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Review

LpR

The Global Information Hub for Lighting Technologies and Design

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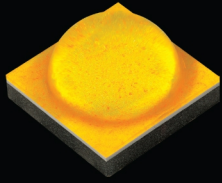
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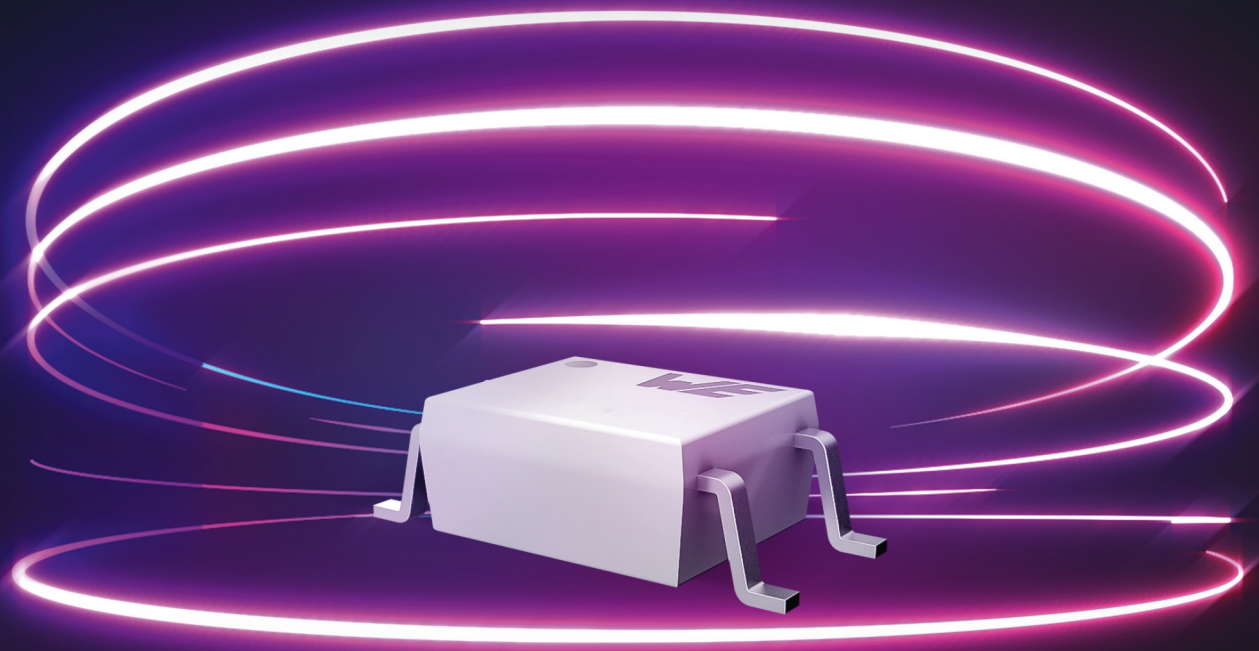
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Highlights

- Innovative coplanar design
- High grade silicon encapsulation
- Copper leadframe for high reliability
- Stable CTR over whole temperature range
- High CTR in low current operation



DIP-4



SOP-4



LSOP-4

Issue 99: Paving the Way to a Luminous Milestone



Dear Esteemed Readers,

As we unfurl the pages of our 99th LED professional Review, we stand at a moment of reflection and anticipation. This edition is not just a collection of articles; it's a mosaic of the past, present, and future of lighting.

Nicolas Martin's discerning commentary navigates the five pivotal trends reshaping our industry. From the embrace of sustainability to the transformative potential of AI in lighting, he paints a vivid picture of a future where light transcends its traditional boundaries.

Our exploration into the beauty of lighting and its profound impact on the brain is a testament to the art and science of illumination. The tips on wallwashing offer practical insights for those seeking perfection in vertical illuminations. Meanwhile, the LpS Digital Summit's introduction of the AI-Curated Awards heralds a new era of recognition, where technology meets creativity in celebrating excellence.

The spotlight on human-centric lighting is particularly close to my heart. As we delve into the therapeutic potential of solid-state UVB vitamin D treatments, we're reminded of the profound ways light can enhance well-being. The feature on smart electrical connections underscores the symbiotic relationship between technology and our daily lives, hinting at a future where every connection is intuitive and efficient. Delve into this research study that illuminates the intricate relationship between plant growth and artificial lighting, tracing the evolution of lighting technologies and their transformative impact on horticultural practices.

Our interview with Janick Ihringer, VP & GM Business-Line Illumination at ams OSRAM, offers a unique perspective from the helm of innovation.

As we inch closer to our landmark 100th issue, I invite you to immerse yourself in this edition, reflecting on our shared journey and envisioning the luminous possibilities ahead.

Thank you for being an integral part of our story.

Yours Sincerely,

A handwritten signature in blue ink, appearing to be 'S. Luger', with a long horizontal flourish extending to the right.

Siegfried Luger

Luger Research e.U., Founder & CEO
LED professional, Trends in Lighting, LpS Digital & Global Lighting Directory
International Solid-State Lighting Alliance (ISA), Member of the Board of Advisors
Member of the Good Light Group and the European Photonics Industry Consortium

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90
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B5-5306

RÖHM

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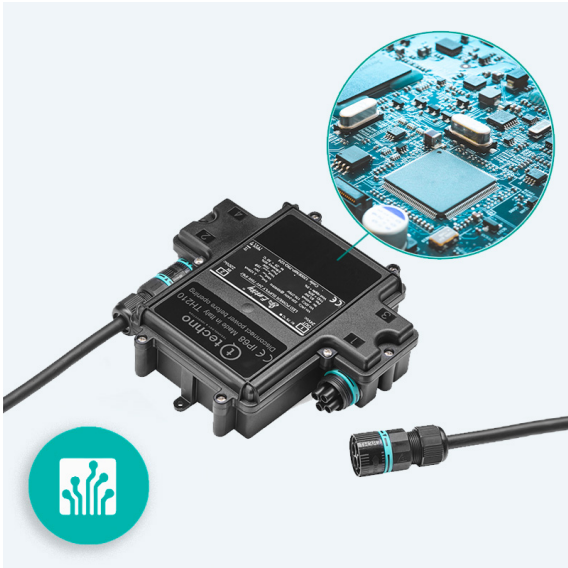
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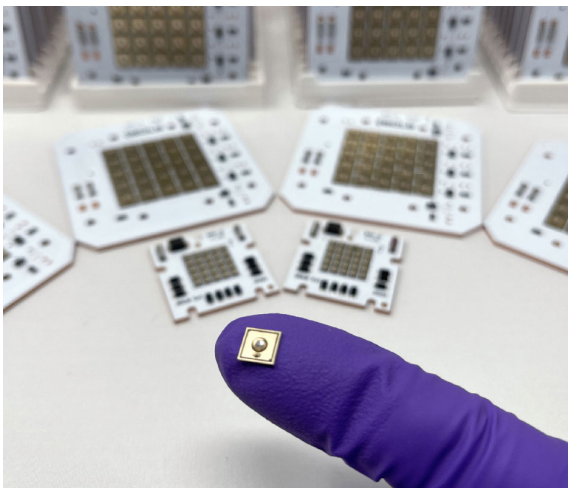
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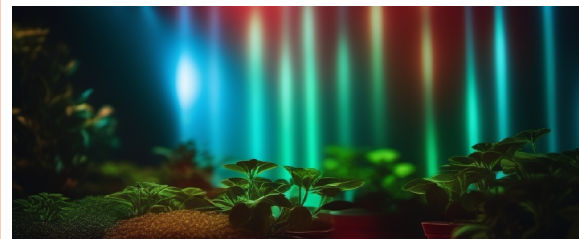
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Nicolas MARTIN

Nicolas is an interior architect. He graduated from Camondo school, based in Paris, in 1998. He worked in the design agency of Sylvain Dubuisson for 10 years, and 5 years at Dior Parfums as Worldwide Visual Merchandiser. At Dior, he oversaw the Group's first full-LED store at Galeries Lafayette in Paris. Nicolas joined the environment team in 2013. The objective being to reduce the energy consumption of the stores. Without compromising quality, he started a program called LVMH Lighting with Christian Galichon, the Group's CPO.

Since 2015, Nicolas has been developing the LIFE in Stores guidelines, the group's rating system. This became the Group's Stores Awards in 2016, 2018, 2020 and 2022. This rating system covers all the topics of green Architecture. During the pandemic, his focus was to train and influence all architects of the Group and to innovate in the field of smart building technologies. 2022, marked the return of the projects and of the Sustainable Store Planning (SSP) community, gathering more than 700 creatives. In October 2022, LVMH signed a one-of-a-kind collaboration agreement with Hang Lung Properties, on sustainability initiatives, orchestrated by Nicolas.

Five Key Trends Reshaping Lighting

Dear lighting manufacturers, After 10 years of inquiry in the lighting industry, I would like to share with you my vision of five changes that the lighting business will face very soon.

Circularity is obvious. The coming regulations will force you to adopt different practices. Another reason will be simply the scarcity of raw materials, resulting in a rise of price per kg. If there's no more metal, your second-hand products become your raw material for novelties. Please rethink your business, collectively, with more traceability, and nice affordable "take back" programs. Great consortiums and labels are emerging in order to evaluate the ecodesign of the products. TM66 is great. For me, the recycling content of a lampshade is not enough. We must go further: aluminum is dirty, and energy-intensive at the production stage. I truly hope that you convert from industrial product-producers to service-providers. Another topic is really the new standards for better compatibility across manufacturers. Not so long ago, you could keep a lamp for 50 years, replacing only the bulb.

Efficacy will also be a criterion of choice for your customers. The professionals are motivated by a LEED or BREEAM certification, or simply by their electricity costs in the future. It will never go down because of the sold-as-green electric vehicles. What I observe is the lack of transparency about the efficacy in this business. How many times do people ask me "system or component level?". We expect to purchase only products above 100 lm/W system, of course. Like circularity, some smart marketing people will highlight clearly (for non-experts) that your product is more efficient than others. LED is not enough; sober LED lighting is expected.

Healthy Lighting is also something hard to sell when you are behind your distributor and your installer, hidden inside a ceiling, or behind a shelf. Your message is lost, or worse: transformed because it is misinterpreted. Nobody knows about the ipRGCs, this is for the elite. At the end of the day, a light is a light. And you simply go for the cheapest one. HCL, 5-6 years ago, became a poor tunable white gamified

ledstrip. As everybody has a phone in their pocket, showing 20 cursors, groups of spots, timers in an app that is cool for the tech geeks, but doesn't speak about health. Let's invent something and avoid adding things like the acoustic functions or other aircon options. Providing healthy lighting for the urbanites that spend 90% of their time inside buildings is a good purpose for you.

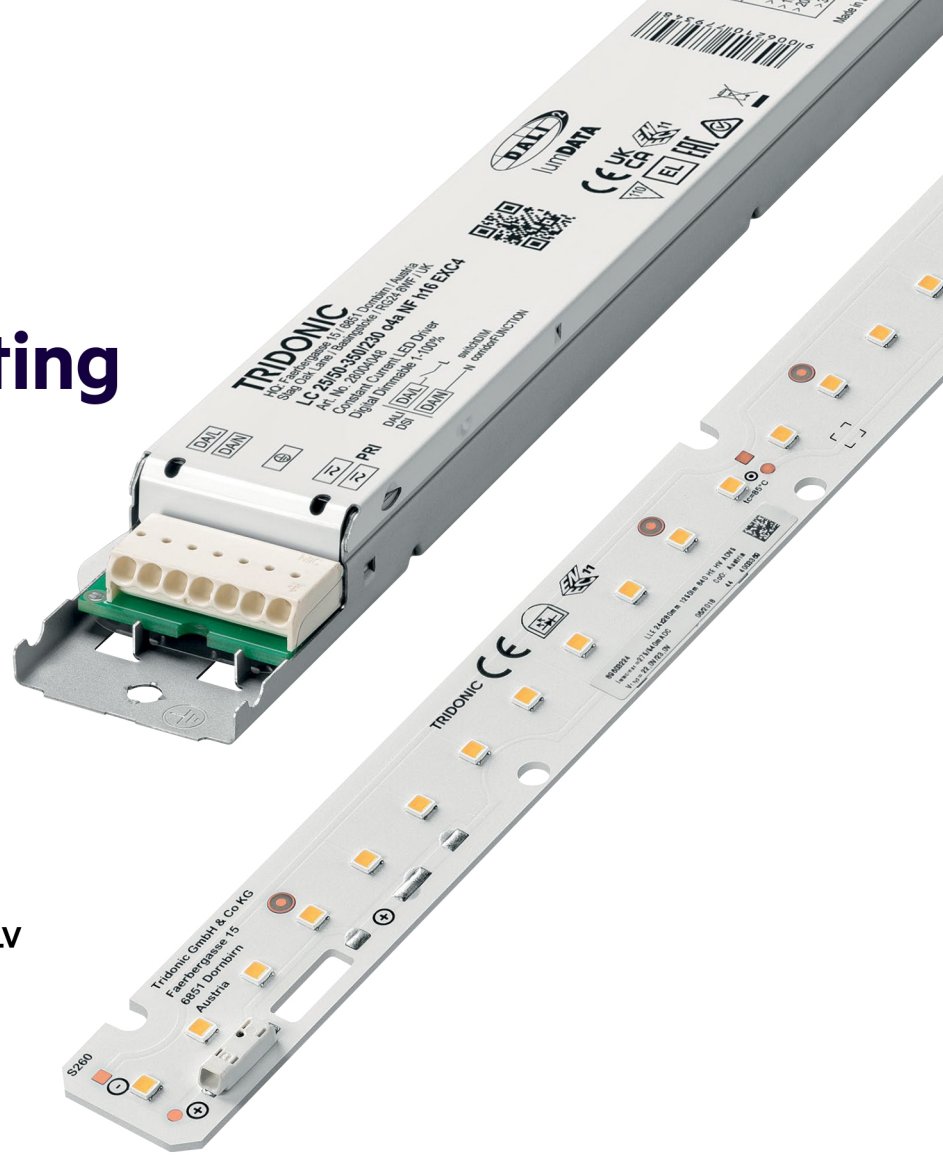
New Shapes will also emerge. Why are the spots round? Because we transitioned from round sources to LED lighting for the sake of energy savings, keeping the same holes, same bodies. I am not talking about the aluminum circles, with ledstrips inside, that we see in all the lobbies of all companies today. I am not asking for more expressionist designs. No, please look at the creativity of the automotive industry. Due to their quantities, we can see free-form lighting systems inside and outside the vehicles. Let's give a chance to the designers to invent something else for the interior, escaping the boring TIR lens. 3D printed lenses might help to open this door, to avoid the expense of the molds, which is always the pain point for risk-averse business owners.

Manageable Buildings will also be pushed forward by a country's regulations and the building's certifications because everybody has seen the benefits for the energy savings. This is already mandatory in big projects. Once everything is connected, and with the help of hundreds of sensors, we should introduce a taste of Machine Learning inside the system. But first, the connectivity. The game changer is Matter®, sponsored by the big ones. We have a lot of hope in this protocol. It could avoid silos in building management and huge savings for the end user, avoiding all the bridges, converters, licenses, and the pay-to-make-it-work contracts. A lot of money can be saved here. As a lighting manufacturer, you become a "compatible" element in a broader system, where all elements have a role to play. As for healthy light, the UX design will be key. I definitely bet on Matter. ■

N.M.

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TRIDONIC

Energy Focus Appoints New CEO and Chairman of the Board

www.energyfocus.com

Energy Focus, Inc. (NASDAQ: EFOI), a leader in sustainable, energy-efficient LED lighting control systems and products for the commercial, military, maritime and consumer markets, today announced that on August 24, 2023, the Board of Directors (the “Board”) of Energy Focus, Inc. (the “Company” or “Energy Focus”) approved the termination of the Company’s Chief Executive Officer (“CEO”), Lesley Matt, effective immediately. The Board appointed Chiao Chieh Jay Huang to serve as the Company’s new CEO. In line with this decision, Mr. Huang will discontinue his role as Chairman of the Board.

Mr. Huang, 48, is the President of Sander Electronics, Inc., which he has served as since 2015 and after holding positions of increasing responsibility since 1997. As an innovative entrepreneur, Mr. Huang has more than 20 years of experience in engineering and management within the LED lighting industry, and he holds over 50 electronic and lighting related patents, including commercial buildings, signages, and medical use. In recent years, Mr. Huang has devoted himself to the development of green energy-related products. In addition to assisting in the development of energy solution and energy storage, he has also assisted several collaborating companies to establish a sustainable governance system. Mr. Huang graduated from St. John’s University with outstanding achievements from the Department of Electrical Engineering, where he specialized in microelectronic circuits, computer structure, engineering mathematics, microcomputer applications, system programming, interfacing technology, and electronic manufacturing.

There are no family relationships between Mr. Huang and any director or other executive officer of the Company. Other than the transactions between the Company and Sander Electronics, Inc. that have been disclosed in the Company’s prior filings with the Securities and Exchange Commission (the “SEC”), there are no transactions between Mr. Huang or any member of his immediate families and the Company or any of its subsidiaries that would be reportable as a related party transaction under the rules of the SEC. Further, there is no arrangement or understanding between Mr. Huang and any other persons or entities pursuant to which Mr. Huang was appointed as Chief Executive Officer of the Company.

Energy Focus has consistently demonstrated a commitment to growth, innovation, and leadership within the industry. As part of our

ongoing efforts to align our leadership structure with the evolving demands of the business landscape, the Board has undertaken a comprehensive review of the organization’s strategic direction and executive responsibilities. The Board has determined that Mr. Huang’s experience, vision, and strategic acumen make him the ideal candidate to lead the Company as the CEO. The Board firmly believes that his transition to the role of CEO from Chairman will further enhance the Company’s position in the market.

As part of this transition, the Board has appointed Kin Fu Chen as the Chairman of the Board. Mr. Chen brings a wealth of experience and a deep understanding of Energy Focus’ operations, values, and strategic goals, making him well-suited to guide the Board in its oversight and governance functions. This strategic decision is driven by the desire to leverage Mr. Huang’s leadership strengths, experience, and expertise in a manner that best serves Energy Focus’ growth trajectory. By concentrating his efforts as CEO, Mr. Huang will be able to direct his focus toward shaping the Company’s operational strategies, driving innovation, and expanding its business horizons.

There are no family relationships between Mr. Chen and any director or other executive officer of the Company. There are no transactions between Mr. Chen or any member of his immediate families and the Company or any of its subsidiaries that would be reportable as a related party transaction under the rules of the SEC. Further, there is no arrangement or understanding between Mr. Chen and any other persons or entities pursuant to which Mr. Chen was appointed as Chairman of the Board of the Company. ■

Luminus Announces Leadership Transition as CEO, Dr. Sun Retires

www.luminus.com

Dr. Sun established the Lightera Corporation in Silicon Valley in 2012 with funding from Sanan Opto. Lightera Corporation quickly acquired Luminus in 2013, merging the two companies with Dr. Sun becoming its CEO. Under Dr. Sun’s leadership, Luminus became a profitable, well-known LED component company achieving success in a broad range of applications worldwide. He moved Luminus from Boston to Sunnyvale in 2014 and recently built the worldwide team of more than 200 employees.

Mark Pugh has been a well-known pioneer in the optoelectronics industry for over 30 years with leadership roles in business

development, marketing, and executive management. His career started with Hewlett Packard in the Optoelectronics Division working with LEDs and infrared devices. This eventually led to an opportunity to represent HP in a new joint venture with Philips that later became Lumileds. In 2007, Mark co-founded Xicato with the goal to replace halogen lights with LED modules that had industry-leading quality of-light and all the benefits of LEDs. In 2015, Mark joined Luminus Devices as Executive VP of Marketing and Sales, and the company quickly tripled in sales and turned profitable. Mark shares his vision for Luminus, “We will continue to further expand our broad product offering of photonics solutions as well as leverage our Sanan group relationship to grow our customer base in new markets with new and compelling semiconductor technologies.” ■

Advanced Lighting Technologies Acquires Cree Lighting

<https://adlt.com.au/>

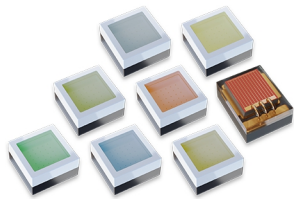
Advanced Lighting Technologies, LLC (“ADLT”) announced that its affiliate, CLNA Holdings LLC, (“CLNA”) has acquired all of the equity interests of CREE LIGHTING USA, CREE LIGHTING CANADA CORP. and E-CONOLIGHT LLC (together “Cree Lighting”) from IDEAL INDUSTRIES, INC., and IDEAL INDUSTRIES (CANADA), CORP.

Cree Lighting is a market leader and innovator of outdoor and indoor LED lighting. Cree Lighting can trace its beginnings to Ruud Lighting, which was founded in 1982 by Alan Ruud. Ruud Lighting launched the industry’s first widely adopted LED luminaires in 2007. Ruud Lighting was part of the ADLT family during this time period before breaking off to become a standalone entity. In 2011, Ruud Lighting became the biggest acquisition of Cree Inc. (now known as Wolfspeed, Inc.) and the resulting Cree Lighting continues as a market leader in a broad range of LED lighting products.

Cree Lighting joins the ADLT Lighting Group family (“ALG”) which will generate combined annual sales of approximately \$350 million and employ over 1,375 associates in facilities located across five continents.

Sabu Krishnan, Chief Executive Officer of ADLT, commented, “We are extremely happy to welcome the Cree Lighting team to the ALG family. Given our common history, the acquisition of Cree Lighting represents a homecoming of sorts. Adding the Cree Lighting brand names to the ALG portfolio will enhance the already strong ALG position in the LED products marketplace. This acquisition represents the achievement of

LUXEON Rubix High Quality White and Saturated Colors in a very small, high performance platform



LUXEON Rubix is ideal for architectural and entertainment applications that offer new possibilities for color, white, and dynamic or saturated light. It enables the smallest LES for discrete clusters, the smallest optic size for tight beam angles, and the ability to mix multiple colors under a single optic so that fixture size can be reduced and there is improved optical mixing at the source.



another step in an ambitious growth strategy that started with our acquisition of Cree Italy in 2022. Look for more acquisitions in the future.”

