent of blue light emitted, divide the amount of blue light radiation by the amount of radiation measured across the complete visible spectrum."

The lower wavelength limit of 440 nm seems somewhat arbitrary unless you also define "violet light," but the upper wavelength limit of 490 nm makes sense; wavelengths in the region of 490 to 570 nm appear to be varying hues of green. This makes it easy – if we eliminate light of all wavelengths below 490 nm, we should not have any concerns about suppressing the production of melatonin and possible sleep disruption. - True or false?

Looking on medical studies

To answer this question, we need to take a closer look at those medical studies. The human retina has a smattering of intrinsically photosensitive retinal ganglion cells, or ipRGCs. Similar to the more familiar rods and cones, these ipRGCs contain a photosensitive protein called melanopsin. The sensitivity of melanopsin varies with wavelength, as shown in figure 2.

It is these ipRGCs that sense "blue light" and send signals to the suprachiasmatic nucleus (SCN), a tiny region of some 20,000 neurons in the brain that is responsible for instructing the pineal gland when to produce melatonin.

Looking more closely at Figure 2, however, it is evident that the ipRGCs' spectral sensitivity peaks at 490 nm, as well as extending to the ultraviolet edge of the visible spectrum at 380 nm. Most important, fully half the the spectral sensitivity of melanopsin is to green light.

Common sense is starting to look rather nervous …

The spectral sensitivity shown in Figure 2 is interesting enough, but it becomes even more so when we consider what it means for how we respond to the radiation emitted by white light LEDs.

Figure 3 shows the relative spectral power distributions (SPDs) of typical white light LEDs with correlated color temperatures (CCTs) of 3000 K and 4000 K, scaled such that both LEDs produce equal amounts of luminous flux.

Determining the relative response of ipRGCs to these LEDS is easy – we simply multiply their SPDs by the melanopic sensitivity function on a per-wavelength basis, as shown in figure 4.

Common sense, it would seem, has good reason to be nervous. Yes, 3000 K LEDs produce less melanopic flux than 4000 K LEDs when they produce equal luminous flux. However, the difference is only ten percent. This is within the tolerance of architectural and roadway lighting design practices. As such, it should not be argued that 3000 K LEDs are required for nighttime lighting in order to minimize circadian rhythm disruption – the difference in melanopic flux does not support this. Rather, it is simply one of several factors that must be considered when designing and specifying lighting systems.

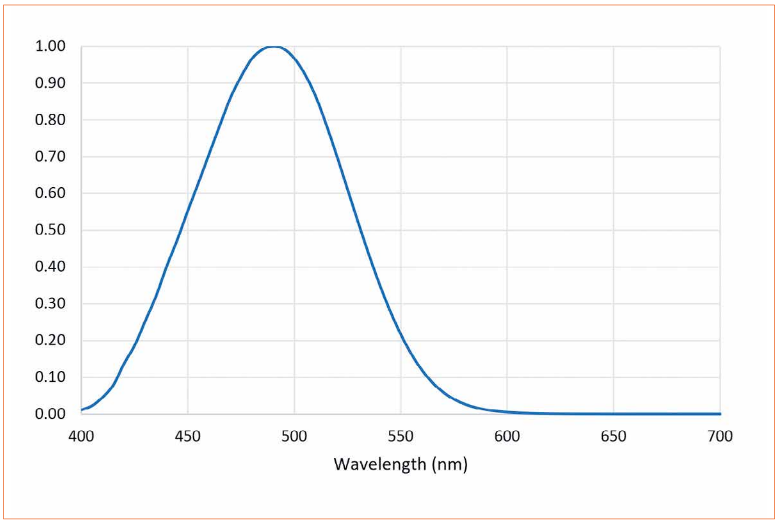


Figure 2: Relative melanopic sensitivity (from CIE 2015) [1]