As to the sale, the IDEAL Industries, Inc. goal was to find a home for Cree Lighting with a company that would allow them to flourish. The combination of ADLT and Cree Lighting will present exciting opportunities for synergy and growth between the companies. Steve Henn, CEO of IDEAL Industries, Inc., said “Cree Lighting has been an integral part of our journey, and we are sincerely grateful for their contributions. However, we believe that this strategic separation will position IDEAL Industries, Inc. for accelerated growth and enhance our ability to capitalize on emerging opportunities in the industry.” ■

Signify Opens New Factory for Light Sources and Luminaires in China, Its Biggest in the World

www.signify.com

Signify, the world leader in lighting, announced the opening of its biggest LED lighting manufacturing site in the world in Jiujiang, Jiangxi Province, China. The new factory of Signify’s joint venture company Zhejiang Klite Lighting Holdings Co., Ltd (“Klite”) will manufacture high-quality branded LED lighting products, including for the Philips brand, for China and the global market.

Fully operational by the end of this year with 192 production lines, the 200,000-square meter facility will utilize world-class manufacturing technology, advanced process control, and intelligent logistics to produce LED lighting sources and luminaires for both professional and consumer markets.

“Further growth in China is a key component of our global business strategy. This new factory is an important addition to our global production capacity, supporting Signify’s growth in China and across the world. Fully in line with our growth vision, the plant illustrates our long-term commitment to China, and enhances our manufacturing and innovation presence in this important market to support

China’s sustainability goals,” said Eric Rondolat, CEO of Signify.

“Opening this state-of-the-art facility not only strengthens our in-house manufacturing capability for LED lighting products, but it also helps us drive even greater speed, efficiency and innovation so we can better prepare for the growth in the global LED lighting market,” said Rowena Lee, Division Leader Digital Products at Signify.

“The new factory will be our largest manufacturing site for LED lamps and luminaires in China and worldwide,” said Yanwei Shen, CEO of Klite. “Jiangxi Province is at the hub of China’s Midwest region with advantages in transportation and labor resources, making it a great location to build a manufacturing base of LED lighting.”

With sustainability at the top of the Signify agenda, energy efficiency measures, manufacturing automation and intelligent logistics technologies are employed in the new facility to achieve its sustainability and smart factory goals.

In 2019, Signify acquired a 51% stake in Klite, a leading manufacturer of high-quality, cost-efficient LED sources and luminaires for a global customer base. In China, Signify also manufactures products at its nine facilities in multiple locations, in addition to this new facility. These in-house production capabilities, as well as Signify’s strategic partnerships with contract manufacturers, form an efficient hybrid supply chain strategy that enables high market responsiveness, accelerates product innovation, and supports Signify’s growth in China and other global markets. ■

ams OSRAM Unveils Profit-Driven Strategy and Q2 2023 Financial Performance Amid Portfolio Restructuring

<https://ams-osram.com>

The released document is the financial report from ams OSRAM for the second quarter of 2023. The company has announced a strategic realignment towards profitability and

structural growth. The future portfolio will focus on differentiated, intelligent sensors and emitters, with an increased commitment towards the Automotive, Industrial, and Medical markets. The company will exit non-core semiconductor businesses with a revenue run-rate of EUR 300 to 400 million.

The company will take non-cash impairment charges on goodwill of EUR 1.3 billion. An efficiency program called “Re-establish the Base” will be implemented, which includes organizational adjustments, yielding EUR 150 million adjusted EBIT run-rate improvements by the end of 2025. The Management Board will be reduced to CEO and CFO effective January 1st, 2024.

For Q2, the company reported revenues of EUR 851 million and an adjusted EBIT margin of 5.9%, which is at the upper end of the guided range. The expected Q3 revenues are EUR 840-940 million with an adjusted EBIT margin of 5-8

“Our innovation power helps simplify an increasingly complex world. As we rebuild around our core business, we will benefit from structural growth trends while making the company stronger in target markets with more differentiated offerings. It’s about being a reliable partner to all our stakeholders. Profitability and monetizing innovation is put at the center of our thinking, whilst keeping our passion for cutting-edge technology that helps make the world safer, simpler and more efficient. This is what I will stand for together with the management team.” Aldo Kamper

The company expects revenues to decline in 2024 due to portfolio decisions. However, the core business is expected to outgrow its target markets assuming end-markets stabilize. The target financial model has been revised to a 6%-10% revenue CAGR based on the reduced base and adjusted EBIT of approximately 15% in 2026.

The company is also making good progress on refinancing considerations. The strategic realignment is expected to make the company stronger in target markets with more differentiated offerings. The focus will be on profitability and monetizing innovation, while maintaining a passion for cutting-edge technology that helps make the world safer, simpler, and more efficient. ■

Future Proofing Energy Efficiency with Networked Lighting Controls

www.designlights.org

The report titled "Economic Potential of Networked Lighting Controls in Commercial Buildings" is a comprehensive analysis conducted by NV5 for the DesignLights Consortium. It delves into the viability and impact of integrating networked lighting controls (NLCs) in commercial infrastructures. Focusing on two representative states, Connecticut and Arizona, the study aims to understand the economic implications and benefits of adopting NLCs in the modern commercial sector.

In the study on the economic potential of Networked Lighting Controls (NLCs) in commercial buildings, significant energy savings are projected by 2030. For Connecticut, commercial buildings can achieve a reduction in electric energy consumption by nearly 10%. Additionally, NLCs have the potential to decrease the 2030 peak demand by approximately 1.8%. When integrated with HVAC systems, NLCs can further reduce the state's 2030 natural gas consumption by 1.3%. The cumulative economic electric savings for the NLC Replacement scenario in Connecticut by 2030 is projected to be 1,064 GWh.

On the other hand, in Arizona, there's a potential to reduce electric energy consumption in commercial buildings by 5%. The state can also expect a reduction in the 2030 peak demand by about 0.7% with the adoption of NLCs. Furthermore, integrating NLCs with HVAC systems can lead to a 0.5% reduction in natural gas consumption by 2030. It's noteworthy that while the energy savings potential is evident in both the NLC Replacement and Controls-Ready Replacement scenarios, the latter achieves its maximum savings 5 years later due to the retrofitting assumptions made in the study. ■

NightScape Technology: White Light With <2% Blue Content

<https://lumileds.com/nightscape>

Lumileds NightScape Technology has been engineered to preserve the well-being of animals, plants, and people, reduce glare and light pollution, and support dark sky initiatives.

Virtually all outdoor solutions, from landscape lighting to area lighting, will be better for the environment with the application of

NightScape Technology with blue light content at levels below 2%.

Scientific studies have shown that high levels of blue light content disrupts the human circadian rhythm at night and adversely affects wildlife, such as birds, insects, and turtles. Across the globe blue light content contributes to the brightening of the night sky.

"It is within our innovation and engineering capabilities to solve real problems with LED technology and improve the lit environment," said Willem Sillevs-Smitt, Lumileds Sr. Director of Business Development. "Too often our collective behavior is to ask how we can adjust our lighting solutions to the LEDs available. What we did instead was ask how we can address this real-world lighting problem. In this case, the potential negative impacts of blue light content are compelling. We challenged our engineers and scientists to create high-quality white light with lower blue content that could improve the night-time environment for everyone and everything."

NightScape Technology will first be available in Lumileds LUXEON 3030 HE Plus and 5050 Square LEDs with a CCT of 1900K and blue light content of just 1.8% in the 400-500 nanometer range of the visible light spectrum. These outdoor proven emitters are widely used around the world for outdoor lighting including streetlights, pedestrian, landscape, and similar applications.

The physical dimensions and optical radiation patterns of the LUXEON 3030 HE Plus and LUXEON 5050 Square LEDs are identical to the existing parts in each portfolio. Any luminaire using either of these products or potentially from other manufacturers can quickly and easily adopt NightScape technology and produce a more environmentally friendly solution.

Wildlife, such as birds, turtles, and even insects, are susceptible to the impacts of artificial light at night on their migration, mating, and nocturnal activities. Outdoor lighting regulations are being rewritten and updated to provide some wildlife protection. Maui County in Hawaii has a new ordinance that took effect on July 1, 2023. This ordinance requires that "All outdoor lighting fixtures, except for neon, must limit short wavelength content to no more than 2 percent of blue light content." Outdoor fixtures using LEDs with Lumileds NightScape technology will easily fall below the 2% requirement.

"I believe that NightScape technology is the first light source to purposely address the problem of light pollution and at the same time deliver good quality, functional lighting," said Willem Sillevs-Smitt, "It's critical that the lighting industry proactively address the impact of outdoor lighting on the environment. We're excited to make it possible for luminaire

manufacturers to reduce the impact on wildlife and dark skies."

The amount of blue light emitted by various light sources is often misunderstood. It is typically measured as the ratio of blue light between 400 and 500 nanometers to the total amount of visible light emitted from the source. The graph at right shows blue light levels for different light sources that are commonly used at night. Incandescent bulbs are more commonly used in residential settings while HPS is used more commercially. ■

Made in the U.S.A. — Lumileds Matrix Integrated Lighting Solutions

<https://lumileds.com>

Lumileds, a world leader in LED innovation and manufacturing, is now producing its LUXEON Matrix products and custom integrated LED solutions for the lighting industry in the United States. This allows Lumileds to provide improved support for North American customers, reduce transportation costs, time, and environmental impacts, eliminate tariffs, and simplify the entire supply chain.

"Improving and simplifying the supply chain has been a priority and bringing solution manufacturing to the U.S. is a win for our customers in North America," said Jason Posselt, VP of LED Marketing at Lumileds.

Lumileds' approach combines industry-leading LUXEON LEDs with the power of proprietary advanced technologies and custom configures them on substrates to fit manufacturers' specific requirements. The result is a game-changing solution tailored to meet the most demanding design specifications and yield maximum supply chain value.

Customers are assured of performance consistency for flux, color, voltage, and more without the need to address product binning and selection. Lumileds engineers work with customers to ensure that solution design and LED selection are optimized for scalability and repeatability over time.

Lumileds is an EnabLED Qualified Supplier and light engine modules (integrated solutions) may qualify for a royalty exemption, further simplifying manufacturers' go-to-market strategies and costs.

To learn more about Lumileds North American manufacturing for integrated LED solutions and how to initiate new programs, email info@lumileds.com. ■

Bridgelux's Gen9 COBs Deliver 200 lm/W Efficacy

www.bridgelux.com

Bridgelux announced the launch of its Gen9 COBs. The Gen9 COB is a result of continuous effort to improve CRI80 efficacy to 200 lm/W warm white and represents a 10% improvement from the previous generation CRI 80 Gen8 COBs. Gen9 COBs are available in a wide range of Light-Emitting Surfaces (LES) from 6 mm to 22 mm in diameter.

Together with Gen9 V Series™ COBs, Bridgelux is offering a set of solder-free COB holders and optical lenses to better serve our customers with a total lighting solution. Both holder and optics meet Zhaga standards. The holders will be suitable for all V Series™ and Vesta™ TW COBs from Gen9 V6 to Gen9 V22. The optics can be clicked on the holders and have diameters from 35 mm, 45 mm, and 55 mm, to 65 mm with a wide range of beam angles from 15 degrees to 60 degrees. Gen9 COBs are particularly robust and can be operated with case temperatures up to 105°C at a maximum drive current of 2X normal while delivering the improved efficacy of 200 lm/W at CRI80. Bridgelux Gen9 COBs are an ideal solution for all commercial and residential lighting applications to meet US DLC and Euro ERP energy saving specifications.

“Bridgelux is emerging as the LED technology leader with the successful launch of new products in recent years, which feature Thrive™ full spectrum wellbeing lighting based on innovative broad blue chip technology and F90™ high efficacy CRI90 based on narrow band red phosphor technology.”, says Dr. Yi-Qun Li, CEO of Bridgelux. “Whether you are a designer, a product developer or a consumer, Gen9 further expands Bridgelux product portfolio to the industry leading efficacy 200 lm/W COB to meet your high energy saving demands.” For more information, please visit <https://www.bridgelux.com>. ■

NEW Boost UE Series High Performing Efficiency

www.edison-opto.com

The PLCC UE series features ultra-high efficiency and is almost equal to a loose part of CRI. The compact package size of the PLCC UE offers high flexibility in lamp design and expands the range of applications. With the outperforming efficiency, we optimized the UE series for use in Down Light, Tri-proof Light, Pendant Light, General Lighting, and boutique and luxury apparel stores.

The many features of the PLCC UE series offer numerous advantages and benefits. The

series' high reliability enables it to produce a high light output from low-profile general lighting fixtures. The PLCC UE series have high color consistency. They possess high energy efficiency with an output of 230lm. Color variation of LED light stays within the Macadam "3-Step/5-step" ellipse from the chromaticity center. The durability of the chip is well tested and reported at L80>72000 hours. Color temperature options range from 5000k to 3000k. The chips are compliant with the ANSI C78.377 Standard.

The features of the PLCC UE series not only offer benefits in performance but in the manufacturing process. We based the chip of the series on Blue InGan technology. They are suitable for all SMT assembly methods compatible with the IR reflow process.

Highly environmentally friendly, all the chips are mercury-free. Plus, they are compliant with CO2 reduction policies and are RoHS compliant. Ideal replacements for halogen and CDM lamps. The best combination of luminous, color uniformity, and efficiency.

About Edison Opto:

Edison Opto from New Taipei, Taiwan, was built in 2001 as the parent company and Subsidiary Edison Opto USA Corp. to service North American base customers. The company's mission is to deliver customers a complete LED product line from components to modules as an integrated design manufacturing service to support customers manage every issue while designing LED lighting products. ■

Featured insertion

XLamp® XP-G4 LEDs: The Best Just Got Better

www.cree-led.com/XP-G4



Cree LED Announces Fourth Gen XLamp XP-G Product Family. XP-G4 delivers superior performance leveraging the latest in LED technology.

Cree LED, an SGH company (Nasdaq: SGH), unveiled the fourth generation of its industry-leading XLamp® XP-G product family. With more than two billion XP-G LEDs shipped to date, the highly anticipated XP-G4 incorporates the latest advancements in high-power LED technology for improved optical performance while delivering leading efficacy. The XP-G4 also boasts a maximum drive current of 3000 mA, which is a first for the XP-G family of LEDs.

The fourth generation of XP-G products introduces an optimized optical profile designed to maximize on-axis light output and yield substantial improvements over the previous XP-G3 LEDs.

These enhancements include a smaller light emitting surface (LES) and up to 69% higher intensity, resulting in tighter beam angles and higher candela. The XP-G4 delivers exceptional color-over-angle performance and a 70-degree cutoff which dramatically improves coupling efficiency with secondary optics compared to all competing high-power LEDs.

“We are excited to launch the next generation of our industry-leading XP-G family of products. This fourth generation offers a remarkable 4% increase in maximum light output compared to XP-G3 Standard, reaching a maximum of 1,130 lumens,” said Joe Clark, president of Cree LED.

“This notable performance combined with the latest optical system delivers a ‘no compromise’ solution for both new and existing systems alike.”

Todd Ernst, vice president product at COAST Products, a Cree LED customer, added, “COAST has a 100+ year history of product innovation. As we design our next generation of portable lighting products, we will use Cree LED’s new XP-G4 LED based on its clear product advantages. This new LED family offers both higher intensity and higher maximum current in the familiar XP-G footprint, allowing us to improve the performance of our products.”

The latest generation of XP-G products is optimized for a wide range of both indoor and outdoor directional lighting applications requiring precise light control, good color over angle and long-term reliability. The new XP-G generation is available in correlated color temperatures (CCTs) ranging from 1800K to 6500K and color rendering index (CRI), including 70, 80 and 90 CRI.

Additionally, broadcast color options featuring Television Lighting Consistency Index (TLCI) will also be offered. ■

Nichia Expands the Color Portfolio of its Direct Mountable Chip Series, a High Luminous Flux Density Chip Scale LED

www.nichia.co.jp/en/

Nichia, the world's largest LED manufacturer and inventor of high-brightness blue and white LEDs, announces the additions of the E11A (1.1mm x 1.1mm) Red, Brilliant Red and Green to its high luminous flux density Direct Mountable Chip portfolio.

The Direct Mountable Chip is a chip-scale LED which has been developed through Nichia's technology and expertise in phosphors and LEDs. Its color series has already been commercialized in the larger E17A (1.7 mm x 1.7 mm), and has received a high reputation through their various key features, including a compact fixture design enabled by high luminous flux density, optimal color mixing provided by its compact light emission size, and uniformed forward voltage in all colors making electrical control easier. While maintaining the excellent characteristics of the Direct Mountable Chip, the E11A color series with a smaller size of 1.1 mm x 1.1 mm has now been added to the portfolio. In addition to landscape lighting, architectural lighting and indirect lighting, Nichia expects that this expansion of the color portfolio will provide flexibility for the fixture designs and contribute to expanding applications.

Additionally, Nichia plans to launch a blue version later within 2023. Nichia continues to develop products that are useful to society. ■

Firmware Updates via the DALI Interface are now Part of DALI-2 Certification

www.dali-alliance.org/dali/firmware.html

The DALI Alliance has extended the DALI-2 certification program to include firmware updates via the DALI interface in devices including control gear, application controllers and input devices such as sensors. Firmware updates are specified in Part 105 of the IEC 62386 standard.

Part 105 defines how firmware in a DALI device can be updated after production or shipping of the product, or in the field. Updates are made via the DALI interface. This can be done either to fix bugs and improve performance, or to add new features.

"The ability to update firmware in DALI devices represents another important step forward for our DALI-2 certification program," says Paul Drosihn, DALI Alliance General Manager. "It offers the possibility to avoid expensive on-site visits or even replacement of components, and future-proofs the installation."

DALI-2 certification is now available for control gear and control devices that successfully implement Part 105. The DALI-2 tests enabling certification were created by the DALI Alliance and are based on Edition 2 of Part 105, which has not yet been published. Edition 2 includes a series of updates compared with Edition 1, which was published in March 2020.

Firmware changes could be made in the DALI-related operation of the product, or in its application-specific part. In the former case, it is likely that some re-testing will be required to maintain DALI-2 certification.

Firmware transfer files are recommended to use the ".d2fw" filename extension.

To provide further support for firmware updates, the DALI Alliance has published a guidance document entitled "Firmware update checklist." This can be used to manage the risk of updating control-gear firmware at a live site in the field. A similar checklist could be used when updating control devices.

The "Firmware update checklist" and additional information about the upcoming Edition 2 of Part 105 is available on the DALI Alliance website (www.dali-alliance.org/dali/firmware.html). ■

JBD Announces the Development of Native Color Monolithic RGB MicroLED Displays

<https://www.jb-display.com>

JBD has announced a groundbreaking native color monolithic RGB MicroLED display aimed at AR glasses. The display features a 5 µm color pixel pitch and a qHD resolution of 960 x 540. The innovation overcomes existing technical challenges in micro-display technology, making it a promising development for the future of AR and the Metaverse.

JBD a leading MicroLED display manufacturer, has announced the development of its single chip native color monolithic polychrome (RGB) MicroLED displays, developed for augmented reality (AR) glasses applications. The display has a 5 µm color pixel pitch and a corresponding 2.5 µm monochrome R, G & B sub-pixel pitch. The display size is 0.22"

diagonal with a qHD resolution of 960 x 540 pixels. The company is currently mass producing its flagship 0.13" 4 µm pixel pitch monochrome Red, Green and Blue displays and will be ramping up capacity at its new Hefei plant, with an annual production capacity of 120 million microLED displays. This is a new product family aimed at next generation AR glasses with even smaller form factor and ease of system level integration.

MicroLEDs is the front-runner micro-display technology for AR glasses, as it offers the highest efficiency, brightness, contrast ratio, longest device lifetime, ultra-fine pixel density and ultra-compact form factor over incumbent micro-OLED, LCoS and DLP technologies. To build a high resolution (< 5 µm pitch) full color microLED display, existing technology would require the integration of three separate monochrome R, G and B display panels, usually combined with an X-cube as demonstrated by JBD's VGA polychrome projector. Whilst a single panel RGB solution is ultimately desired to maintain smallest light engine footprint, the advent of such technology remains elusive, as pick and place technology used for large TVs is not suited for ultra-fine pitch displays. Other approaches such as color conversion using quantum dots typically results in low efficiency due to re-absorption losses and device lifetime issues associated with high flux densities required for AR applications. Native color RGB grown by selective area epitaxy have also been proposed, although a convincing prototype at ≤ 5 µm pixel pitch has yet to demonstrated.

JBD founder and CEO Qiming Li said: "This product is a new milestone for the company. We believe that only native colors can meet the brightness and reliability demands of a monolithic RGB display for AR glasses, and our technology will pave the way for the Metaverse. We welcome potential new partners to design-in the monolithic full color projector into their next generation glasses". Prototypes are expected to be shipped early next year with a 3 µm color pixel pitch version to follow after that. ■

ams OSRAM Launches Intelligent Multipixel EVIYOS® 2.0 LED for Precision Adaptive Headlights

<https://ams-osram.com>

ams OSRAM (SIX: AMS), a global leader in optical solutions, introduces a ground-breaking innovation in automotive forward lighting with the launch of EVIYOS® 2.0, a new type of intelligent multipixel LED that enables fully adaptive, dynamic headlight operation and image projection.



XLamp® XP-G4 LEDs: The Best Just Got Better

Designed with the latest high-power LED technology, XLamp® XP-G4 white LEDs have higher intensity and better color-over-angle than the competition. New 3A max current enables more light output than ever from the XP-G family and lowest thermal resistance for long-term reliability. Optimized for outdoor, portable, architectural, entertainment and horticulture lighting applications.



www.cree-led.com

EVIYOS® 2.0 can selectively illuminate the road ahead to maximize the driver's view in high-beam mode without creating the glare typically experienced by other road users. The chip's 25,600 individually controllable LEDs with a pixel pitch of 40 µm can also project high-resolution images on to the road surface, for instance, to display warning symbols to the driver or other road users, or to guide the driver past obstacles.

Use of EVIYOS® 2.0 dramatically improves road safety by increasing the time for drivers to react to hazards that would be invisible or partially hidden with conventional headlights. The superior view of the road also promises to transform the driver's experience of the road at night, making night driving both easier and safer.

Until now, many automotive safety features have been designed to keep the driver and passengers inside the vehicle safe. EVIYOS® 2.0 goes a step further. Through the ability to project images on the road at night, the car communicates in new ways both to the driver, but also to others in the car's surroundings. For example, headlights based on EVIYOS® 2.0 can project a snowflake symbol on to the road surface to warn of icy or slippery conditions, helping to heighten awareness of danger and so reducing the risk of accidents.

The innovative EVIYOS® 2.0, the result of 10 years of continuous engineering development at ams OSRAM, is now in volume production.

Wolfgang Lex, Senior Vice President Automotive at ams OSRAM, said: "High-resolution adaptive forward lighting is set to become the next big differentiator for vehicles from the world's premium brands. EVIYOS® 2.0 is the enabler of the most precisely controllable forward lighting systems, and is a major new value creator for the automotive industry."

Monolithic architecture produces homogeneous light output

The design of EVIYOS® 2.0 draws on multiple ams OSRAM innovations in chip design and fabrication. The 25,600 pixels are fabricated in a monolithic µ-LED chip array, which enables ams OSRAM to achieve exceptionally high uniformity of color and brightness.

The EVIYOS® 2.0 product consists of the multipixel emitter and a driver which individually controls the operation of each of the 25,600 LEDs. In Adaptive Driving Beam systems, the multipixel headlamp is mounted in a lensed headlamp assembly, and combined with an intelligent camera for scanning the scene in front of the vehicle. This enables the headlamp in high-beam mode to dynamically switch off enough LEDs to avoid glare for other road users while maximizing the driver's view of the road. Dynamic control of individual LEDs also enables the headlight to project accurately along curves, extending the driver's view of the road ahead.

EVIYOS® 2.0 is a high-output, high-efficiency automotive light source that enables energy saving in vehicles: only those LEDs are energized that are required to maximize the driver's view safely, so light is not wasted.

The LED chip has a compact 40 mm² footprint to ease integration in sleek headlamp assemblies and is available with a 1:4 (25,600 pixels) or 1:3 (19,200 pixels) aspect ratio.

First design implementation with Marelli: microLED module uses EVIYOS® 2.0

Several globally significant car manufacturers and Tier One suppliers are designing EVIYOS® 2.0 into new product concepts. For instance, Marelli has announced its first multipixel LED headlight module to be based on EVIYOS® 2.0: the h-Digi® microLED.

Didier Thalgot, Senior VP at Marelli's Automotive Lighting & Sensing Division, said "ams OSRAM and Marelli are cooperating to transform the future of automotive front lighting. The h-Digi® microLED platform module based on the ams OSRAM EVIYOS® 2.0 enables us to develop solutions for global carmakers providing more safety and comfort for drivers at night. In addition, thanks to its compactness, improved power consumption and affordable pricing, the system opens doors to applying the technology also in mid-level car segments. With h-Digi® microLED, Marelli is driving the next generation of digital vehicle lighting."

A leading automotive component supplier

ams OSRAM is a global leader in the areas of Automotive and Mobility, and number one in the market for automotive lighting

(TrendForce's LED Industry Quarterly Report 2/2023). The company's optical components and innovative technology are used in almost every major area of a vehicle: from exterior lighting with top LED technology for headlights, to rear lighting, decorative lighting and interior lighting.

The company is a leader in LiDAR technology, providing both edge-emitting laser (EEL) and vertical-cavity surface-emitting laser (VCSEL) technology. In-cabin sensing technology enables driver and passenger monitoring, while highly precise sensing technology for electric vehicles includes stray-field immune position sensors and battery monitoring sensors. Additionally, ams OSRAM is the leader in automotive aftermarket and replacement lighting. ■

Optical Testing of Curved Displays

www.instrumentsystems.com

Instrument Systems presents its latest goniometers of the DMS series: the fully automated 7-axis DMS 904 goniometer was designed specifically for the optical characterization of large and curved displays.

This also includes pillar-to-pillar displays that extend over the entire width of the vehicle. The new DMS 904 features seven motorized axes for automated display measurement. The seventh axis enables additional linear movement of the measuring head and thus decentralized, angle-dependent measurements for displays up to a width of 1.8 m. The enlarged temperature chamber allows movement in X- and Z-direction during the measurement process and has dimensions of 160 x 60 x 20 cm.

Metrological challenges of curved-display systems

Among the new display trends, so-called curved displays in cars have undergone a particularly impressive development. Their curvature opens up a multitude of new possibilities in terms of design and applications. They embrace the functions of the individual cockpit instruments and give the driver an almost vertical view of all displays. The instrument display should be perceived as

pleasant, legible in sunlight and switch instantly, even at low temperatures. A further quality factor is the stability of the perceived image content. If contrast and color change with viewing direction, for example, it is perceived as unpleasant.

Characterization of the quality of curved displays involves the measurement of many metrological parameters: color gamut, chromaticity and luminance of the grey states, luminance contrast between black, white and grayscale, as well as the change in these sizes with the viewing direction and in ambient light. The ever-increasing size of curved displays thus presents a very special challenge for optical display measurement technology.

DMS series – goniometer systems for perfect displays

Instrument Systems developed the DMS goniometer system specifically for the characterization of displays. Established display measurement systems offer many options for view direction-dependent optical evaluation of displays in consumer electronics and automotive engineering. They are regarded as a global standard and reference for extensive analyses of electro-optical displays in construction phases and production processes.

All DMS models enable the following measurements:

- Luminance, color and contrast under different viewing directions and display operating conditions
- Electro-optical transfer functions (EOTF) and flicker
- Spectrally diffuse and direct reflection and transmission
- Qualification of the effects of ambient lighting and temperatures

The basis of a DMS system is a high-precision goniometer that permits a full scan of viewing direction by motorized azimuth rotation Φ and angle of inclination Θ . Uniformity scans can be made with control of the lateral DUT position (X, Y). The integral DUT driving unit controls samples, e.g. analog signals, source meters or display interfaces. An optical microscope enables reproducible selection of measurement spot size. Additionally, two light meters – a spectrometer and a photometer – are connected to the microscope via fiber optic cable. Sophisticated software controls the automated measurement processes and prepares comprehensive result reports.

Development for large automotive displays

The new goniometer DMS 904 was specially developed for large and curved displays for customers in the automotive sector. It has seven motorized axes for automated measurement, a motorized microscope aperture wheel and an integrated alignment

camera. The additional X-axis enables decentralized, angle-dependent measurement of curved displays up to a width of 1.8 m. A heat-cool system can be integrated if needed for temperature-dependent measurements and conformance testing. The HCS-7 temperature chamber permits movements in X- and Z-direction. Its enlarged interior of 160 x 60 x 20 cm can be temperature controlled in a range between -40°C and +105°C.

Quality control is of great importance in the automotive industry, in order to ensure compatibility throughout the supply chain. This calls for clear, precisely specified and standardized testing and measurement methods as a basis for reproducibility. The DMS systems from Instrument Systems are used worldwide in both R&D and production, in order to ensure the highest quality for our customers and promote display development. ■

Shedding Light on Circadian Health: The Transformative Role of Melanopsin in Human Well-being

https://files.cie.co.at/CIE_TN_015_2023.pdf

The "Second International Workshop on Circadian and Neurophysiological Photoreception" technical note provides a comprehensive overview of the proceedings and consensus from the 2019 workshop. This document, prepared by the CIE Division Reporter 6-46 of Division 6 "Photobiology and Photochemistry", aims to shed light on the intricate relationship between light exposure and its impact on human circadian rhythms.

Circadian rhythms, which are biological processes that follow a roughly 24-hour cycle, play a pivotal role in various human physiological functions. These rhythms are influenced significantly by environmental factors, with light exposure being the primary determinant. The discovery of a photopigment called melanopsin in the human retina in 2000 marked a significant advancement in understanding this relationship. Melanopsin, found in intrinsically photosensitive Retinal Ganglion Cells (ipRGCs), plays a central role in regulating the body's response to light, impacting various physiological and behavioral aspects, including sleep regulation.

The 2019 Manchester workshop emphasized the importance of optimizing light exposures to promote circadian health, well-being, and performance. The workshop highlighted the significance of melanopsin-based photoreception in predicting human physiological responses to light. The outputs from this workshop are intended to guide governments, the lighting community, and

public health professionals, emphasizing the importance of scientific advancements in this domain.

One of the workshop's primary outcomes was the identification of the melanopsin-based photoreceptors' role, known as ipRGCs. These receptors process signals from other photoreceptors in the retina, combining this information with their melanopic response to light. This combined information is then transmitted to various brain targets, including the region responsible for circadian timekeeping.

The workshop also provided recommendations on healthy light exposures. For day-active adults aged between 18 and 55 years, the recommendations include:

- A minimum melanopic equivalent daylight illuminance (EDI) of 250 lx during the daytime, preferably from natural daylight.
- A maximum melanopic EDI of 10 lx during the evening, starting at least three hours before bedtime.
- A maximum ambient melanopic EDI of 1 lx during the night, with the sleep environment being as dark as possible.

These guidelines, derived from extensive scientific research, are intended to be applied to architectural and lighting designs, as well as general lifestyle advice. The workshop's consensus underscores the importance of understanding and predicting how circadian rhythms respond to environmental light, paving the way for a healthier relationship between humans and their light-filled environments. ■

A Legacy of Light: LED professional Review Marks its 100th Edition!

<https://www.led-professional.com/>

LED professional Review, commonly referred to as LpR, stands as a beacon in the realm of lighting technology publications. Dedicated to the rapidly evolving field of LED and OLED lighting, LpR offers its readers a comprehensive overview of the latest trends, innovations, and research findings in the industry.

At its core, LpR is more than just a magazine; it's a knowledge platform. Each issue delves deep into the technical aspects of lighting, ensuring that professionals, researchers, and enthusiasts are equipped with the information they need to drive the industry forward. Topics range from the intricacies of LED design and the challenges of thermal management to the potential of smart lighting solutions and the impact of lighting on human health.

One of the standout features of LpR is its commitment to quality and depth. Articles are often penned by leading experts in the field, ensuring that readers receive accurate, up-to-date, and relevant information. This commitment to expertise is evident in the magazine's regular inclusion of in-depth research studies, technical discussions, and reviews of the latest products and technologies.

Beyond the technical, LpR also recognizes the importance of sustainability and the role of lighting in creating a greener future. Issues often feature discussions on energy efficiency, the environmental impact of lighting solutions, and the potential of renewable energy sources in the industry.

In addition to its printed issues, LpR's online presence offers a wealth of resources. The website is a hub for the latest news, events, and webinars, ensuring that the global lighting community remains connected and informed.

In summary, LED professional Review is not just a magazine; it's a movement. It champions the fusion of technology and sustainability, driving the lighting industry towards a brighter, more efficient, and environmentally-friendly future.

LED professional Review (LpR): Nov/Dec 2023 (preliminary)

Celebration Issue #100, with the Brightest Visions of Tomorrow

Dive into the Future of Lighting with our upcoming issue that promises to be a **treasure trove of insights and innovations**. Join **Prof. Shuij Nakamura**, the esteemed **Nobel Prize Winner** from **Santa Barbara University**, as he shares his profound commentary on the evolving landscape of technologies and lighting. Get an exclusive peek into the mind of **Monica Luz Lobo**, the **President of IALD**, as she unveils the latest trends shaping the world of lighting designs. **Bronwen Rolls**, a renowned marketing expert, takes us on a journey with the lighting maestros at **StudioZNA**, delving deep into luminaires, sustainability, and transformative user experiences. **Dr. Oliver Stefani**, founder of **Chronolight** and affiliated with the **University of Lucerne**, poses the pivotal question, **"What is Good Light?"** and explores the tools and techniques that will define our luminous future. **Nichia** presents a compelling case study, showcasing the application of cutting-edge lighting technologies in real-world scenarios. And, **Arno Grabher-Meyer** challenges us to think **Beyond Efficiency** in lighting, emphasizing the importance of sustainability and environmental protection in the modern era. This issue promises to be a beacon of knowledge, innovation, and inspiration for everyone in the world of **Solid State Lighting**. ■

LpS Digital Summit to Host the Inaugural AI-Curated LpS Digital Awards

www.LpS-Digital.global

The LpS Digital Summit, renowned for its commitment to innovation in the lighting sector, is set to make history with the introduction of the first-ever AI-Curated LpS Digital Awards. This groundbreaking initiative will be a highlight of the LpS Digital Summit 2023, scheduled for December 7. The LpS Digital Awards, now powered by state-of-the-art AI models, promises an unbiased and meticulous evaluation of entries, setting a new standard in award recognition. Entries will be assessed by AI Judges, specifically directed to evaluate based on Innovation, Market Dynamics, and Technological Advancements.

Winners will not only receive the prestigious LpS Digital Awards Certificate but will also be celebrated for having their products evaluated by the pinnacle of AI technology, ensuring a verdict that's both independent and unparalleled. The LpS Digital Summit 2023, set to unfold on December 7, will be a confluence of industry and research giants, offering attendees a deep dive into the forefront of lighting innovations. Esteemed panels will unravel cutting-edge trends shaping the future of lighting, making it an unmissable event for industry professionals and enthusiasts.

Recipients of the LpS Digital Awards will be heralded at the Summit, with accolades showcased on platforms like LED professional and Trends in Lighting. Furthermore, winners will be granted the esteemed opportunity to deliver a featured talk, amplifying their voice to a vast audience of 45,000+ industry contacts.

"In the dynamic landscape of innovation, it's not enough to simply recognize brilliance; we must challenge it. With our AI-curated awards, applicants don't just seek recognition — they have the unique opportunity to stress-test their innovations on the AI bench, ensuring that their creations aren't just novel, but resilient and future-ready." — Siegfried Luger, Organizer and Head of Luger Research e.U.

The combination of the LpS Digital Summit and the AI-Curated LpS Digital Awards marks a revolutionary step in the lighting industry, merging technological advancements with industry recognition.

Unlocking Excellence: 5 Compelling Reasons to Apply for the AI-Curated Awards

- **Objective Recognition:** The AI-curated awards ensure a bias-free evaluation, offering a transparent and fair recognition



High-speed MicroLED in-process inspection

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- ▲ Fast and accurate optical inspection of every LED on a wafer in seconds
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- process that purely focuses on the merit of the innovation.
- **Stress-Test Innovations:** Beyond mere recognition, applicants have the unique opportunity to stress-test their innovations on the AI bench, validating their creations against rigorous, machine-driven criteria.
 - **Position as Industry Leaders:** Being recognized by an AI-curated award positions an organization as forward-thinking and adaptive to modern technological advancements, enhancing its reputation in the industry.
 - **Valuable Feedback:** The AI-driven evaluation process can provide detailed insights and analytics, offering invaluable feedback that can guide further refinement and development of their innovations.
 - **Broadened Exposure:** Given the novelty and intrigue surrounding AI-curated awards, participating organizations can expect heightened media attention and exposure, amplifying their reach to potential clients, partners, and stakeholders.

Submitting to the AI-curated awards not only offers a chance for recognition but also provides a platform for organizations to validate, refine, and showcase their innovations to a wider audience.

For more information
www.LpS-Digital.global. ■

LpS DIGITAL AWARDS 2023

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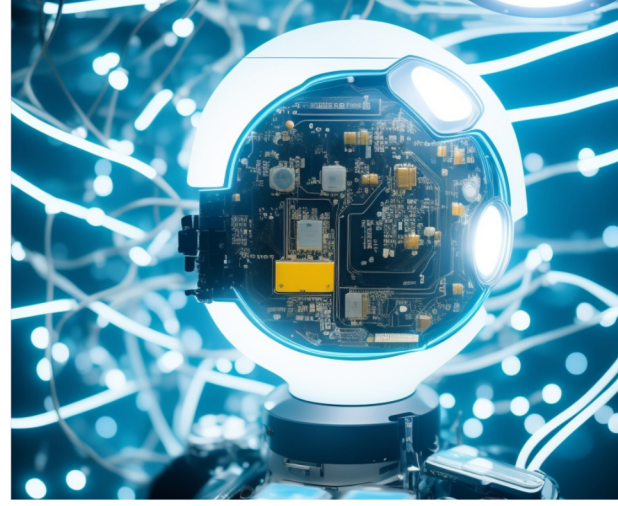
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Dive into a
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era where the
brilliance of
lighting meets
the precision
of artificial
intelligence.



“Given the novelty and intrigue surrounding AI-curated awards, participating organizations can expect heightened media attention and exposure, amplifying their reach to potential clients, partners, and stakeholders.”

“In the dynamic landscape of innovation, it’s not enough to simply recognize brilliance; we must challenge it. With our AI-curated awards, applicants don’t just seek recognition — they have the unique opportunity to stress-test their innovations on the AI bench, ensuring that their creations aren’t just novel, but resilient and future-ready.”

SIEGFRIED LUGER

Organizer and Head of
Luger Research e.U.

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Fostering Innovations in Light – Janick IHRINGER, VP & GM Business Line Illumination, ams OSRAM



Janick IHRINGER:

“My management style has always been to empower employees and help foster their success and career growth.”

ams OSRAM is a global leader in intelligent sensors and emitters. ams OSRAM continuously advance their industry-leading technologies in sensing, illumination and visualization to make the world safer, simpler and more efficient. They provide high-performance LEDs and lasers, mixed-signal analog ICs and sensors.

<https://ams-osram.com>

LED professional: We are delighted to have the opportunity to conduct this interview with you. To start, can you give us a review of your career?

Janick IHRINGER: I am an experienced leader in Illumination as well as the LED industry with almost 15 years of experience, being with ams OSRAM since 2010. Over the course of the last decade, I have covered roles in application engineering, product marketing and strategy with plenty of customer engagement. Working four years out of Asia, I built up new business functions in Malaysia, lead global teams and managed several product lines as a director. Through all that time, I got to interact with customers and partners, gaining insights into their needs and how our technology and innovations can help them to differentiate in their businesses.

I returned to Germany in June 2020, taking on once again the lead for a Product Line and a business area new to ams OSRAM. Since early 2022, I have been responsible for Global Leadership, Strategy and have P&L Responsibility for ams OSRAM's Illumination Business Line. I have one of the best and most exciting jobs in the company!

LED professional: Could you give us a brief summary of your business and technical education?

Janick IHRINGER: My education is broad. I studied experimental physics. I focused very quickly on LEDs and semiconductors because I could eas-

ily see the link between my university education and a tangible example of how to do things in the real world. Later, I understood that a piece was missing in my education about understanding what drives a company and customers on the commercial and financial side. I went on to get my MBA on top of that which gave me a good understanding of how we work as a company and how other companies operate. A big part of my education was when I first came to OSRAM, and I could speak to hundreds of customers, visit different conferences, and talk to industry buddies. From a learning experience and what is valuable today, it's the first few years when I worked with my first boss, who taught me a lot about how customers work, applications work, and LEDs work.

LED professional: Would you explain the strategic orientation of ams OSRAM and which core areas the company focuses on?

Janick IHRINGER: Our success lies in cultivating core competencies in illumination, visualization, and sensing technology. At ams OSRAM, we offer the customer a comprehensive suite of solutions from emitting to sensing. Our commitment to innovation is second to none, as evidenced by game-changing products including incredibly pixelated headlights and miniature medical imaging systems as well as our innovative UV-C and horticulture products.

Energy consumption is a high priority for us, and one where we excel. Consider

smart lighting, where we continue to lead the way in energy efficiency, whether it's street lighting, connected lighting, or horticultural lighting. Measuring the light spectrum not only optimizes effectiveness but also helps save energy, a critical driver towards achieving energy-saving standards.

We also have the automotive business line, our biggest one, covering all automotive applications such as interior, exterior, forward lighting, in-cabin lighting, and displays in the automotive. Our newest addition in opto semiconductors is our display business line, where we focus predominantly on small LEDs for display technology in industrial applications and include more recent applications.

LED professional: Let's discuss some applications in more detail. Can you update us on ams OSRAM's horticulture lighting product strategy and innovations?

Janick IHRINGER: Two significant megatrends are currently driving the horticulture market. Firstly, there's a movement towards organizations encouraging people to source their food supplies locally. Rather than importing food from far away countries, there is an increased focus on producing locally. Secondly, there's a growing health awareness, with people looking to eat cleaner and live better. This includes health benefits for both us and the environment. The use of LED lighting for growing fruit and vegetables not only saves water, soil, pes-

ticides, and energy but also helps keep food prices low.

LED professional: What are the significant challenges and trends shaping the market?

Janick IHRINGER: Our most significant area is greenhouse lighting, with new installations adding artificial light to sunlight to help plants grow better. When it comes to indoor farming or vertical farms, there are important trends to consider. A more sustainable part of the market for regular indoor farms focuses on herbs, vegetables, and leafy greens. These can grow without sunlight but just use artificial light in controlled environments, which can be tailored to different plant types.

Urban farming is a rapidly growing trend in metropolitan areas with limited space, and LED technology is revolutionizing the way we grow crops indoors. Our team specializes in developing energy-efficient LEDs that are essential for the success of urban farming. Plants cultivated indoors require 100% artificial lighting, given that sunlight is not available. Our cutting-edge LEDs generate the energy that plants need to thrive, and we pride ourselves on our ability to provide the full spectrum of light that different types of plants require to grow and flourish.