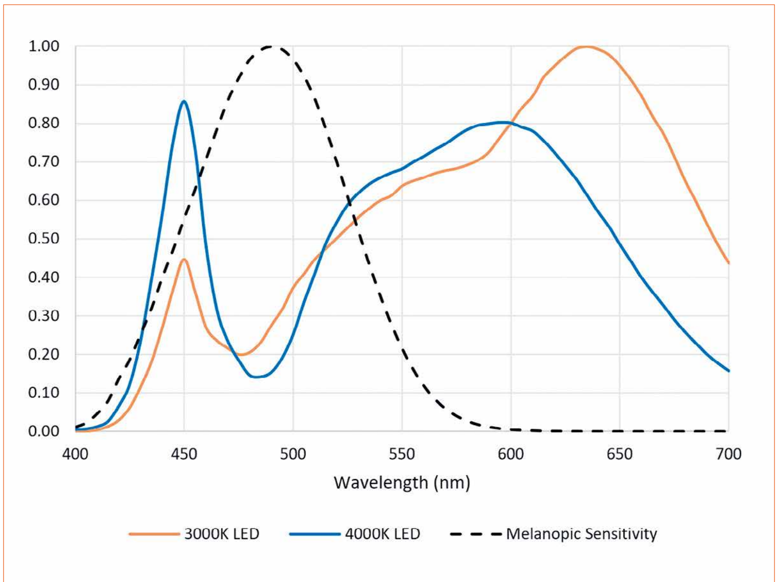


Figure 3: White light LED spectral power distributions

Blue-Blocking Glasses

Figure 4 highlights another issue: the efficacy of blue-blocking glasses, which are often marketed as promoting better sleep (Figure 5).

If we assume that the yellow filters provide a perfect cutoff at 490 nm, they are only 33% effective in blocking melanopic flux from 3000 K (warm white) LEDs and 43%

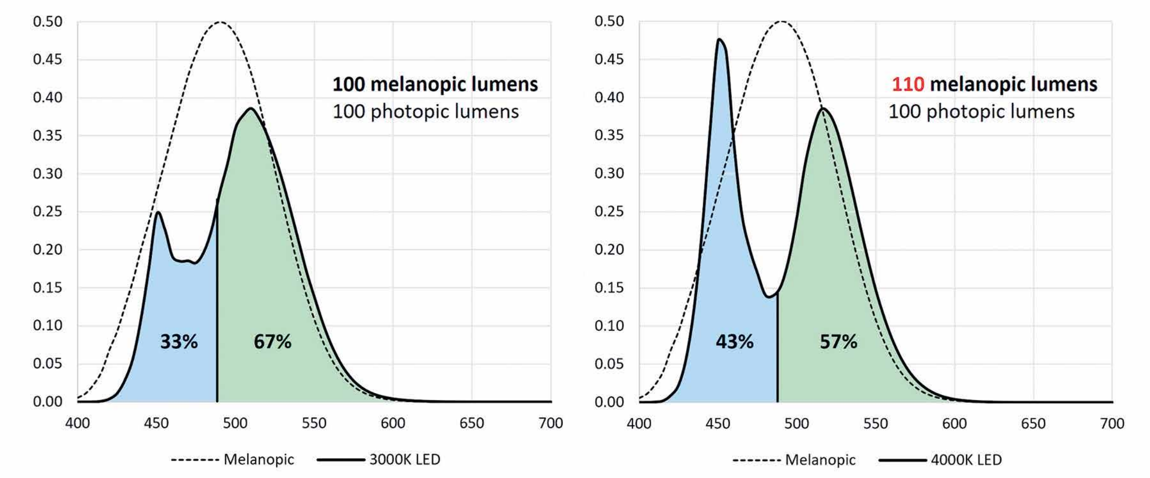


Figure 4: Examples of LED melanopic lumens; 3000 K (a) and 4000 K (b)

Figure 5:
Blue-blocking glasses (Credits: www.swanwicksleep.com)

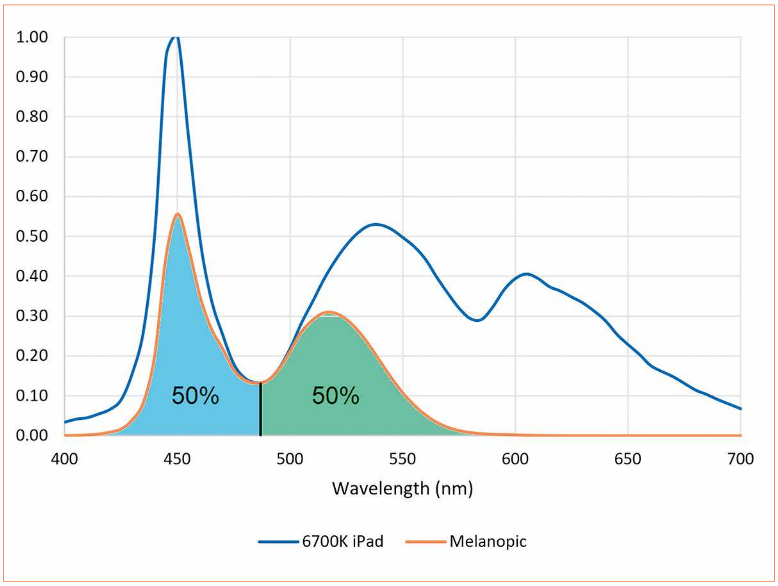


Figure 6:
Apple iPad melanopic flux

effective with 4000 K (neutral white) LEDs. In reality, the filters likely let through some amount of blue light in the region of 470 nm to 490 nm, and so they may be even less effective.

Simply put, we cannot prevent melanopic flux emitted by white light sources from impacting our circadian rhythms unless we use deep-red filters. This is not to say that blue-blocking filters on eyeglasses or light sources do not work – they inarguably block blue light. However, melanopic flux includes both blue and green light.

From a marketing perspective, it is fair to say that blocking blue light may alleviate circadian rhythm disruption and loss-of-sleep issues, even if it is due to the placebo effect. (There are many other psychophysiological and environmental parameters involved in circadian rhythm entrainment that are not discussed here.) However, it is incorrect to claim that blocking blue light will eliminate melatonin suppression and so prevent circadian rhythm disruption. The facts state otherwise.

Electronic Devices

Finally, what about those evil electronic devices that threaten our sleep? Figure 6 shows the spectral power distribution of an Apple iPad™ and the resultant melanopic flux when the display is set to full white (which has a CCT of 6700 K, somewhat higher than the 6500 K white point of most computer monitors).

As shown by Figure 6, the best any optical filter or software-based change in the device white point (that is, a change in CCT) can hope to achieve is a 50 percent reduction in melanopic flux.

What is more important, however, is that iPad screen luminance is approximately 400 cd/m^2 (nits). This is on the order of 50 to 100 times the light levels recommended for residential street lighting. If we are to complain about light trespass from residential street lighting into our bedrooms causing sleep deprivation, we cannot ignore the influence of the televisions, computer monitors, and tablets that we often stare at for hours before going to bed, and in much closer proximity.

Conclusions

Research into the influence of spectral content and retinal illuminance on circadian rhythms is ongoing [1,2]. As such, this article should not be taken as evidence (or lack thereof) for the effect of "blue light" on our sleep patterns. Rather, it is a reminder to look beyond the marketing claims of "blue-light blocking" products and ask what this really means.

To answer the question of whether we should specify warm white (3000 K) light sources for street lighting, the answer is, "it depends." All things being equal, the difference in melanopic flux between 3000 K and 4000 K LEDs is only ten percent. This is within the uncertainty of light design practices, and so more weight should be given to residents' concerns, aesthetics, color discrimination, and energy savings when making design and specification decisions.

To answer the question of whether eliminating light of all wavelengths below 490 nm (that is, "blue light") will eliminate any concerns about melatonin suppression and possible sleep disruption, the answer is clear: FALSE! ■

References:
[1] CIE. 2015. Report on the First International Workshop on Circadian and Neurophysiological Photometry, 2013. CIE Technical Note TN 003:2015
[2] Nagare, R., et al. 2017. "Does the iPad Night Shift Mode Reduce Melatonin Suppression?" Lighting Research and Technology


TiL® 2019
2019
September 24–26, 2019
Opera House Bregenz
TRENDS
iN
LIGHTING
for Architects
Lighting Designers
Planners
Investors
Forum
&Show
3rd International Trends
in Lighting Forum &Show
Human Centric Lighting
Light Quality & Visual Perception
Smart Lighting & IoT
Lighting Technologies
Best Practice for Smart Buildings & Cities
Investment, Business & Process
Networking & Inspiration
CALL FOR
SPEAKERS
www.TiL2019.com
© Luger Research e.U. – 2019

LED professional Review (LpR) - Annual Subscriptions

LpR Digital Magazine

- 6 issues
- pdf download
- high resolution pictures and graphs
- printable
- commercial use
- access to all previous issues
- Euro 78.80