It is critical to monitor the growth stages of different plants, considering that each one has a unique set of lighting requirements. Our state-of-the-art technology, combined with our wealth of knowledge and experience, enables us to deliver optimal growth for any type of plant grown indoors. There is a tremendous amount of science, research, and ingenuity that goes into creating these sophisticated LED fixtures that help to nurture thriving crops in urban environments. From optimizing growing recipes by illuminating greenhouses, to supporting cultivation in vertical farms. Beyond the spectrum, illumination's unique ability lies in optimizing the photon flux ratio to cater to the individual needs of different plants, setting it apart from other market solutions.

Our latest product launch, the OSOLON[®] Square Hyper Red¹, has even brighter prospects. The technology behind it enables system cost optimization by overdriving current and reducing LED

counts. Unique optics like the Batwing family also provide growers with ample design capabilities to cater to the needs of individual plants, trimming down system costs by reducing the size of optics and PCB.

Boasting years of experience working with lights in agriculture, we have introduced the market's most efficient LEDs for horticulture applications under Hyper Red 660 nm technology.

“Our success lies in cultivating core competencies in illumination, visualization, and sensing technology.”

JANICK IHRINGER

What's more, we have further developed a combination of sensors and LEDs to offer additional value to customers. In June, we launched two new products for horticulture: the OSOLON[®] Optimal family of horticultural lighting LEDs with a new 640 nm Red LED, and the fifth generation of our popular OSOLON[®] Square Hyper Red 660 nm horticulture LED designed to offer quicker plant growth and enhance system cost outcomes.

LED professional: What's new in UV-C solutions for public and private areas?

Janick IHRINGER: Our UV-C technology holds the potential to revolutionize everyday life, making it healthier, safer and more comfortable. The events of the past few years have highlighted the importance of health and safety, and we are keen to help people cope with these new realities. That's why we are proud to offer the OSOLON[®] UV series of high, mid, and low power UV-C LEDs - a planet of possibilities for industrial and consumer applications.

Our OSOLON[®] UV series² has been designed to offer flexible solutions for various types of UV-C applications - from point-of-use water treatment to air purification in portal devices or air conditioning systems, and from automotive interior disinfection to many more areas besides. Until recently, UV-C mercury vapor lamps were the choice for clean

water and surfaces. However, our UV-C LED solutions are a game-changing technology with vast potential. Their small and robust design, as well as their mercury-free nature, will help bring UV-C radiation to completely new application areas and overcome the limitations of existing solutions.

In just ten years, we predict the widespread adoption of UV-C LED technology. This technology will be used to clean and purify what we touch, eat and drink, and will have benefits for established solutions for presence detection, tamper/misalignment detection, smart access control as supportive safety measures, and even for horticulture. To ensure maximum efficiency, precise UV sensors can be used to monitor radiation doses, optimizing treatment processes for safe and effective deployment of invisible UV-C light.

LED professional: ams OSRAM also offers lighting solutions for smart cities, e.g., homes and industrial buildings. Please explain to us the product strategies and innovative solutions in these fields.

Janick IHRINGER: When it comes to creating smart lighting solutions, the need for improved efficiency and cost reduction still ranks highly. But, customers are increasingly gravitating towards miniaturization and enhanced color quality, as they look for ways to optimize value. At our company, we always prioritize delivering products that meet the highest quality and reliability standards.

As you know, there can be regional differences in lighting applications, but differences in standards are most pronounced at the application level. Consider street lighting, where safety standards run high. Our High-Power White LED portfolio leads the industry in meeting these requirements. These LEDs perform exceptionally well, even in harsh outdoor conditions, and boast industry-leading lifetimes.

We cover a broad spectrum of lighting applications, from Horticulture and UV-C treatment to Street, Tunnel, and Urban lighting, as well as Industrial and standard industry solutions, like runway lighting, Emergency Vehicle Lighting, signaling applications, and indicator button backlighting.

¹OSOLON[®] Square

²UV-C LEDs

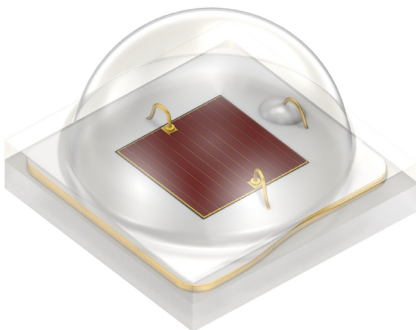
“We see LEDs as the predominant technology.”

JANICK IHRINGER

LED professional: Where are the main markets for ams OSRAM globally? And how do you support the international markets with your design-in expertise?

Janick IHRINGER: In terms of lighting, ams OSRAM will focus on five main areas of illumination:

Agricultural and Horticultural lighting: Horticultural lighting is a new and innovative method of growing food in a controlled environment that is often situated near urban centers. Crops can be grown smart, sustainable, and easily using precise LED lights and advanced sensing technology. These LED-based solutions can adapt to the particular needs of different plants, meaning growth can be monitored and harvests optimized while reducing fertilizer use and energy costs. This technology is proof that our lives can be significantly improved using innovative technology.

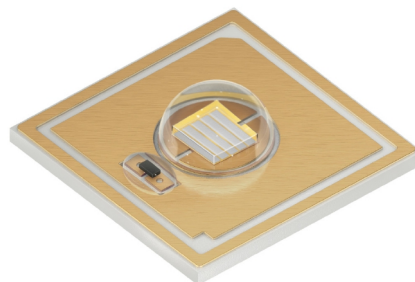
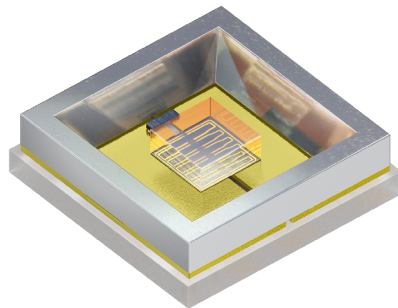


Hyper Red LED with best value for highest PPF/W. Most compact high-power LED with proven robustness, high reliability, long lifetime and low thermal resistance (OSLON® Square).

ams OSRAM is a global leader in professional LED horticulture lighting and sensing. Our optimized LEDs and spectral sensors improve plant growth for a variety of different crops. Our high-efficiency luminaires also minimize energy consumption when energy costs are increasing, and we offer the best-in-class illumination uniformity that can reduce overall energy usage. Our LEDs provide maximum design flexibility and have a long-life performance, offering the lowest overall system cost.

UV-C treatment: At ams OSRAM, we work alongside our clients to create

ground-breaking solutions that enhance safety. Our cutting-edge UV-C technology enables accessible and straightforward purification of public, private, and commercial spaces. Our miniaturized designs make it possible to integrate high-efficiency UV-C LEDs and presence detectors into various appliances. These can be embedded in standard light sources to sanitize public areas, placed in purification boxes to sanitize handheld devices, or even incorporated into taps to purify water. We also offer intelligent air filter systems that combine UV-C LEDs with spectral sensors to monitor organic pollution levels and enable predictive maintenance solutions, such as determining when filters must be replaced.

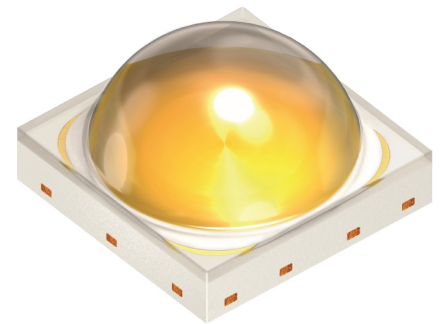


The OSLON® UV series is designed for applications such as sanitization, purification, treatment and sensing (top: OSLON® UV 3535; bottom: OSLON® UV 6060).

Our UV-C LED portfolio is scalable and has a best-in-class lifetime with various power classes that support flexible and fast switchable designs, allowing for extremely space-optimized integration. Additionally, full irradiation is available after switching on, whilst producing no ozone in the treated air. The technology even features pulsed dimming, enabling users to adjust dosimetry to control the rate at which pathogens are removed. Ultimately, this results in systems that work smarter, and our customers can benefit from being able to replace filters only when necessary.

Outdoor and Industrial Lighting: When it comes to industrial lighting, the qual-

ity of light is essential for consistent high performance and precise working processes. Our products offer uniform distribution of light, high efficiency, and constant intensity and color - making them the best in the market. Our LED range comes in various sizes and power packages, combined with sensors for high flexibility in luminaire design, suitable for any workplace setting. High-quality outdoor lighting benefits society in numerous ways, including providing clear visibility at night - particularly for pedestrians, cyclists, and drivers.



High-power LED with high performance, superior robustness and long lifetime (OSCONIQ® P 3737).

Our cutting-edge spectral sensors and LEDs cater to all professional outdoor lighting needs, highlighting the designs of buildings and physical structures. Our sustainable LED components offer outstanding performance, reliability, and an industry-leading lifetime, even in harsh outdoor conditions. Furthermore, we offer spectral power distribution (SPD) quantification to support specialized outdoor lighting technologies. Using ambient light sensors and time-of-flight sensors for presence detection, we lead the way in creating the latest generation of energy-saving lighting solutions. ams OSRAM lighting components help shape the future of smart cities.

Indoor lighting: Lighting is a crucial element in shaping the personality and ambience of our indoor spaces - be it in offices that encourage creativity and productivity, schools that facilitate better learning environments, hospitals that prioritize rest and recovery, or smart homes where comfort and convenience are paramount.

Human-centric lighting (HCL) utilizes optimal daylight patterns to regulate our circadian rhythms, enhance our emotional and mental well-being, and elevate our overall performance.



PRIVA

Greenhouse Application lit with ams OSRAM's LED technology.

At ams OSRAM, we offer innovative LEDs and intelligent sensors designed specifically for HCL. Our LEDs provide endless possibilities for lighting and design, while our smart lighting controls enable flexible and cost-effective tunable lighting that can dramatically transform any space. Our ambient and spectral light sensors also help improve room monitoring systems, ensuring maximum comfort and well-being for everyone indoors.

Entertainment lighting: Professional lighting designers have trusted us for decades to turn their creative visions into breath-taking performances while addressing their digitalization, efficiency, and sustainability needs. At ams OSRAM, we offer innovative, high-quality entertainment lighting products that bring any event to life. From concerts and theatre performances to TV shows and architecture, our lighting solutions create unforgettable visual experiences for audiences and help artists and designers take their light shows to the global stage. Our advanced lighting solutions allow for high-efficiency and power level color mixing, thanks to controllable LEDs linked with smart sensor technology. Based on over a century of innovative heritage, our intelligent lighting solutions offer endless design possibilities to increase productivity, create beauty, and evoke emotion. ams OSRAM provides a range of unique LEDs, spectral and ambient light sensors, and miniaturized, efficient components that give our customers maximum accuracy (precision), exceptional performance, and outstanding cost-effectiveness.

LED professional: The question of which light source will prevail when it comes to LEDs, micro LEDs, OLEDs, and lasers has come up. What are your expectations when it comes to light sources?

Janick IHRINGER: You have to pick the right technology for the right application. We offer LEDs, lasers, mini- and in the future, microLEDs. There are use cases for all these technologies. Market researchers see that microLEDs will start having use cases in consumer applications. So there will be a more significant share of microLEDs in consumer applications and industrial display use cases longer-term. Lasers are strong in visualization and sensing applications. We see LEDs as the predominant technol-

ogy. LED and microLED have the same technology base and we can rely on our know-how and expertise.

LED professional: Does ams OSRAM offer Design-In support for its clients?

Janick IHRINGER: That is an elemental part of what we do and what we are at ams OSRAM. We have a function in each business line and our sales departments called System Solution Engineering. It is essential to go hand in hand with the customer to understand the design targets and challenges along the way and the opponents that play a role. So each business line has a team that understands the customer application and the ecosystem to support the customer and give recommendations.

LED professional: A topic we haven't touched on yet is sustainability. What are your thoughts?

Janick IHRINGER: Fundamentally, our business supports sustainability and energy efficiency by its nature. We look holistically at sustainability, we create sustainable value and improve lives with our solutions. I think that's a journey. Beyond focusing on business and innovation, we also live up to our responsibility in terms of environment and our society.

LED professional: Where do you see ams OSRAM in five years?

Janick IHRINGER: At ams OSRAM, we aspire to maintain our position as a global leader in intelligent emitters and sensors and to offer groundbreaking technologies and applications. Our unique product and technology portfolio includes prime quality light emitters, micro-modules, light sensors, ICs and related software for sensing, illumination and visualization. With our expertise in designing pioneering optical solutions, we inspire our customers and demonstrate our ability to meet their needs. In the next five years, we aim to further develop our deep engineering expertise, while continuing to be the trusted partner for the entire value chain of optical solutions. By doing so, we will enable our customers in the consumer, automotive, industrial, and healthcare sectors to maintain their competitive edge.

LED professional: Aldo Kamper, a new CEO, is now on board. Are there already unique accents for the company or in the management style?

Janick IHRINGER: With almost thirty years of experience in the semiconductor industry, Aldo Kamper is a veteran of the semiconductor industry. He initiated his career with OSRAM and he pioneered the development of microLED technology, dynamic forward lighting, and LED performance roadmaps for new applications, such as horticulture lighting. He is an invaluable asset to the company.

LED professional: How do you manage ams OSRAM, the people, and the teams?

Janick IHRINGER: I've learned that the most critical factor for achieving success is having the right people. To foster an innovative climate, it's important to create an environment that values and nurtures its people. My management style has always been to empower employees and help foster their success and career growth.

LED professional: Thank you very much for the detailed interview, and we wish you, your team, and ams OSRAM continued success!

Janick IHRINGER: It was great talking to you. Thank you very much. ■

For additional information please visit <https://ams-osram.com>.



How Beauty Could Actually Save Our Brain

Martina FRATTURA, M.Sc., Beauty-informed Lighting Designer and Independent Researcher

As people spend a significant amount of time indoors, understanding how built environments can positively impact physical, mental, and emotional well-being is becoming increasingly important.

The traditional approach of designing spaces to meet mandatory standards is being challenged: the evolving perspectives on design and research related to the built environment and its impact on human well-being acknowledge the importance of going beyond minimum requirements to create environments that truly enhance the human experience.

The changing perspective on design also impacts both designers and scientists. Designers need to consider factors beyond functional requirements, focusing on creating spaces that positively influence human well-being. Scientists are encouraged to collaborate with designers to provide empirical insights into how places affect people, to allow a seamless and meaningful connection between humans and their environment.

We investigated both ascending (bottom-up) and descending (top-down) attentional mechanisms, while hypothesizing that the phenomenon of “soft fascination” could be reproduced in built environments and, secondly, that it can be connected to the subjective perception of beauty. The full article about this study was published in the Proceedings book of the SS21 Conference Senses&Sensibility: A Beautiful Light - Fascination Against Depletion, written by Martina Frattura, Massimiliano Mancini Tortora, Professor Eduardo José Gonçalves and Natalia Olszewska.

The question is, how can interiors have a remedial or healing potential, as per outdoors? On the table, there is the realization that a space itself can also be the reason why we do, or we don't, exert our mental strength. Environmental psychology offers two key concepts in this direction: “restoration” and “soft fascination”. While the first is used to describe an automatic recovery of attentional resources, in response to environmental stimuli mainly present in natural contexts, the second is identified as one of the four characteristics of an environment that helps restore a tired mind. “Soft fascination” is described as an ability of a space or an object to subtly and effortlessly capture attention (Kaplan & Kaplan, 1989). Specifically, we talk about selective attention, or the process of focusing on a particular object in the environment for a certain period of time. This type of attention allows us to fine-tune unimportant details and focus on what matters, and could be achieved in two ways: bottom-up, involuntary, and stimulus-driven, depending on the salience of the stimulus, and top-down, voluntary allocation of attention to certain features, objects, or regions in space.

How exactly built environments can provide a restorative experience and replicate the beneficial qualities of natural settings, is the initial question and we choose to try finding an answer through the aesthetic experience.

We recently published a study investigating both ascending (bottom-up) and descending (top-down) attentional mechanisms, while hypothesizing that the phenomenon of “soft fascination” could be reproduced in built environments and, secondly, that it can be connected to the subjective perception of beauty.

Beauty Is

The aesthetic experience is a necessary physiological response that puts us in direct communication with what we have around us while beauty, on the other hand, is commonly recognized in the various names of the things and/or people in which we see it. Everything we see is the result of our own interpretation of the experiences we are living and have lived, therefore only if we first identify ourselves with “the good” we want to find, only expanding it as a continuation of our own person in the world, then we will be able to find it in front of us.

The action verb associated with our mind's pursuit of beauty and its pleasantness is inherent within the concept of beauty itself. In other words, the pursuit and enjoyment of beauty are integral components of what defines it. Beauty encompasses not only the visual or sensory appeal of something but also the act of seeking and appreciating it. This aligns with the notion that beauty is an experience that involves both the perceiver and the perceived, and it reflects the inherent connection between our cognitive and emotional responses to the world around us.

In light of all of this, an investigation set off to look at how beauty perception might impact attentional mechanisms, suggesting a potential connection between exposure to beauty and the brain's ability to focus and restore attention, with the hypothesis that exposure to personal beauty references may help decrease attentional fatigue.

A Beautiful Light

A Beautiful Light research project explores how individual perceptions of beauty might impact emotional processing, attentional mechanisms, and autonomic responses.

We investigated how the personal idea of beauty could possibly modulate emotional processing and attentional mechanisms by analyzing changes in emotion and the alpha and beta asymmetry related to attention restoration, together with observation of the autonomic response via skin conductance.

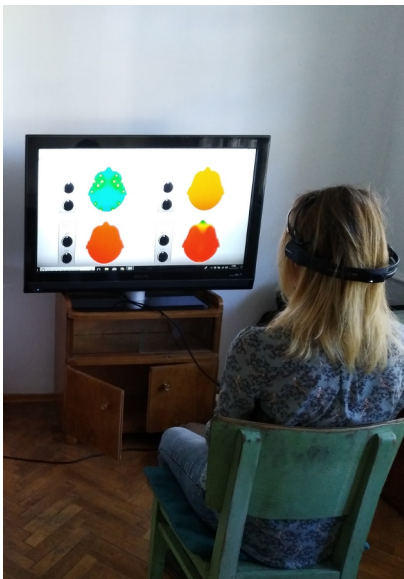


Figure 1: A beautiful light research project in Sofia, Bulgaria. Image Credit: Martina Frattura.

Looking at a beauty emblem compared to other selective attention tasks could be linked to the activation of the right temporal areas of the brain, involved in various cognitive functions, including perception, attention, and recognizing salient stimuli. This activation pattern could be associated with bottom-up, stimulus-driven attention, which is influenced by the characteristics of the stimuli themselves, drawing attention to salient or important elements in the environment. In addition, this may be linked to attentional restoration, which refers to the process of replenishing cognitive resources by engaging with less demanding stimuli.

#WhereDoYouSeeTheBeauty

The research journey spanned across 10 different countries (Bulgaria, Canada, England, Greece, Iceland, Italy, Portugal, Spain, Sweden, Turkey), involving over 150 participants from various regions and reflecting a diverse range of cultural backgrounds and geographical locations.

The primary objective of the research was to understand where people find beauty. This encompassed various aspects of life, including natural landscapes, artistic creations, personal relationships, cultural expressions, and more, believing that they would have significantly influenced how individuals define and appreciate beauty.

Data was collected with an EEG instrument to monitor brain electrical activity and an EDA to track galvanic skin response (GSR), testing the hypothesis that exposure to one's individual idea of beauty could lower attention fatigue (as per a prolonged exposure to nature), while enabling the process of fascination.

A total of 154 students and professionals, were recruited, between 20 and 40 years old. They were asked to participate in a 15-minute experiment, whose procedure involved the participants observing images displayed on a screen, examining their own beauty emblem, and engaging in a memory task.

In the initial part of the research, focusing on selective attention, each image was viewed for a total of 30 seconds, resulting in a combined observation time of one minute.

Following the image observation phase, participants were asked to spend 5 minutes looking at their own "beauty emblem." This emblem likely represented a personal object, image, or concept that the participant associated with beauty. This part of the study aimed to test the hypothesis that the perception of beauty could be connected to the experience of fascination. The final part of the experiment involved participants trying to remember as many of the ten letters that appeared on the screen as possible. This memory recall task aimed to assess participants' ability to retain and retrieve information.

The Results

The central hypothesis was that the experience of beauty, associated with the concept of 'soft fascination,' will lead to specific patterns in brainwave asymmetry.

Specifically, the study posited that there would have been higher frontal alpha power asymmetry and higher temporal beta power asymmetry during moments of beauty experience, compared to selective attention moments, checked on the total group and on each individual nation. It is considered no-asymmetry when the



Figure 2: A beautiful light research project in Athens, Greece. Image Credit: Martina Frattura.



This photo relates to both the beauty emblem and the explanation of soft fascination. Photo by Martina Frattura.

relation between left and right power is equal to zero, while it is a considerable presence of asymmetry when there is a higher activity of the right hemisphere over the left one (Baehr et al., 1999).

There was no evident association with beauty and frontal alpha asymmetry, often associated with emotional and cognitive processes, similarly to the activation of the Parasympathetic system, on the GSR value, exploring how exposure to beauty might be linked to changes in skin conductivity as an indicator of stress reduction, not showing significant shifts.

We saw, instead, a possible correspondence between being exposed to the personal idea of beauty and a higher temporal beta asymmetry, likely explored in the context of soft fascination, which refers to a captivating and immersive state induced by aesthetic experiences.

As visual information interpretation and global visual attention is in fact regulated by the right temporal areas of the brain (Fink et al., 1997), which could justify the impact of personal ideas of beauty on them, looking at a beauty emblem could be linked to the activation of the right temporal areas of

the brain. This pattern could be associated with bottom-up, stimuli driven attention directed at the salient stimuli, which can be linked to attention restoration.

The Power of Fascination

As an early attempt to examine a possible relation between beauty and fascination, the results supporting one of the hypotheses - a greater beta power asymmetry - was very satisfying.

Fascination can only happen when we are not forced to act or to feel, in those situations when vitality can also be experienced - starting with resting the inhibitory mechanism, the one used by the directed attention and that could also lead to depletion. The subjective perception of beauty can help in this direction, while having restorative effects on energy levels. In other words, being exposed to an object representing our own subjective idea of beauty could be linked with the involuntary attention mechanism, which is compatible with a positive emotional state.

Despite the high degree of subjectivity, the influence of aesthetics on brain and mental

states could have benefits for attempting to bridge the gap between natural and man-made environments, in terms of reparative signals. Indeed, the results revealed a major finding that could support one of the hypotheses: an increased asymmetry of beta power, perhaps directly related to exposure to beauty.

A shift towards a more holistic and people-centric design approach that prioritizes well-being, is mandatory and only possible through the collaboration between designers and scientists in effectively exploring how spaces can positively affect individuals. This interplay between personal aesthetic experiences, emotional responses, attentional processes, and physiological reactions, aims to provide insights into how exposure to beauty might impact various aspects of human experience and cognition.

Beauty could save our brain! ■

AUTHOR: Martina FRATTURA, M.Sc.

Class 2020 of the 40 under 40, IALD³ Jr. Associate and Women in Lighting⁴ member, Martina has the goal to implement psychological and biological responses to architectural planning.

Graduated from KTH Royal Institute of Technology with a Master's degree in Architectural Lighting Design and Health, she researched at the Human-Technology Interaction Department of TU/e (The Eindhoven University of Technology) in Eindhoven, Netherlands.

With 8 years of experience as an architectural lighting designer in international offices, mainly between the UK and Portugal, she is the founder of the *A Beautiful Light* research project that investigates how lighting can help maintain attention levels, and of *The Beauty Movement*, a think tank whose goal is to inform and educate people about the role of aesthetics' experiences in their life.

Reference/Credits

From the article: *A Beautiful Light - Fascination Against Depletion*.

Martina **Frattura**, Massimiliano Mancini **Tortora**, Eduardo José **Gonçalves** and Natalia **Olszewska** **. SS21-Proceedings Proceedings book of UNIDCOM/IADE Conferences First Published: December 2022 ISBN: 978-989-53943-0-2.

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Martina FRATTURA, M.Sc. is a beauty-informed lighting designer and independent researcher. Class 2020 of the 40 under 40, IALD Jr. Associate and Women in Lighting member. Photo by Patrik Gunnar Helin.

³<https://www.iald.org/>

⁴<https://womeninlighting.com/>

Wallwashing: Benefits and Tips for Perfect Vertical Illuminations

ERCO

50 years ago, ERCO, specialist for sustainable architectural lighting, launched its first wallwashers onto the market. Since its development in the United States in the 1950s, wallwashing has been an essential component of holistic lighting concepts. Vertical surfaces determine the spatial perception of people and have a much greater impact on the perception of brightness than light on horizontal surfaces. Wallwashing is also an elementary component of lighting design for offices and of sustainable lighting concepts.

More Well-being and Productivity: Wallwashing for Offices in Accordance with the New EN12464

The revision of EN 12464, the 2021 standard for the lighting of indoor workplaces, has made wallwashing more relevant. The new version no longer recommends 75 lx but 150 lx as the average illuminance on vertical surfaces for work in offices. In rooms with little daylight or to accommodate the visual abilities of all age groups, this value should even be raised to up to 300 lx. Wallwashing can help prevent visual fatigue and eye strain. It reduces the contrast between otherwise barely lit walls and backlit computer monitors. This means that the eyes do not have to constantly adjust to different levels of brightness, which can lead to visual fatigue.

Wallwashing is Part of Sustainable Lighting

When it comes to the subject of sustainable lighting, the luminous efficacy of the luminaire in lumens per watt (lm/W) has been reflexively cited as a criterion for years. However, efficiency is no guarantee of sustainability. Sustainable lighting means using light only where it is needed - in other words, where it is required for human perception. More important than a lm/W consideration is therefore the question of what illuminance is achieved with the electrical energy used. The metric for sustainability is effectiveness in lux per watt (lx/W). However, since uniform wallwashing is not accent lighting, it is advisable to consider the connected load per area for 100 lx (W/m² per 100 lx): Efficient ERCO track-mounted wallwashers, for example, require only 1.7 W/m² per 100 lx, the new Invia modular light structure only 1.6 W/m² per 100 lx.

A room only appears really bright when the walls are uniformly illuminated because they are in the direct field of vision. This requires comparatively far less light and energy than the area-wide illumination of the floor for a similar impression of brightness. If the walls are illuminated with 100 lx instead of the floor, the room appears three to five times brighter - simply because another surface is illuminated.

How to Use Wallwashing as a Versatile Design Tool

Wallwashing is a central component of qualitative lighting design. Brightly lit walls can perform differing tasks:

Providing Orientation

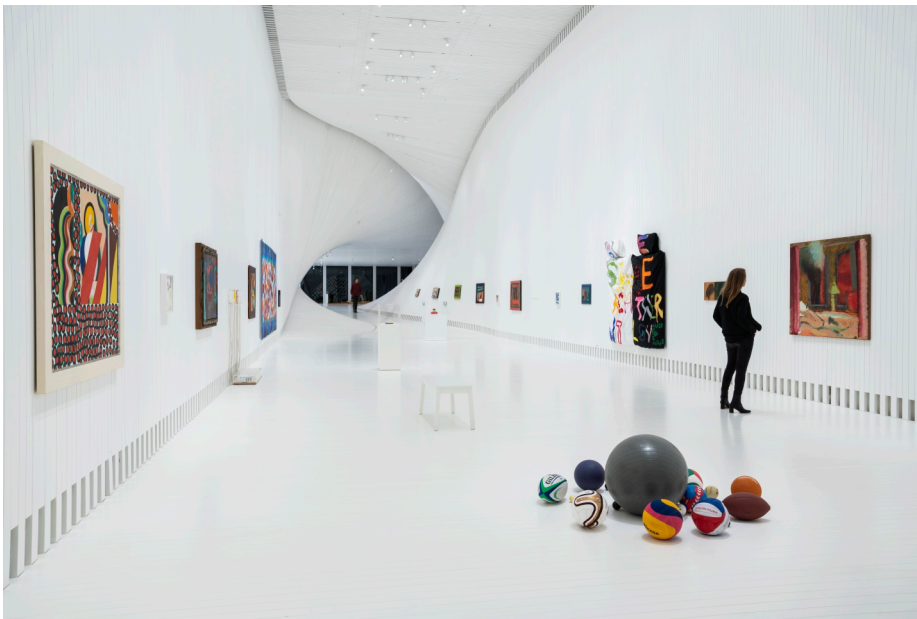
When we enter a room we see the brightest surface first. Wallwashing points out the axes of architecture and helps us to comprehend different functional levels and spatial transitions. Lighting thus creates clearly recognizable entrance zones. Well planned, illuminated walls guide visitors in large buildings.



Aurecon Brisbane Offices; ©Jackie Chan.

Creating Brightness

With identical levels of illuminance, a vertical surface produces a much higher impression of brightness than an illuminated horizontal surface, because walls are in our natural field of vision. High reflectivity on the wall can significantly increase our impression of brightness.



At The Twist gallery, designed by the Bjarke Ingels Group, and located in the Norwegian museum and sculpture park, Kistefos, wallwashing, designed by Light Bureau, provides even lighting effects in the nearly 30 foot tall exhibition rooms and emphasizes the curved architecture; ©Tomasz Majewski.



Whitestone Gallery, Taipei. Lighting Design: Light and Licht Ltd.; ©Jackie Chan.

Increasing Visual Comfort

In offices, wallwashing contributes to greater visual comfort. Light on walls helps a great deal in reducing the contrast between self-illuminated screens and the visual surroundings. The bright background creates a lighting effect that is pleasant to the eye and prevents fatigue.



VicRoads Ringwood Office, Melbourne. Lighting Design: ADP Consulting; ©Jackie Chan.

Creating Distance

Uniformly illuminated walls visually expand the dimension of a room. Narrow rooms, in particular, gain in quality of stay. Large areas can be zoned and structured by bright walls. The lighting is particularly important in very high rooms such as atria. If daylight

only enters from one side and the distance to the opposite wall for the daylight is too far, wallwashing compensates for the missing light.



Centennial Tower, Singapore; ©Kawana Masano.

Refining Surfaces

If you want to emphasize the texture of a material, such as stone, luminaires should be positioned close to the wall. Wallwashers that are installed either in the floor or in the ceiling and providing grazing light are suitable for this purpose. Grazing light clearly highlights surface textures through the high-contrast interplay of light and shadow.



Buckford Office, Melbourne; ©Jackie Chan.

Five Tips for Perfect Wallwashing

Clean Look with Recessed Luminaires

The most elegant solution is recessed wallwashers. The luminaire recedes, the generous lighting effect in the room is convincing. The optimum wall spacing is 1/3 of the room height.



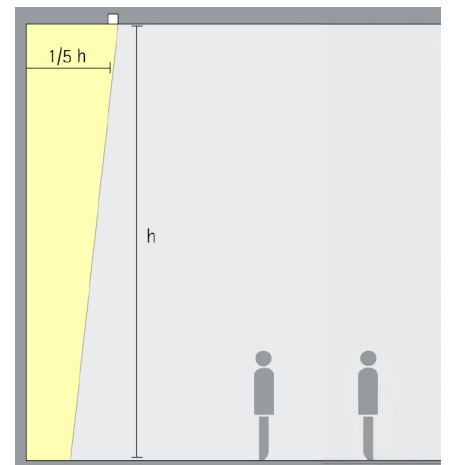
Primo Marella Gallery, Milan; ©Thomas Mayer.

Tall Rooms: Shorten the Wall Distance

When using wallwashers in high rooms of eight meters or more, the rule of thumb "wall distance equals one third of the room height" often becomes a challenge. It is important that even illumination is achieved even with a relatively small wall distance. The optimum wall spacing here is 1/5 of the room height. For good horizontal uniformity, the luminaire spacing should be equal to or less than 1.3 times the wall spacing.



Millenia Tower, Singapore; ©Kawana Masano.



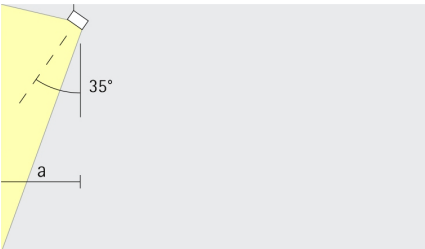
Design-Guideline.

Flexible Wallwashing with Wallwashers for Track

Changing exhibitions require flexible lighting solutions, such as wallwashers from spotlight families that can be flexibly positioned in a track. For optimum uniformity on the wall, the luminaires are set to 35° inclination. The distance to the wall should be about 1/3 of the room height.



In Sir David Adjaye's new museum building for Ruby City art center in San Antonio, wallwashing is used to generate uniform ambient lighting for high rooms. Ruby City, San Antonio Lighting Design: Tillotson Design Associates; ©Timothy Schenck.



Design-Guideline.

Using Grazing Light

The uniform illumination of walls is often less important in representative rooms. It is more important to emphasize materials and textures through the play of light and shadow. For this type of lighting, linear grazing light wallwashers for ceilings or floor installation are the right tools.



Indoors and outdoors: Grazing light wallwashers emphasize the texture of the wall and set visual highlights to attract and welcome visitors. Norrköpings Konstmuseum; ©Johan Elm.

Uniform Wallwashing for Corridors

To achieve a bright room impression in narrow situations such as corridors, wallwashing is a good solution. Wallwashing creates a homogeneous brightness that extends from the ceiling to the floor. A row

of double wallwashers can be used to efficiently illuminate opposite walls in corridors evenly.



VicRoads Ringwood Customer Hub, Melbourne. Lighting Design: ADP Consulting; © Jackie Chan.

Summary

For the past 50 years, ERCO has been pioneering sustainable architectural lighting, particularly with its wallwashers. The role of wallwashing is to illuminate vertical surfaces, an approach that has now become integral to holistic lighting design. This practice is rooted in both aesthetic and normative rationales, especially in relation to human spatial perception. Vertically illuminated surfaces significantly influence brightness perception, much more than light on horizontal planes.

The recent revision of the EN 12464 workplace lighting standard underscores the increased significance of wallwashing. The updated standards recommend a rise in average illuminance on vertical surfaces for office work, from the previous 75 lx to 150 lx. In low daylight spaces or to accommodate different visual abilities across age groups, this illumination should be increased to 300 lx.

Scientifically, wallwashing helps mitigate visual fatigue and eye strain. It moderates the contrast between dimly lit walls and backlit computer monitors, preventing the need for eyes to constantly adjust to varying brightness levels, thus reducing the likelihood of visual fatigue.

In terms of sustainability, wallwashing shifts the focus from luminous efficacy (lm/W) to the illuminance achieved per watt of electrical energy used (lx/W), thereby prioritizing effectiveness over efficiency. Uniform wallwashing, while not accent lighting, calls for considering the connected load per area for 100 lx (W/m² per 100 lx). Efficient ERCO track-mounted wallwashers require only 1.7 W/m² per 100 lx, illustrating their energy efficiency.

In conclusion, wallwashing represents a significant advancement in architectural

lighting design. It enhances spatial perception, reduces visual fatigue, and aligns with the principles of sustainable lighting. The future of lighting design will likely continue to leverage this approach, given its benefits to both human health and environmental sustainability. ■

About ERCO

ERCO, headquartered in Lüdenscheid, Germany, stands as a premier global authority in sustainable architectural lighting utilizing LED technology. Established in 1934, this family-owned entity has transformed from its humble beginnings to a worldwide influencer with a robust presence in approximately 55 countries through independent sales and partner networks. ERCO's groundbreaking efforts during the 1960s ushered in a new era for architectural lighting across Europe. Marking its legacy, half a century later, ERCO is distinguished as the pioneering luminaire manufacturer to transition its entire portfolio exclusively to LED.

The company's vision for sustainable illumination is encapsulated in "ERCO Greenology®," blending technological mastery with a profound commitment to environmental stewardship. This ethos is embodied by the 1,000 passionate ERCO employees scattered globally. Their collective mission transcends merely employing LED technology; they strive to evolve it into innovative, ecologically-responsible lighting instruments.

For additional information please visit <https://www.erco.com>.

For inquiries, please write to us at k.klein@erco.com.

ERCO



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Matter for Professional Lighting

Dr. Markus BECKER, Software Engineer Embedded Systems IoT, Tridonic

Matter is currently serving as the beacon of hope for interoperability in the Internet of Things. It's supported within the ecosystems of major smart home service providers including Google, Apple, Amazon, and Samsung, and has backing from a variety of chip manufacturers and device producers. Through the concerted efforts of all participants, a robust specification, a reference implementation, test specification, and a certification program have been established, benefiting everyone involved.

Tridonic has been an active player in Matter's development since early 2020. Several factors make participation in Matter attractive. These include the opportunity to gain a significant presence in the smart home sector, the absence of license fees for using this technology, and the collaborative nature of the development effort.

While Matter's initial focus is on the home sector, there's no technical barrier preventing its expansion into the professional lighting sector. Tridonic is proactively working on introducing various features tailored for these specialized areas. An essential aspect of Matter's appeal is its ability to build bridges to other pre-existing systems through the use of 'Matter bridges'. These bridges facilitate a seamless transition to Matter while accommodating current systems and installations.

However, it's worth noting that Tridonic envisions these bridges as components of the luminaires rather than as central units in the network, typically seen as wireless hubs.

Overview of the Ecosystems and Matter Controllers

All major ecosystems have now integrated support for Matter into their products and apps. Google [1], Apple [2], Amazon [3], and Samsung [4] have all incorporated Matter into their existing home offerings. Additionally, there is a beta preview available in the DIY system Home Assistant [5].

The Google Home app can be found in both the Android Play Store [6] and the iOS App Store [7]. The Apple Home app is only available in the App Store [8]. Samsung's SmartThings is available in both stores [9,10], as is Amazon's Alexa [11,12].

For the commercial sector of lighting management systems (LMS), no integration has been reported so far. An integration of Matter into a building management system has been announced by NETxAutomation Software [13].

Standardization Organization

Matter is being standardized in the standardization organization Connectivity Standards Alliance (CSA)⁵, and membership is open to all interested organizations. During the development of Matter, the CSA rebranded from its former name, Zigbee Alliance, to reflect that it no longer standardizes Zigbee alone. Zigbee and Matter are now workgroups within the CSA. Other workgroups in the CSA include the Data Model WG, the Health & Wellness WG, and the Data Privacy WG. With over 600 members, the CSA is one of the largest standardization organizations. The CSA Member Group China and the Europe Interest Group enable regional cooperation and the incorporation of region-specific requirements into the CSA. The CSA main-

⁵<https://csa-iot.org/>

tains connections with other standardization organizations such as the NFC Forum, the IETF, the Thread Group, the DiIA, and others.



Figure 1: Working Groups of the CSA. Image Credit: Connectivity Standards Alliance.

Matter Technology Overview

During the development of Matter 1.0, the participating companies (ecosystem operators, chip manufacturers, device manufacturers) simultaneously worked on the specification, reference implementation, test specification, certification tool, and end devices. Progress was continuously monitored in regular test events. The reference implementation is available under the Apache License on Github [14], but it is also distributed bundled with development kits by chip manufacturers. In addition to the reference implementation written in C/C++, there are now also initial implementations of the Matter specification in other programming languages (e.g., JavaScript/Node, Kotlin, and Rust). The reference implementation includes examples to implement lights, switches, door locks, sensors, pumps, thermostats, televisions, blinds, and bridges.

The finalized specification texts are available for download at the CSA [15] and comprise over 3000 pages for Matter 1.0 alone. To participate in the further development of Matter and to receive preliminary versions of the upcoming specification, one should become a member of the CSA [16].

System Overview

A Matter system consists of Matter end devices ("Accessory"), Matter controllers, and Matter commissioners, as well as other typical IT devices such as an Access Point and possibly a Thread Border Router. The commissioner creates the Matter network (a so-called Matter Fabric) and provides

the necessary information to the end devices so that these devices can become part of the Matter network. This transfer of information can occur via Bluetooth Low Energy, WiFi, or Ethernet, depending on the end device (Figure 2).

Overview of the Protocols

The typical structure of the protocols used in an internet-enabled device is shown in Figure 3. Devices communicate with the nearest devices in the network via Ethernet, WiFi, or 802.15.4/Thread. IP (here in version 6) enables networking of devices with other devices. The transport protocols TCP and UDP then create connections be-

tween devices that want to communicate with each other, and the application layer implements the function (e.g., switching light on and off).

In greater detail, the application part of the Matter stack is shown in Figure 4. When a light is to be switched on, the application sends the "On" command, which is part of the data model in the Matter/Zigbee On/Off Cluster. This command is sent in an InvokeCommandRequest in the Interaction Model layer. Other defined interactions in the Interaction Model include Read, Write & Subscribe. In the Action Framing layer, this message is then converted into bytes so that it can be encrypted and signed by the Security layer. After adding additional information and Matter's Message Reliability Protocol, the data is passed to the IP Stack of the device.

Device Identity

The identity of a Matter device consists of several components. Firstly, a device-specific electronic certificate is created by one of the Matter Product Attestation Authorities (similar to a Certificate Authority for https in the web area) which attests that this is uniquely a device of the respective manufacturer. Secondly, during the commissioning process, an Operational Certificate is installed on the device by the Matter Commissioner, and the device is assigned a Node ID, through which the device is addressed instead of the complete IPv6 address.

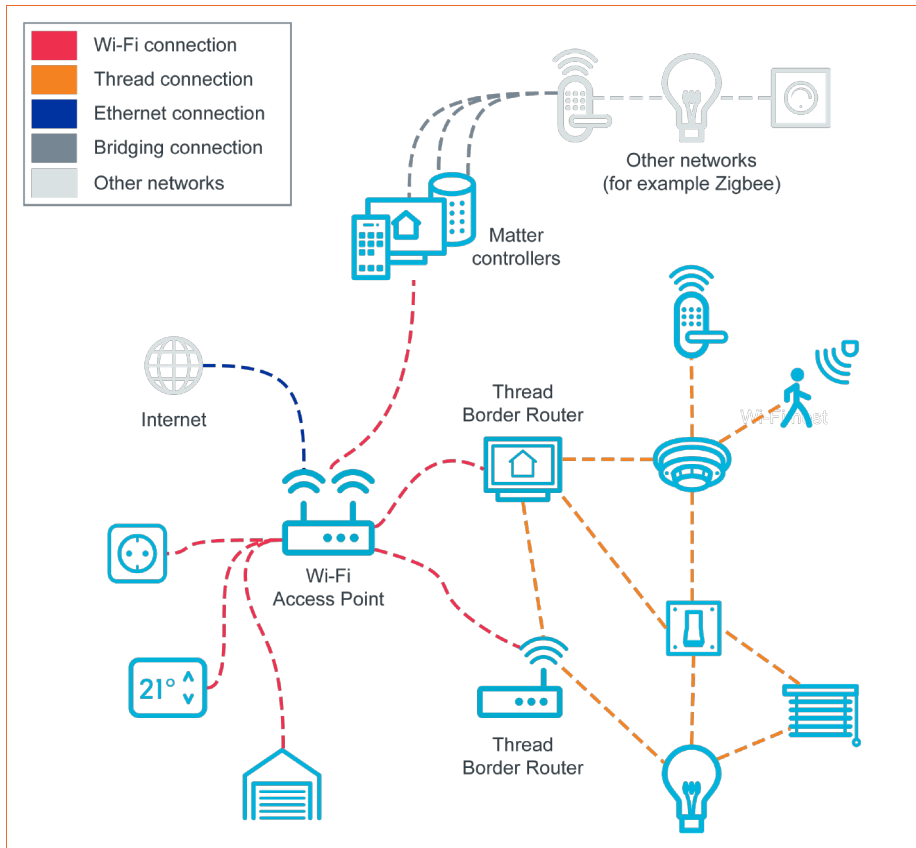


Figure 2: Overview of a Matter System. Image Credit: Nordic Semiconductor.