LpR Printed Magazine

- 6 issues
- Euro 158.40

http://www.led-professional.com/subscription

Cover-page

Artwork: Thomas Klobassa, ©LED professional 2017

Main Image: Thomas Klobassa, LED professional

Surgery lamps belong to the most challenging applications

Next LpR

FUTURE PROOF SYSTEMS
Issue 72 - March/April 2019

TECH-TALKS BREGENZ

Scott Wade, Technical and Certification Manager, DiiA

Dr. Scott Wade has been Technical & Certification Manager for DALI/DiiA since August 2013, and for around 14 years has been an industry expert member of the IEC 62386 standardization team. At LpS 2018, we talked about the new DALI-2 standard and how it is different to DALI version 1, which changes are relevant for users, what DiiA is planning for the DALI-2 certification in the future, and what makes DALI-2 future proof. ■

RESEARCH

"Best Papers" at LpS 2018: Semi-Empirical Characterization of Freeform Microlens Arrays (FMLA)

Microlens arrays (MLA) have been used for imaging and non-imaging applications for a long time as cost-effective solutions. Non-symmetrical beam shapes require more advanced non-symmetrical freeform microlens arrays (FMLA). The required FMLA molding tools convey a high cost and an iteration process is required for the final design. A method to overcome these limitations based on 3D surface sampling, computer generation of a ray-traceable model and ray-tracing performance simulation is proposed and demonstrated for several commercially available freeform asymmetric thin-film diffusers. ■

Thermo-Optical Design Approaches in Automotive Lighting

Solid State Lighting changed the lighting environment in automotive lighting almost more than in the field of general lighting. While efficiency of the devices increased and new improvements are being reported, thermal management remains a critical part of the system. The authors explain the dependencies between photometric, electrical and thermal parameters of an automotive lighting application. ■

TECHNOLOGIES

Shared Office Space – Intelligent Solutions for Future-Proof Building Usage

Shared office spaces are gaining popularity as a flexible, resource-efficient and creativity-inspiring way to work. The dynamic nature of such office spaces requires building automation and lighting control solutions that can quickly be deployed and easily be adapted to new office layouts. This article takes a look at different connectivity architectures (wired, wireless, hybrid) and protocols (Bluetooth, ZigBee, EnOcean, PoE) to assess their usability and show how minimizing the need for maintenance is a key for increasing profitability of service-based offerings. ■

LED Lighting Systems in Smart Buildings with DC Microgrids

While electric motors for ventilation and air-conditioning systems were DC-based in the past, powerful IT systems, LED lighting systems, photovoltaic systems with batteries and charging systems for electro mobility are now increasingly being used in modern building environments. They all need direct current (DC). Therefore, an obvious step is to equip modern buildings with DC grids. A number of unresolved questions will be discussed in this article and possible solutions will be presented. ■

subject to change

Imprint

LED professional Review (LpR), ISSN 1993-890X

Publishing Company

Luger Research e.U.
Institute for Innovation & Technology
Moosmahdstrasse 30
A 6850 Dornbirn, Austria / Europe
phone +43 5572 39 44 89
fax +43 5572 20 60 70
info(at)lugerresearch.com
www.lugerresearch.com

Publisher
Siegfried Luger +43 699 11 33 55 70
s.luger(at)led-professional.com

Editor-in-Chief
Arno Grabher-Meyer +43 699 11 33 55 18
a.g-m(at)led-professional.com

Int. Account Manager
Theresa Koenig +43 699 11 33 55 20
theresa.koenig(at)led-professional.com

MarCom Manager
Bronwen Rolls +44 797 401 2962
bronwen.rolls(at)led-professional.com

Your Sales Contacts

Int. Sales Manager
Brigitte Lindner +43 699 11 33 55 19
brigitte.lindner(at)led-professional.com

China, Hong-Kong
Lolo Yeung +852 9732 2081
lolo(at)castintl.com

Germany
Armin Wezel +49 30 526 891 92
armin(at)eurokom-media.de

India
Priyanka Rai +91 124 478 7331
priyanka.rai(at)binarysemantics.com

Japan
Eiji Yoshikawa +81 3 6751 0090
scala(at)s3.dion.ne.jp

South Korea
Jung Won Suh +82 2 78 58 222
sinsegi(at)sinsegimedia.info

Taiwan
Leon Chen +886 2 256 81 786-10
leon(at)jkmedia.com.tw

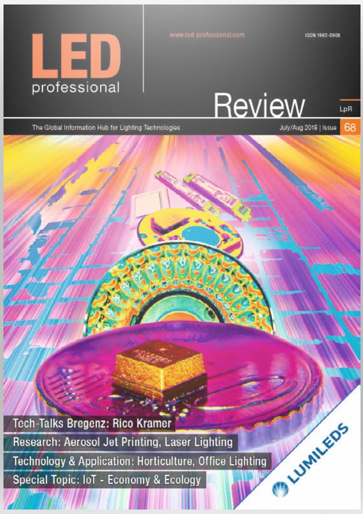
UK, Irdand, Benelux, Scandinavia
Zena Coupé +44 1923 85 25 37
zena(at)expomedia.biz