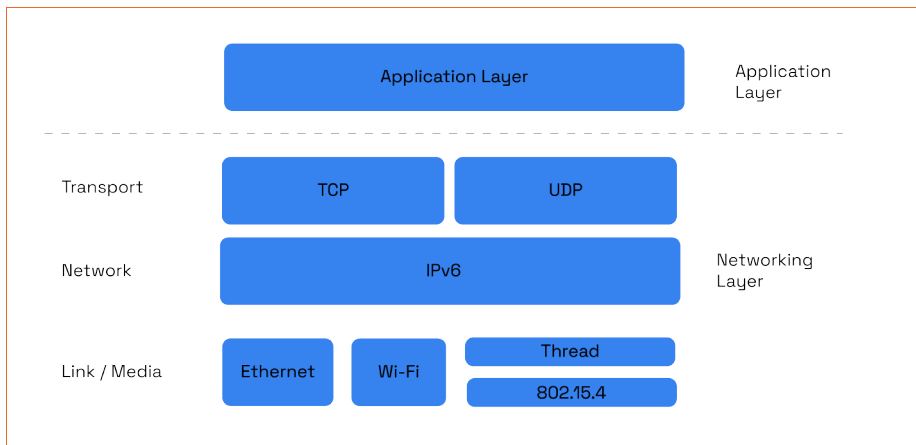


Figure 3: Typical structure of the protocols used in an internet-enabled device. Image Credit: Connectivity Standards Alliance.

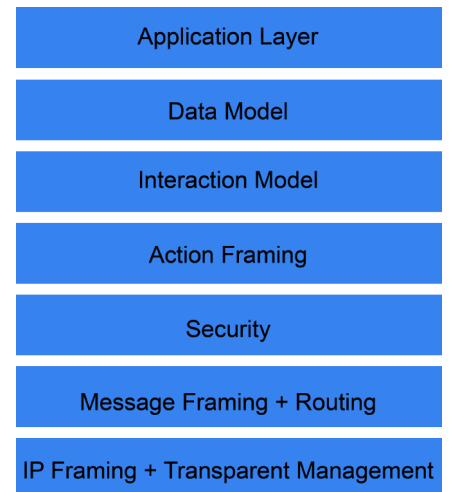


Figure 4: Application part of the Matter stack. Image Credit: Connectivity Standards Alliance.

Access Control

Every action performed on a Matter device is checked against an Access Control List to determine if it is allowed. The Access Control List (ACL) is filled during the commissioning process by the Matter Commissioner and can be modified later if permissions allow. An entry in the ACL can include restrictions based on the re-

quired privileges (View, Operate, Manage, Administer) for performing the action on the target cluster (e.g., On/Off) and the executing subject.

Data Model

The data model of Matter is based on the Zigbee data model, which has been extended and is now being updated together with Zigbee in the Data Model Working Group of the CSA.

In the Matter domain, the data model consists of the following terms defined in **Table 1**.

This can be visualized as follows:

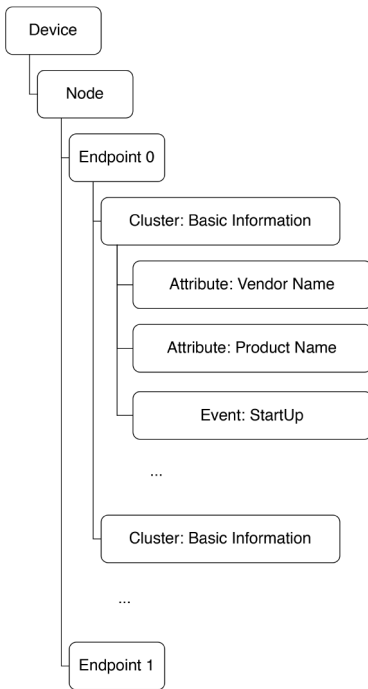


Figure 5: Visualization of Matter's data model terms.

Device Types

A Matter/Zigbee device type defines the requirements that a device must meet at the endpoints, i.e., which clusters, commands, attributes, and features must be present. The device types are found in the so-called Matter Device Library Specification.

In the lighting area, the device types On/Off Light, Dimmable Light, Color Temperature Light, Extended Color Light, On/Off Light Switch, Dimmer Switch, Color Dimmer Switch, Generic Switch, Light Sensor, and Occupancy Sensor are of interest. However, other device types from different application areas are also available. Based on these device types, Matter devices are certified, ensuring interoperable functionality.

A device with an endpoint of the Dimmable Light type, for example, must necessarily

Terms	Definitions
Fabric	A fabric is a set of nodes that interact by accessing data model elements as defined in the Interaction Model. A fabric is a security domain that allows a set of nodes to be identified and communicate within the context of the domain.
Node	A Node encapsulates an addressable, unique resource on the network that has a set of functions and capabilities that a user recognizes distinctly as a functional whole.
Endpoint	A node is composed of one or more endpoints. An endpoint is an instance of something that could be a service or virtual device as indicated by a device type.
Cluster	Clusters are the functional building block elements of the data model.
Access	R: Read Access W: Write Access R[W]: Read Access and optionally Write Access
Conformance	M: This is part of the base mandatory feature set. O: This is a purely optional element with no dependencies, except the M set.
Command	A cluster command is a set of data fields, each of a data type that is conveyed between client and server cluster instances to invoke a behavior on the receiver of the command.
Attribute	An attribute is cluster data
Event	An event defines a record of something that occurred in the past.
Device Type	A device type defines conformance for a set of one or more endpoints. A device type defines a set of requirements for the node or endpoint in the market.

Table 1: Terms of the Matter data model.

include the Server Cluster Identify, Groups, Scenes, On/Off, and Level Control. A Matter device must support the basic Matter device types on endpoint 0. This is at least the Descriptor Cluster, which describes what functionality is available on the device's other endpoints. Furthermore, a Matter endpoint typically also includes several other utility clusters on endpoint 0: Root Node & OTA Requestor. The Root Node device type requires, among other things, the Basic Information Cluster, which provides information such as manufacturer, serial number, article number, and name. Also, the clusters used during device commissioning (ACL, General/Network/Administrator Commissioning, Node Operational Credentials) as well as diagnostic clusters are part of the Root Node device type.

Cluster

The clusters, their commands, and attributes are found in the so-called Matter Application Cluster Specification. These range from the Identify Cluster, through Group & Scene Cluster, to On/Off, Level & Color Control Cluster. With Occupancy Sensing and Illuminance Measurement, the most important functionalities for the lighting area are available. Further clusters from the HVAC, window covering, and media areas round out the applications in Matter 1.0.

Commissioning

The Matter commissioning process consists of several phases:

- Finding the device
- Proving ownership
- Verifying device attestation
- Setting the configuration
- Joining the network
- Generating encryption material
- Using the encryption material



Figure 6: The device can be found by scanning the Matter QR code that is attached to it.

Finding the device is accomplished by receiving Bluetooth advertisements, scanning for ad-hoc Wi-Fi networks, or discovering via MulticastDNS on Ethernet. Information from the Matter QR code (or from the typically 11-digit number under the QR code or from an NFC tag) is used to find the device in the Commissioner application.

Typically, the ID of the manufacturer and product, a description of the commissioning mechanism supported by the device, a discriminator, and a passcode are included. With the help of the passcode, the commissioner can prove to the device that they own the device and have the right to bring it into the desired network.

A Matter device that uses Bluetooth for commissioning uses the Bluetooth Service UUID 0xffff6. A noncommissioned Matter device is commissionable for 15 minutes after it is turned on. After that, for security reasons, it stops advertising itself via Bluetooth.

Cryptography

The cryptography algorithms and protocols used in Matter are up-to-date with the current state of the art in cryptography (Table 2).

Firmware Update

The firmware update must be implemented by Matter devices and controllers and is a mechanism prescribed by Matter. The controllers (device type Firmware Update Provider) download update files provided by the device manufacturers and inform the devices about available updates. The devices (device type Firmware Update Requestor) then download the firmware update from the controller and apply it with the user's consent.

Multi-Admin

Thanks to Multi-Admin, Matter devices can be operated not only in one ecosystem but also in multiple ecosystems simultaneously. Many smart home users nowadays no longer have just one ecosystem in the house and understandably want to be able to use the existing sensors and actuators from all their smartphones and assistants. For this purpose, Matter devices can be opened for commissioning in a second ecosystem after they have been commissioned in one ecosystem. A smartphone from the first ecosystem creates a new QR code or a numeric code, which is used by the second ecosystem for commissioning.

Distributed Compliance Ledger

The Matter Distributed Compliance Ledger [17] is a distributed database in which device manufacturers provide data about themselves, their devices, and links to firmware update files. Here, Matter controllers can find out if there are updates for devices in their network.

Matter 1.1 and 1.2

The update Matter 1.1 was already released in the spring of 2023. This update included improvements for sensors and similar devices as well as adjustments and corrections in the specification and SDK. Matter 1.2 is expected in autumn 2023, and will bring support for additional device classes.

Matter Products

In addition to many lighting products (LED bulbs, color light strips) for home users that are already Matter certified, there are already a large number of smart sockets and door locks available. The official list of certified devices can be found on the CSA website [18].

As one of the first manufacturers, Tridonic offers Matter-compatible components for professional lighting:

Constant Voltage Driver

The dimmable 24 V constant voltage LED driver is designed for use with flexible constant voltage LED flex tapes. It can be used for luminaire installation or as an independent LED driver with snap-on strain relief.

Wireless Module MTR

Available in two variants - with and without integrated DALI power supply - the Wireless Module MTR is intended for luminaire installation and can also be used to upgrade a DALI luminaire to Matter operation. The module can also be installed in a flush-mounted box.

Wireless Module with Strain Relief (SR) MTR

The Wireless Module with optional strain relief is designed for new installations or for retrofitting in the false ceiling. It upgrades a DALI luminaire to Matter operation and is optimal for spot and downlights or suspended luminaires.

Tools

With smartphone apps that can display Bluetooth LE Advertisements - such as Nordic's nRF Connect for Mobile [19] - commissionable Matter devices can be found. The Matter devices can be recognized by the UUID 0xFFFF6. With the Nordic Thread Topology Viewer [20], the structure of the Thread network can be visualized (Figure 7).

The Nordic Thread Sniffer [21] can be used to receive IEEE 802.15.4 radio packets and pass them on to Wireshark. A variety of development kits and software development kits for Matter are available from manufacturers of Thread and Wifi radio chips [22]. The usual tools available in network technology can be used when using Matter. For example, with Wireshark, the contents of network packets can be examined. An initial Matter dissector will be included in Wireshark 4.2; an advanced dissector is available on Github [23]. With ping6, the accessibility of Matter devices can be tested. With the mDNS tools avahi-browse or dns-sd, Matter devices on the network can be found. The regular IP firewalls can be used to secure these networks.

Cryptography Element	Algorithm/Protocol
Deterministic Random Bit Generator (DRBG) NIST 800-90A	CTR DRBG (with AES-CTR) HMAC DRBG (with SHA-256) HMAC DRBG (with SHA-512) Hash DRBG (with SHA-256) Hash DRBG (with SHA-512)
True Random Number Generator (TRNG) NIST 800-90B	
Hash function (Hash) FIPS 180-4	SHA-256
Keyed-Hash Message Authentication Code (HMAC) FIPS 198-1	HMAC-SHA256
Public Key Cryptography FIPS 186-4 / NIST 800-186	secp256r1
ECDH for shared secret computation	
Certificates X.509 v3 DER	
Message privacy is implemented using a block cipher in CTR mode	
Key Derivation Function (KDF)	Password-Based Key Derivation Function (PBKDF)
Password-Authenticated Key Exchange (PAKE)	SPAKE2+

Table 2: Cryptography Algorithms and Protocols in Matter.

Current Issues

Matter is a comprehensive project, both organizationally and in terms of the amount of software that has been created, integrated, and modified. As a result, it is inevitable that problems will arise in the early stages, which are already being addressed by the CSA, the ecosystems, and device manufacturers.

Currently, not all device types are implemented in all Matter controllers (Google [24], Apple [25], Amazon [26]). One problematic issue is the support for switches, which is lacking either entirely or missing certain features. The ability to use manufacturer-specific clusters that provide extended functionality is currently only possible in one ecosystem [27]. To increase interoperability between devices and controllers, the CSA has already established an Interoperability Testing Facility. For Matter devices built on Thread, there is currently the problem that the Thread Border Routers of different ecosystems each open individual networks, rather than a shared network, making the Thread Mesh less interconnected than it could be. This issue is currently being addressed in collaboration between the CSA and the Thread Group.

Matter for Professional Lighting Solutions

For the professional lighting sector, Matter currently lacks support for data provided by DALI LED drivers through D4i, as well as support for emergency lighting systems. The clusters Luminaire Asset Management, Energy Reporting, and Luminaire Diagnostics & Maintenance, already present in Zigbee, can be reused in Matter without significant effort. In a similar fashion, DALI emergency lighting functionalities can be made available in Zigbee/Matter clusters. However, this implementation of Matter when bridging to DALI is not yet certifiable.

The current commissioning process for Matter is not ideal for the installation of a large number of devices. Scanning multiple QR codes, some of which may be located inside luminaires, within 15 minutes of starting the device is not practical for everyday use. More advanced methods beyond manual commissioning are needed, such as automatic commissioning based on radio signal strength measurements, as demonstrated in the Lite4more project by Tridonic.

Tridonic will continue working on the usability of Matter in the professional lighting sector. Integration of Matter devices into building and lighting management systems is being considered, offering additional value.

Summary

This article delves into the advantages and technical details of the Matter standard, including communication protocols, device types, data models, and more. It also introduces some of the initial products that Tridonic has added to its portfolio.

Work on Matter is not complete; instead, it continues with significant effort. With the release of Matter 1.2 in the fall of 2023, it will be possible to support robotic vacuum cleaners as well as white goods such as washing machines, refrigerators, and dishwashers. At Tridonic, as part of the CSA, the collective goal is to encourage more component and luminaire manufacturers to participate in standardization organizations like CSA, ThreadGroup, and DiIA. The aim is to ensure that Matter can replicate the commercial successes of DALI in the wireless professional lighting sector. ■

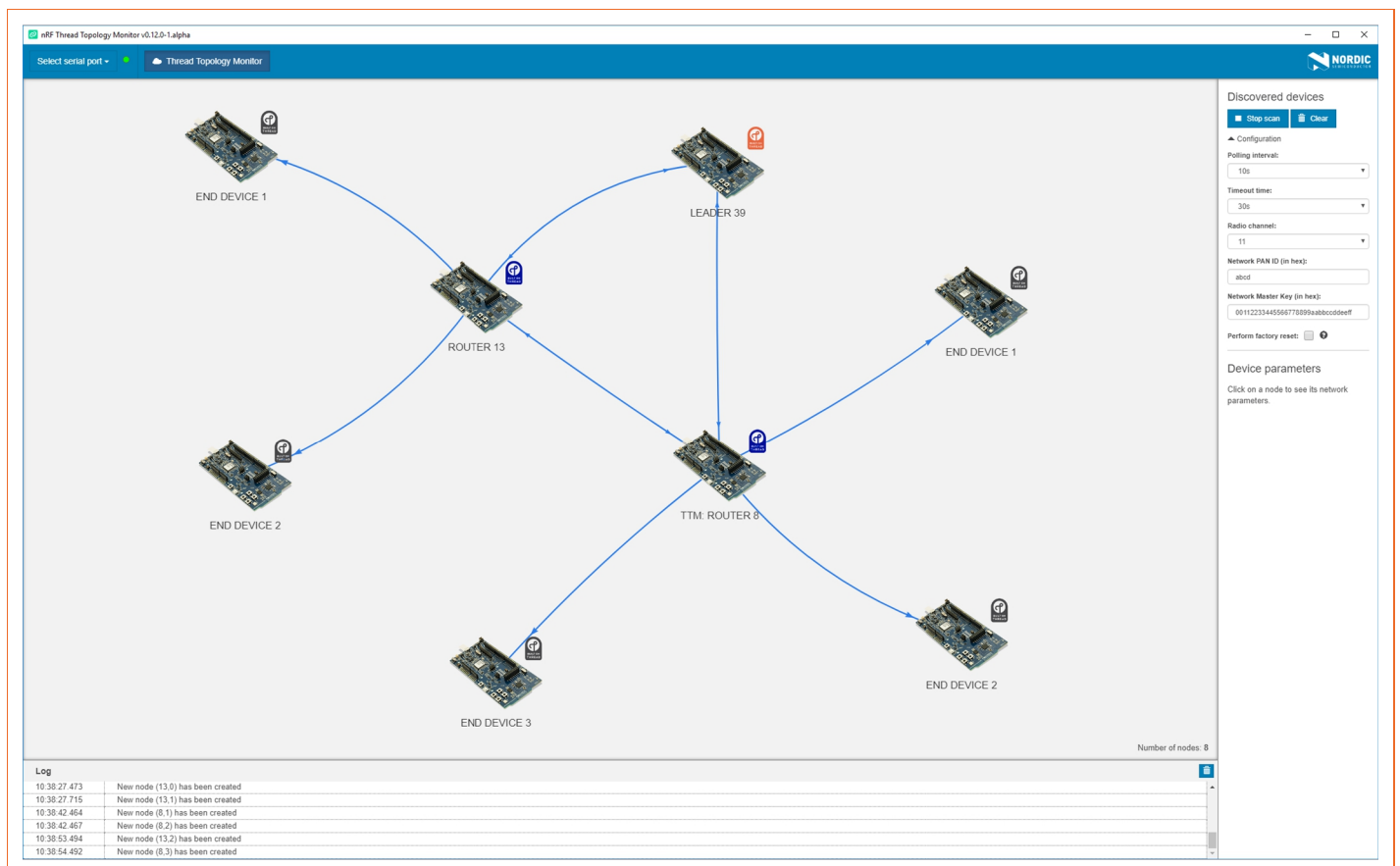


Figure 7: With the Nordic Thread Topology Viewer, the structure of the Thread network can be visualized. Image Credit: Nordic Semiconductor.

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Advantages of Matter with Tridonic at a Glance

A Unified System: Thanks to Matter compatibility, multiple Matter-compatible devices can seamlessly work together and be set up with any of the major platforms. Communication is always ensured – regardless of the manufacturer or the (radio) technology.

Communication over Thread: Tridonic devices use the Thread protocol for mesh communication and benefit from its advantages such as low power consumption, low latency, self-healing, and security benefits. In addition, Thread Board Routers can be integrated into products, making hubs unnecessary.

Easy Commissioning: For setting up Matter devices, there is an easily understandable process using QR codes or numeric code entry – as part of the Matter protocol.

Future-proof: Every day more and more companies are joining the CSA. The more manufacturers that engage with Matter, the broader the range of potential applications becomes.



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For additional information please visit www.tridonic.com.

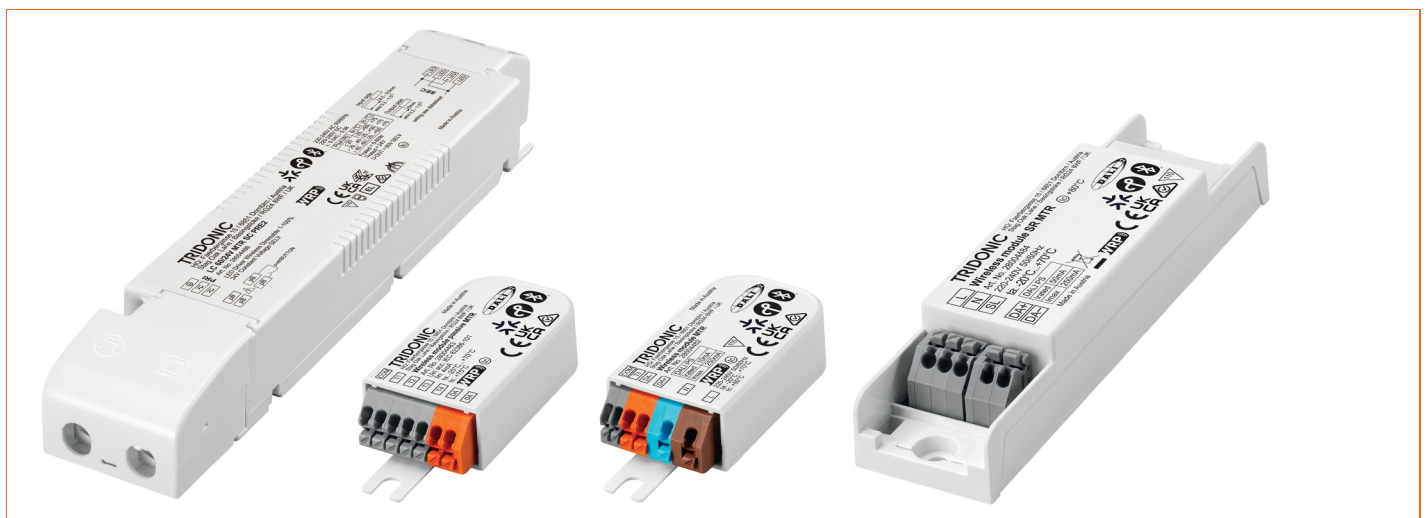


Figure 8: Tridonic's Matter products.

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Modularity and Interoperability: A Winning Combination

Techno is undergoing a transformation, focusing on innovation by expanding the possibilities of connection solutions. These solutions move beyond being merely “passive” to becoming “active” and IoT-ready. This means they are capable of reading and/or communicating information within advanced systems. Techno achieves this by offering connection systems suitable for the communication of devices of various kinds, whether they are wireless, wired, or related to sensors.

Techno has embraced the challenge of identifying solutions that can integrate devices with different communication protocols into a single system, taking into account the multiple existing connection standards. Leveraging their inherited experience in modular connections, IoTH® enables the inclusion of dedicated and highly professional innovative solutions within the same system. These solutions are also open to major international communication standards.



Figure 1: IoTH Zhaga Book 18 Solution.

A Multidisciplinary Organization for Complex System Support

The primary goal of developing innovative products for new applications has led to the need for establishing new and virtuous multidisciplinary partnerships. As a result, solutions have been co-designed with various commercial and technological partners, both in Italy and worldwide, with the ultimate aim of meeting the ever-changing market demands.