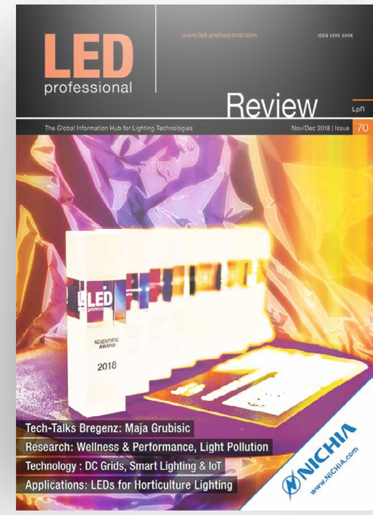
US East
Karen C Smith-Kernc +1 717 397 7100
KarenKCS(at)aol.com

US West & Canada
Alan A. Kernc +1 717 397 7100
AlanKCS(at)aol.com

Copyrights - Luger Research e.U.

PUBLISH WITH US AND SHOWCASE YOUR TECHNICAL EXCELLENCE





CONTRIBUTE

to the LED professional Review

EDITORIAL CALENDAR 2019

ISSUE N°	IN THE SPOTLIGHT*/**	DUE	ARTICLE DUE	ONLINE PUB.	PRINT PUB.
71 Jan./ Feb.	**TECHNOLOGIES FOR HEALTH & WELL-BEING** Efficient lighting has become a prerequisite. Ongoing discussions question whether efficient lighting is also healthy lighting and if it supports well-being. Findings, technologies, designs and applications supporting health and well-being are the focus of this issue.	Oct. 15, 2018	**Oct. 22, 2018**	Jan. 15, 2019	Feb. 01, 2019
72 Mar./ Apr.	**FUTURE PROOF SYSTEMS & SOLUTIONS** Most buildings are constructed to last at least four decades. Owners and operators are only willing to invest in long lasting future proof solutions for the infrastructure. The topic of this issue is the question of if and what future-proof solutions and technologies are available.	Dec. 17, 2018	**Jan. 04, 2019**	Mar. 15, 2019	April 01, 2019
73 May./ June	**DISRUPTIVE TECHNOLOGIES & APPROACHES** A good part of the lighting industry suffers from high production costs – especially in Europe and the US. New concepts, designs, materials and manufacturing methods may be advantageous. This issue reveals the most ingenious approaches.	Feb. 25, 2019	**Mar. 04, 2019**	May 15, 2019	June 03, 2019
74 July/ Aug.	**TECHNOLOGIES FOR SPECIFIC TASKS & APPLICATIONS** Light is not only used for illuminating rooms and open spaces. The applications of LEDs are manifold. This issue acknowledges the importance of LED light sources in automotive, horticultural, medicinal, cosmetic, and environmental applications, to name just a few.	April 24, 2019	**May 06, 2019**	July 16, 2019	Aug. 01, 2019
75 Sept./ Oct.	**ENVIRONMENTAL FRIENDLY DESIGN & ENGINEERING** The EU Commission supports the move towards a more circular economy. Additionally, research demonstrates that artificial light may negatively affect the environment. Technologies, designs and solutions that recognize these two aspects are addressed in this issue.	June 26, 2019	**July 05, 2019**	Sept. 02, 2019	Sept. 24, 2019
76 Nov./ Dec.	**TECHNOLOGIES FOR VISUAL PERFORMANCE & COGNITION** Some research results suggest that the spectral properties of a light source have great influence on visual performance, cognition and arousal. But it is more than just the spectrum that counts. This issue presents supporting concepts, technologies and solutions.	Aug 06, 2019	**Aug 26, 2019**	Nov. 15, 2019	Dec. 02, 2019

Submit your article proposal to a.g-m@led-professional.com

LED professional

powered by Luger Research e.U.


HortiCoolture.
LED it grow!
WÜRTH ELEKTRONIK
© eiPal
#LEDITGROW


TEAM WORLD CHAMPION
FIA FORMULA E
2017/2018