This necessary reorganization within the complex IoT ecosystem propels Techno beyond the traditional supplier-client relationship. It enables the company to exploit new opportunities for diversifying its offerings and staying responsive to evolving market needs.

A Comprehensive Service for IoT Projects

IoTH® connection solutions are designed to meet various application and market needs.

For more information, check out:
www.ioth.it

Techno offers a range of pre-configured, ready-to-use kits for quick connections. For more complex projects, Techno is capable of creating customized components with a strong focus on quality and reliability. All connection solutions feature meticulously designed aesthetics, integration capabilities, and are certified IP44/IP66/IP68/IP69 to meet professional technical requirements for both indoor and architectural or full outdoor applications.



Figure 2: ioTH Configurator.

ioTH
INNOVATION • READY

NEW! TEE IoT WIRELESS

NEW! TEE IoT WIRELESS

TH212
• New mini junction box
• Different configurations
• Wide range of accessories
• Can be integrated with sensors, electronics and drivers

Wireless solutions (e.g. industrial applications)

Wired solutions (e.g. urban and sports applications)

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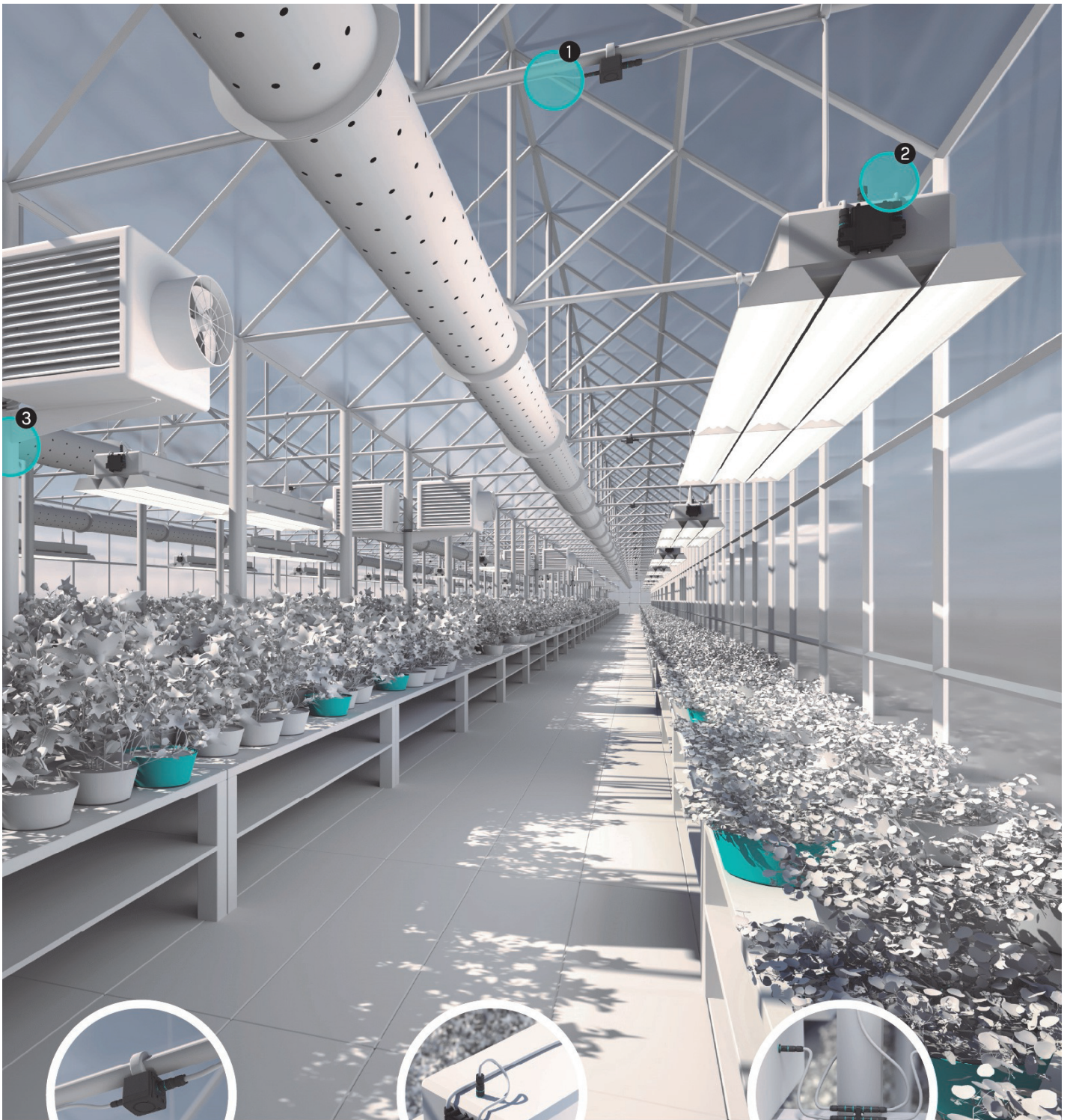
1 TH210 | IP66|IP67|IP68 Junction box with integration of sensors for CO2 monitoring, solar-powered system.

2 TH212 | IP65|IP66|IP67 mini junction box with sensors integration to manage signal and lighting elements keeping safe pedestrian crossing.

3 TH212 | IP65|IP66|IP67 mini junction box with sensors integration for the urban lighting intelligent management.

4 TH212 | IP65|IP66|IP67 mini junction box wired with standard functionality for video security.

Figure 3: ioTH Connection Ecosystem for Smart Cities – From single need to product solution.



1 TH212 | IP65|IP66|IP67 screw-less compact junction box wired with sensors for detecting micro-climatic conditions.

2 TH210 | IP66|IP67|IP68 IK10 electrical and electronic configurable junction box to connect the lighting system with control elements and LED source management.

3 TH625 | IP66 Plug&play micro current distributor to connect ventilation devices to improve the indoor climate in the greenhouse.

To facilitate the process of identifying the suitable solution for a project, Techno has developed a configurator—a useful and intuitive tool that allows users to independently explore all IoT solutions compatible with Techno’s product ranges through a guided process. If specialized consultation is required regarding mechanical, electronic, or wiring aspects, a knowledgeable and well-prepared team is ready to address any questions and assist customers in selecting the solution that aligns with their overall project goals.



Figure 4: IoT212 Zhaga Book18 Ready Configuration.



Figure 5: TH212 Modularity & Accessoriability.

Installation Ready: Innovative Solutions for Advanced Systems

From junction boxes to plug-and-socket connectors, the IoT[®] range can accommodate everything from IoT devices for integration, to electrical and installation features, to provisions for maintenance and upgrades. It can handle various types of electronics, power supplies, or sensors, all while incorporating the performance characteristics of Techno products. Eye-catching design, IP66-IP68-IP69 protection rating, and high mechanical impact resistance are essential features that allow the full utilization of the technological potential of IoT[®] solutions across different application areas.

Modular Solutions and IoT Standards Compliant

Techno has taken up the challenge of bringing together devices with different communication protocols and different types of connections into a unique connection platform. Thanks to the experience it has developed on the subject of modular connections, IoT[®] includes dedicated innovative solutions, capable of creating a «connected» platform, open to the main international standards of interoperability. The products in the IoT[®] range, when appropriately integrated, are designed to be used in modern infrastructures, including civil and architectural projects, agritech and farmtech installations, and Industry 4.0 industrial systems, to name a few examples. In particular, for lighting projects and smart city applications, IoT supports the ZHAGA alliance by offering 'Book 18 ready' solutions to ensure standardized and interoperable connection solutions. These solutions leverage the technological advancements to meet the diverse demands of advanced systems across various industries. ■

Read more about Smart Electrical Connections:
<https://www.techno.it/solutions-ioth>
<https://ioth.it/en/>

Techno s.r.l.: Techno's journey embodies meticulous planning and connection at every work phase. Their goal is to address diverse client needs, transforming concepts into bespoke “Smart” products. In an innovative landscape, Techno crafts reliable, high-performance electrical connection solutions. They prioritize designing accessible and intelligent electrical connectors, especially for clients needing high-protection solutions (IP66/IP68/IP69). Their team leverages three decades of family-passed experience, blending it with modern creativity and evolving technologies.

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Enhancing Human Health with Solid State UVB Vitamin D Treatment

Frank HARDER, Executive Vice President/CRO at Bolb Inc.

Vitamin D, often referred to as the "sunshine vitamin," plays a pivotal role in maintaining human health. However, a staggering 42% of the U.S. population suffers from its deficiency, leading global researchers to term this phenomenon an "invisible epidemic." While the majority of those affected remain asymptomatic, the repercussions of this deficiency can be severe, manifesting in symptoms ranging from fatigue to bone pain. The significance of Vitamin D extends beyond bone health; recent studies have highlighted its potential role in cardiovascular health and its deficiency's broader implications in the elderly population. This article delves into the intricacies of Vitamin D deficiency, its global prevalence, and the innovative solutions being explored to combat this silent pandemic.

Vitamin D Deficiency

The Global Silent and Invisible Pandemic

Vitamin D deficiency is extremely common, affecting approximately 42% of the U.S. population, according to research published in the National Institutes of Health database. Because of this, some researchers across the globe have referred to Vitamin D Deficiency (VDD) as an "invisible epidemic."

According to University of Nebraska-Lincoln [1], most people with Vitamin D deficiencies are asymptomatic. However, if you're exhausted, your bones hurt, you have muscle weakness or mood changes, that is an indication that something may be abnormal within your body. Symptoms of Vitamin D deficiency may include fatigue, not sleeping well, bone pain or achiness, depression or feelings of sadness, hair loss, muscle weakness, loss of appetite, getting sick more easily or pale skin. If these symptoms sound familiar, it is maybe time to see your doctor. They may do a blood test to check your Vitamin D levels to see if they are within the normal range.

Further, NIH (The National Institutes of Health, a part of the U.S. Department of Health and Human Services) has demonstrated in a study, Vitamin D deficiency in the elderly, risk factors and drug impact on Vitamin D status [2]. In a sample consisting of 125 patients, aged 75 years and older, the plausible association between the serum D 25(OH)D level, and patient age, sex, body mass index, renal function, cholecystectomy history, and the prescribed drugs were investigated. Surprisingly, results show that elderly males suffered from a serious Vitamin D deficiency compared to elderly females. The study concludes that advanced age is an independent risk factor for Vitamin D deficiency. The supplementary dose of Vitamin D should be precisely defined to achieve

the optimal serum 25(OH)D level for elderly people.

The study [2] further shows the Vitamin D status by patient sample. More than a quarter of the patients were classified as a "very severely Vitamin D deficiency" group. The Vitamin D recommended level was found in only 15% of the patients.

Vitamin D Status	Percentage
Very severe VD deficiency	27%
Severe VD deficiency	16%
Moderate VD deficiency	27%
Minor VD deficiency	15%
Normal level	15%

Table 1: Vitamin D status in the study patient sample [2].

A complimentary study by NIH, July 2009 "Vitamin D Deficiency and Risk for Cardiovascular Disease" [3] provided relevant insight that the classic function of Vitamin D is to increase the absorption of calcium for proper mineralization of bone. The active form of Vitamin D acts as a steroid hormone by binding to the Vitamin D receptor, which is present in many cells throughout the body, including vascular smooth muscle. Recent evidence has demonstrated that individuals deficient in Vitamin D are more likely to have Cardiovascular Disease (CVD). The mechanism for how Vitamin D may protect individuals from CVD has not been fully researched and concluded. However, several mechanisms have been proposed, including negatively regulating renin to lower blood pressure, improving vascular compliance, decreasing parathyroid hormone (PTH) levels, and improving glycemic control.

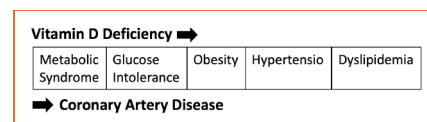


Figure 1: The relationship between Vitamin D and potential risk factors.

The Power of Vitamin D

What Experts Already Know About the ‘Sunshine Vitamin’

As described earlier, one third of human adults have low 25(OH)D levels; ~85% of elderly (75+) suffer from partially severe Vitamin D deficiency, which causes bone loss and heart diseases.

To combat Vitamin D deficiency there are three paths [1]:

- **Get Vitamin D from Food**
 - Fatty fish like salmon, trout, tuna and mackerel, fish liver or canned fish like herring and sardines
 - Egg yolk
 - Beef liver
 - Breakfast cereals
 - Milk, almond milk, soy milk
 - Orange juice, among others
- **Take a Vitamin D Supplement**
 - Over the counter Vitamin D3 supplements including cod liver oil
 - The recommended dietary allowance of Vitamin D for young adults is 600 international units (IUs)
 - Extremely high Vitamin D levels are harmful and can cause nausea, vomiting, confusion, excessive thirst and kidney stones
 - Cystic fibrosis (CF) and short bowel syndrome (SBS) patients are unable to absorb Vitamin D from the diet and thus are frequently found to be severely Vitamin D deficient
 - Long-term oral Vitamin D supply may cause Vitamin D Toxicity (VDT) and aortic lesions
- **Get Vitamin D from sunlight**
 - 20% of the human body skin needs to be exposed to the sun for about 20-40 minutes to get 0.25 MED (Minimum Erythema Dose), resulting in a daily dose of 700 – 1,000 IU of Vitamin D
 - The sky needs to be cloud-free and the sunlight exposure direct to human skin
 - Human skin without sunscreen blocker

Human Behavior Statistics and Insight

We spend 90% of our time indoors, says a study by The National Human Activity Pattern Survey [4]. The survey was funded by the U.S. Environmental Protection Agency (EPA). **Table 1** from the NHAPS study shows that Americans spend 86.9% of time indoors, plus another 5.5% inside a vehicle.

Groups	Percentage
In a Residence	68.7%
Other Indoor Location	11.0%
Outdoor	7.6%
In a Vehicle	5.5%
Office, Factory	5.4%
Bar, Restaurant	1.8%

Table 2: NHAPS study shows that Americans spend 86.9% of time indoors, plus 5.5% inside a vehicle.

This supports the thesis that we can simply not get enough sunlight for Vitamin D production given our habits especially in the post COVID era. We have decided to stay inside, and when we go outside, we usually protect ourselves from the elements such as heat, cold, sunlight, rain, or any other environmental impact.

In addition, tight control of our daily nutrition, eating habits, and even getting the right Vitamin D supplements might be difficult given the statistics on global Vitamin D deficiency with all risks involved. Especially given the fact that supplements can have other harmful side effects.

UVB Photo Light Therapy

Treatment of Vitamin D Deficiency with UV Light

Another study by [5] NIH Treatment of Vitamin D deficiency with UV light in patients with malabsorption syndromes demonstrated, that “A UV lamp that emits ultraviolet radiation similar to sunlight and thus produces Vitamin D3 in the skin” is an excellent alternative for patients who suffer from Vitamin D deficiency due to fat malabsorption, especially during the winter months when natural sunlight is unable to produce Vitamin D3 in the skin. Such UV lamps are widely available for commercial home use and could potentially be prescribed by doctors to patients with CF or SBS.

The Minamata Convention – United Nations Environment Program

New Regulations Signal the End of Mercury Lamps | California in Leadership Position

Major highlights of the Minamata Convention include a ban on new mercury mines, the phase-out of existing ones, the phase-out and phase-down of mercury use in a number of products and processes such as UV mercury lamps. Controlled measures on emissions to air and on releases to land and water, and other regulation. The Convention is supported by 92 countries led by the United Nations; new regulations have been in force since 2020.

According to LEDs Magazine, issue Nov. 2022 [6], across the United States, fluorescent phaseouts are gaining momentum. In September 2022, California’s Governor, Gavin Newsom, signed AB 2208 into law which will prohibit sales of mercury-containing compact fluorescent light bulbs in 2024, among others.

By banning the sale of fluorescent lamps, California extends existing legislation to protect consumers from toxic mercury while at the same time accelerating its transition to LEDs.

California was once on the forefront of banning Mercury through Tile 24 [7] introducing LED based lighting to commercial and residential buildings, which was developed by the leadership of Prof. Dr. Michael Siminovitch, Director of CLTC California Lighting Technology Center, University of Davis, CA, Rosenfeld Chair and the CA Energy Commission in 2010 and onward.

It is to be expected that California will lead the Solid State (LED) UV based disinfection paradigm shift for the betterment of human health in areas such as air, surface, water, and food disinfection while driving significant improvement on building energy improvements and decarbonization and reducing so called HAI – Hospital Acquired Infections.

Recommended Daily – Vitamin D (IUs)

As we explained before, by reference to research, long-term oral Vitamin D supplements may pose the risk of Vitamin D Toxicity (VDT) and aortic lesions.

If we consider additional UVB light therapy the general guidance, exposing 20% of the body surface (around 3.400 cm²) to an amount of sunlight equal to 0.25 MED is equivalent to ingesting approximately 700–1000 IUs of Vitamin D3.

This is equivalent to taking a daily dose of 295 nm of light of 3.9 mJ/cm² for 20% of the skin, conveniently and safely. The safety limit of 295 nm light is 5.6 mJ/cm² over a period of eight hours. (MED = Minimum Erythema Dose).

Life Stage	Rec. Amount
Birth to 12 months	10 mcg (400 IU)
Children 1-13 years	15 mcg (600 IU)
Teens 14-18 years	15 mcg (600 IU)
Adults 19-70 years	15 mcg (600 IU)
Adults 71 years and older	20 mcg (800 IU)
Pregnant and breast-feeding women	15 mcg (600 IU)

Table 3: Recommended daily Vitamin D dose (IU = International Unit).

UVB Lighting Technologies

Mercury UVB Lamps

Their Inherent Disadvantages

Mercury lamps contain poisonous metal that poses a risk to human health and the environment. The glass tube is fragile, bulky, and optically inefficient in a lighting fixture. Since it is a radial light source, much of the generated light gets lost in the optical system and therefore energy consumption is a concern as well as the overall system efficiency, and therefore, total cost of ownership. In addition, UVB mercury lamps have a short lifespan, require maintenance through regular lamp changes, and therefore generate hazardous waste.



Figure 2: Example of a light therapy fixture with an integrated mercury fluorescent lamp.

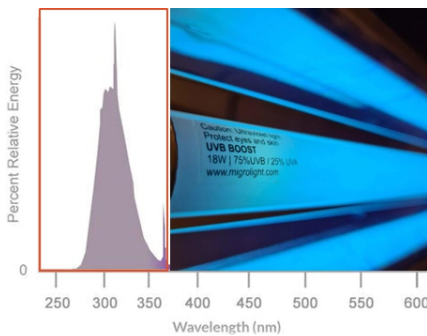


Figure 3: Traditional UVB light sources have a spectrum wide distribution.

Mercury lamps require a warmup time to reach their full efficiency and emission. They cannot be switched on and off frequently, nor modulated in brightness. The efficiency of UVB mercury lamps is below 4% since UVB light is generated by filtering out other unwanted neighboring wavelengths. In conclusion, mercury lamps and especially UVB lamps, are highly inefficient, difficult to use and problematic to dispose of.

UVB LEDs

295 nm Narrow Band UVB Light is the Best to Cure Vitamin D Deficiency

Bolb's recently released high power, highly efficient UVB LEDs in industry common SMD packages, such as S6060 demonstrate the perfect match between the Vitamin D required "activation" or "action" spectrum for human skin Vitamin D production and the Bolb UVB LED emission spectrum. Also, it shows that natural sunlight has little photometrical energy in the 295 nm range which results in longer time exposure needs by natural sunlight therapy (Figure 6).

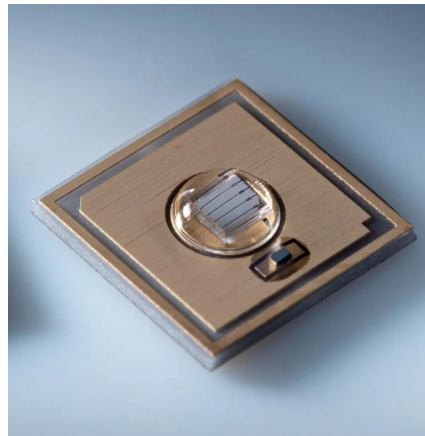


Figure 4: High power, highly efficient UVB LEDs in industry common SMD package S6060 from Bolb.

It has also been confirmed that [8] Ultraviolet B Light Emitting Diodes (LEDs) are more efficient and effective in producing Vitamin D3 in human skin compared to natural sunlight.

Therefore, the optimal range of LEDs emitting UVB radiation for Vitamin D production was found to be between 293 nm and 298 nm. The 293 nm LED was found to be 2.4 times more efficient in converting to Vitamin D3 in human skin than the sun, thus improving its safety profile. This data provides helpful information for medical device development in the future that can be used for Vitamin D supplementation for both healthy and diseased individuals.

Wall Plug Efficiency (WPE) of 10-15% Enable New UVB Solid State Vitamin D Deficiency Cure

Bolb's narrow band, 290-300 nm UVB LED demonstrates in mass production the worlds highest WPE of 10% from a single chip at nominal current of 250mA (Figure 7, Figure 8), provides a long-life robust performance of 10,000 hrs. (L70 = 70% of light output still available after 10,000 hrs. of operation within specification requirements), and is available for sale.

Applications

UVB LED lighting Therapy to Improve Vitamin D Deficiency

It is recommended to take a 295 nm light daily dose of 3.9 mJ/cm² on 20% of a person's skin, which is equivalent to an intake of 700-1,000 IUs of Vitamin D (the doctor's recommended dose).

We need to shine the light of about 6 LEDs (approx. 700 mW of UVB power) on people's skin while they are wearing goggles or shades with an effective UVB filter at a 1-meter distance for about 10 minutes each day. Once one side of the body is exposed for 5 minutes, one can turn around to expose the other side of the body for about 5 minutes. This will give Vitamin D deficient individuals the full Vitamin D dose for the day.

Also, lifestyle choices about the risks of sun exposure may lead to insufficient exposure and result in Vitamin D deficiency.



Figure 5: Examples of applications with UVB LEDs embedded in a modern office environment or in showers.

Some foods can provide significant amounts of Vitamin D when considered cumulatively in a diet. However, most research has not focused on assessing edible plant foods for potential Vitamin D content. It is less well-known that Vitamin D is also biosynthesized in plants.

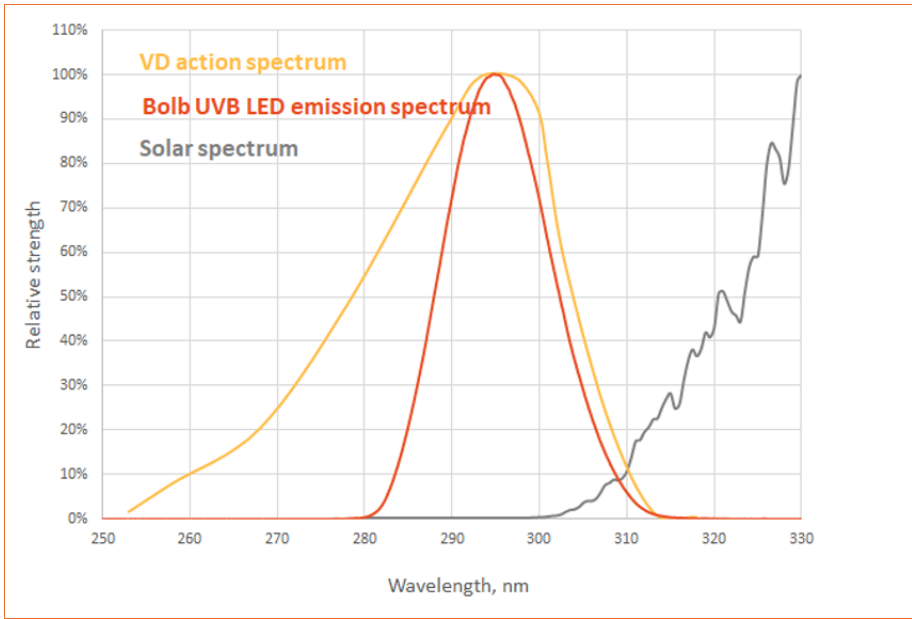


Figure 6: Spectrum comparison Bolb UVB LEDs and Vitamin D "action" spectrum.

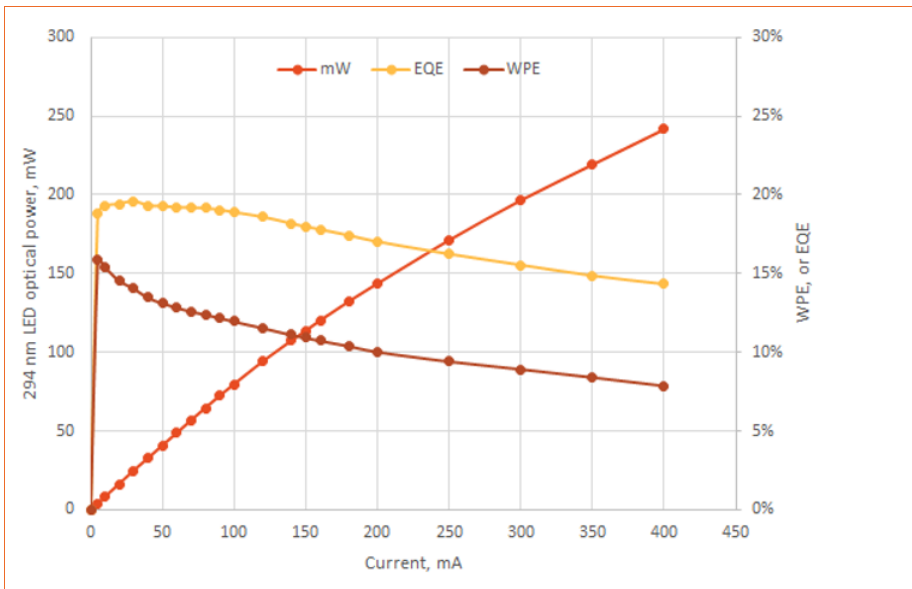


Figure 7: WPE Wall Plug Efficiency (%) and optical output (mW) over drive current (mA).

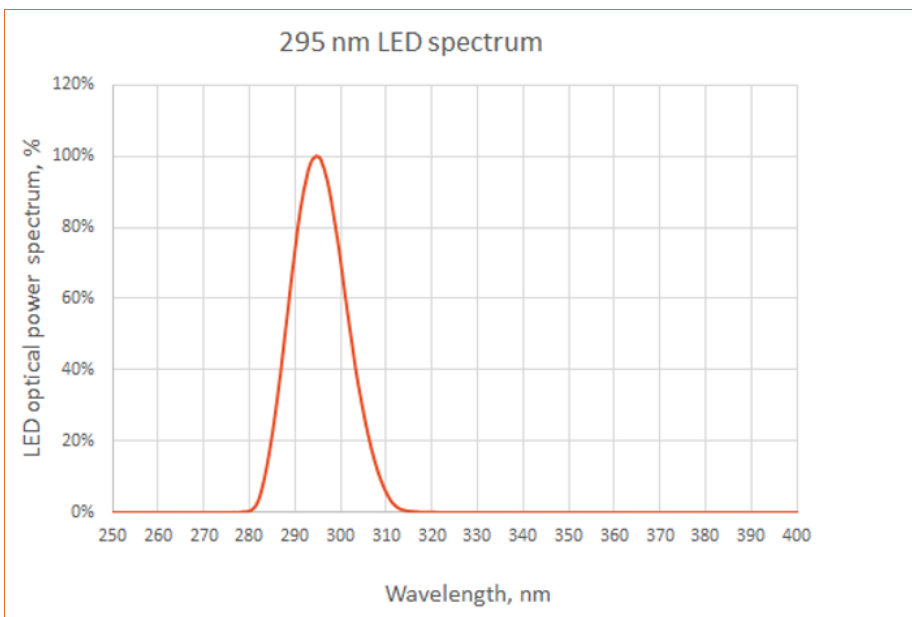


Figure 8: Bolb S6060 UVB LED spectrum (nm) as a function of optical power (%).

Metabolism of Vitamin D in plants - UV-B irradiation results in the production of Vitamin D3 in mammalian skin and Vitamin D2 in yeasts and fungi. Both forms have been used as Vitamin D supplements and in food fortification.

How UVB Light Works in Plants and Horticulture

A PhD thesis Massey University, Manawatu, New Zealand [9] has an intuitive explanation on why UVB works to boost growth and increase crop yield. Basically, if you shine UVB at seed and seeding stage in a greenhouse, the high amount of unnatural UVB light will tell the plant that there is no competition and it's already tall enough, not in shade. So it will focus on building up disease defense mechanisms early, when it's just germinated and yet vulnerable. When the seedling is then planted out into the field, the UVB suddenly drops and the plant will think it's now in the shade, so the growth factors are programmed and boosted to grow much taller to get out of the shade.

The UVB dosage to achieve this effect at seedling stage is high, about $10 \text{ kJ/m}^2 = 1.000 \text{ mJ/cm}^2$ per day for a week. A 5x5 UVB LED array from Bolb, Inc. puts out min 0.25 mW/cm^2 from 1 meter, that means $1000/0.25/3600 = 1.1$ hours is the required dose of radiation per day to achieve maximum Vitamin D enhancement.

Conclusion

The pervasive issue of Vitamin D deficiency has prompted a multifaceted exploration into its causes, implications, and potential remedies. From the traditional methods of sun exposure and dietary intake to the innovative UVB LED lighting therapies, the quest for effective solutions is ongoing.

"The advent of UVB LEDs, with their precise emission spectrum matching the Vitamin D activation spectrum in human skin, offers a promising avenue for addressing this deficiency. Moreover, the application of UVB light in horticulture presents intriguing possibilities for plant growth and crop yield enhancement."

– Dr. Ling ZHOU, CEO of Bolb Inc.

As we advance in our understanding and technological capabilities, it becomes imperative to harness these innovations for the betterment of human health and the broader ecosystem. ■

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Bolb, Inc. has developed and patented breakthrough technologies to enable 'never before possible' disinfection systems for air, water, surfaces, and food to scale on a global basis to benefit human health and increase productivity in key verticals with the objective to preserve valuable resources.



For further information please visit <https://bolb.co> or send your inquiry at info@bolb.co.



Author: Frank HARDER

Frank HARDER accumulated broad experience in global Sales, Marketing, and P/L functions. As founding member of IoT End to End Platform ARTIK with Samsung, and Marketing and Sales leadership functions at LED pioneer Philips Lumileds, he demonstrated his track record of building and sustaining several \$100M businesses in LED, IoT, Cloud and Systems. He has provided leadership to disruptive start-up technology and business companies, raised successfully seed and A-rounds for start-ups. He received his Masters Degree in Electrical Engineering from University of Duesseldorf and his Business Training from Wharton University of Pennsylvania and Royal Philips Electronics. He joined Bolb, Inc. in 2019.

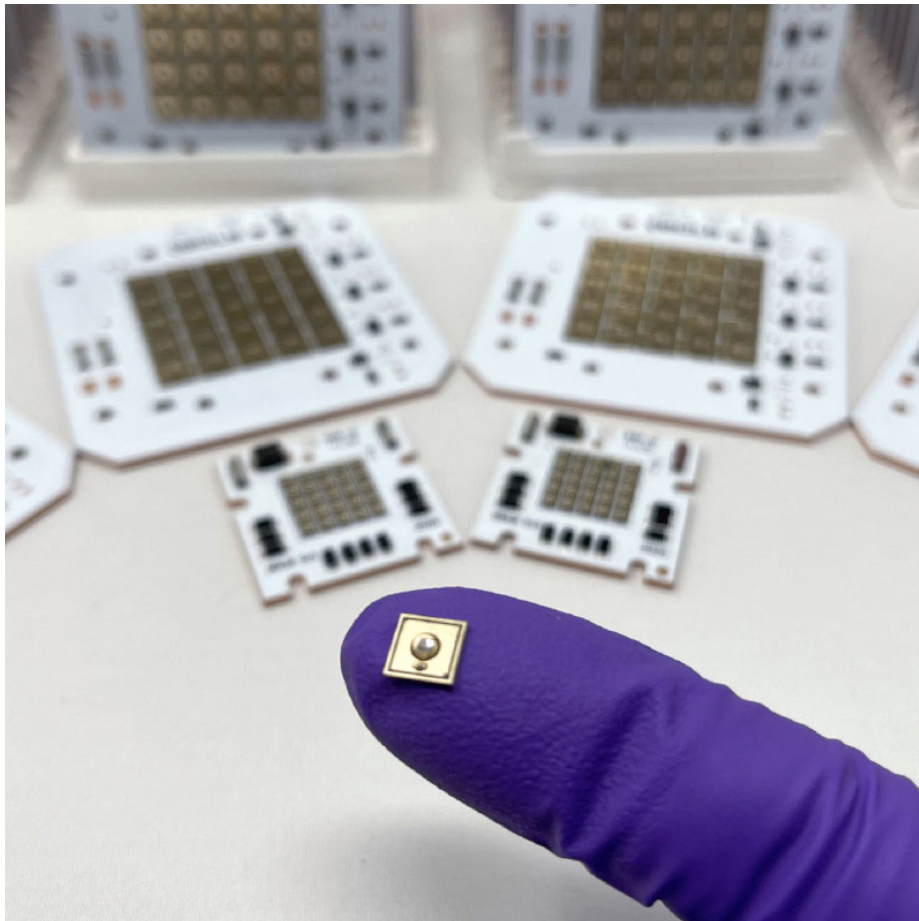


Figure 9: A photo taken in the laboratory rooms of Bolb Inc. shows the size dimension of a single UVB chip, including the UV-B module boards. Image Credit: Bolb Inc.



Co-Founder & CEO: Dr. Ling ZHOU

Dr. Zhou co-founded Bolb Inc, and successfully raised \$26M in venture funding for the company from 2014-2021, serving as CEO of the company. He received training on semiconductor materials growth and processing technology and subsequently worked at Philips Lumileds as Lead Engineer on ultraviolet light-emitting diodes for the DoD-funded Solid-state Ultraviolet Optical Sources (SUVOS) project. He was awarded an Outstanding Performance Award from DARPA for his pioneering work on world's first thin-film UVC LEDs in 2004.

The Comprehensive Guide to the Lighting World

The Global Lighting
Directory 2023

Improving Light to Support Our Shared Natural Ecosystem and Dark Sky Initiatives

Willem Sillevius Smitt, Senior Director of Strategic Marketing at Lumileds, discusses the evolution and challenges of the lighting industry.

Shedding Light on the Future: Nightscape Technology Pioneers Eco-Friendly Illumination!

In a groundbreaking LpS-Digital lecture, Willem Sillevius Smitt, Sr. Director of Strategic Marketing at Lumileds, delves deep into the transformative journey of the lighting industry, introducing the revolutionary Nightscape Technology. This innovation promises to harmonize our lighting needs with the preservation of our natural ecosystem and the dark sky initiatives.

Video at a Glance

- Presenter: Willem Sillevius Smitt
- Job Title: Sr. Director Strategic Marketing
- Organization: Lumileds
- Country: USA
- Recording: August 9, 2023
- Duration: 23:53 min

Video Links

LpS Digital YouTube



<https://is.gd/zlqRSY>

LpS-Digital.global



<https://is.gd/c3pTx7>

Content of the Talk

Historical Perspective: 15 years ago, there were concerns about LED technology, questioning its light output, lifespan, and efficiency. Regulatory measures like Energy Star, DLC, LM80, TM21, and European lighting regulations emerged to address these concerns.

Current Concerns: Recent headlines highlight the negative impacts of lighting, such as light pollution affecting humans and wildlife. Concerns about the amount of blue light and its effects on human health are prevalent. Light pollution laws are being implemented in various states in the US, with places like Maui regulating the amount of blue light in new installations.

Impact of Light at Night: Factors to consider: shielding of light, managing blue light content, timing of light, and direction of light. The lighting industry needs to focus on minimal environmental disruption in addition to efficiency and longevity.

Nightscape Technology: Lumileds introduces Nightscape, a technology aiming to produce white light with less than 2% blue content. A comparison of different light sources shows that Nightscape meets the 2% blue requirement while maintaining a higher CCT than other sources. Nightscape aims to provide a balance between pleasant light quality and minimal environmental disruption.

Conclusion: The lighting industry should address end-user concerns and view them as opportunities for improvement. Collaboration is key to creating a better end-user experience.

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Improving Light to Support Our Shared Natural Ecosystem and Dark Sky Initiatives

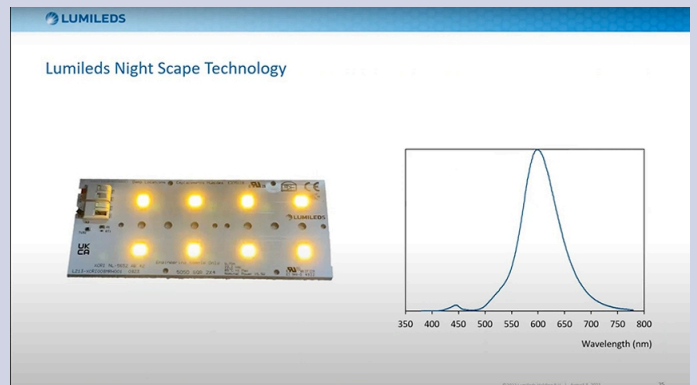
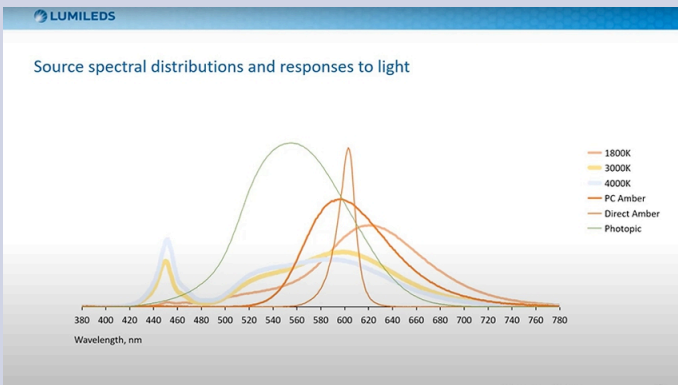
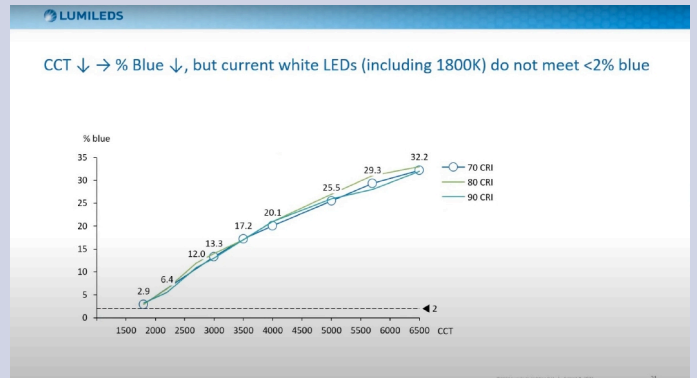
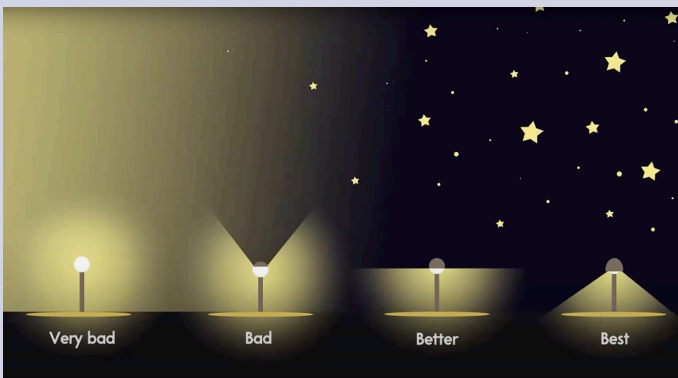
Willem Sillevs Smitt
Sr. Director Strategic Marketing
Lumileds

L230809-Expert Talk, Lighting Technology

Improving light to support our shared natural ecosystem and dark sky initiatives

Lumileds
August 2023



Options to achieve <2% blue

	3000K white	1800K white	PC Amber	Amber	Filtered 3000K	Nightscape Optimized
% Blue	13.3% ❌	2.9% ❌	1.2%	0%	0.8%	1.8% ❌
Efficacy	100%	75%	78% ❌	40% ❌	85%	87% ❌
L90 L70	Best	Best	Best	Poor ❌	Question? ❌	Best
CCT	3000K	1800K	1600	N/A	2370K	1900K
Duv	0.000	0.000	0.004	N/A	0.015 ❌	0.006
CRI	72	72	53	-27	55	52
Rf Rg	74 93	78 78	64 70	1.3 2.2 ❌	47 44	64 69

HPS: 6.5% Blue, Rf | Rg: 37 | 61

Summarizing

- Looking ahead, end users ask us to change how we think about lighting, especially at night
- Concerns in the general public, can be translated into actions
- As an LED manufacturer, we implement improvements to help address the general public's concern
- Complaints about lighting is a great opportunity for addressing those

Controlled LED Lighting for Horticulture: A Review

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As energy gradually becomes a more valuable commodity, the desire for reduced energy losses strengthens. Lighting is a critical field on this matter, as it accounts for a large percentage of the global electricity consumption and modern lighting systems are markedly more efficient than incandescent, discharge, and fluorescent lights. Previous research has proven that plants do not require the entire visible spectrum but react only to specific wavelengths, making it possible to control their growth and yield via artificial lighting. The flexibility of control of Light Emitting Diode (LED) lights allows for the combination of great energy losses reduction and controlled plant growth, achieving the improvement of two major parameters in a single action. This review paper summarizes the current research on the effect different light wavelengths have on specific plant species and discusses the applications of LED lighting for horticulture, yield storage, and disease protection.

Introduction

Artificial lighting for horticultural use has been studied since 1860 but practical application was unfeasible at the time [1,2]. Research progressed over the following decades using carbon arc and low-pressure discharge lamps [3,4,5,6], yet no technology reached commercial use. The prospect of cultivation in controlled environments with artificial lighting came into existence in the 1980s, when the ever-rising population in conjunction with the failing crops due to climate change pushed for the development of alternative food sources [7]. The development of more efficient forms of lighting, such as high-pressure sodium (HPS) lamps marked the point where artificial crop lighting became both technically and economically feasible, with researchers directly or indirectly identifying the significantly lower energy requirements [8,9].

Light-Emitting Diodes (LEDs) first appear in the early 20th century, when Henry Josef Round observed the emission of light when applying current to silicon carbide crystals [10]. Still, the first commercial LEDs were developed many decades later, with the first products appearing in the late 1960s [11]. The potential of LEDs as a lighting source for horticulture was first explored in the early 1990s [12], revealing distinct advantageous features and configurations that the use of LEDs unshackles [13]. Their efficiency and very low radiant heat offer more than just lower energy cost; they allow for the design of much denser horticultural canopies, greatly decreasing space requirements. Furthermore, the use of LEDs allows for control of the light spectrum, as they can be configured to produce light in the spectral range required by the application. Nowadays, controlling the light output of LEDs is easy and cheap [14,15].

The rapid development of LED lighting over the past decade is a technical and economic opportunity for horticulture; LEDs can markedly outlive HPS lamps and consume significantly lower amounts of energy. LED luminaire efficacy has more than

doubled over the past five years, with projections suggesting that efficacy will improve by at least another 25% by 2025 [16]. With plants using radiant energy only in the photosynthetically active region of 400 nm to 700 nm [17], LED technology allows for the control of the exact light wavelength and intensity output, providing the unique opportunity to design lighting systems that are both technically and energetically optimized for specific cultivations [18]. In this review, we summarize the research on LED lighting for horticultural use and classify what effect specific LED light wavelengths have on cultivations.

Red (610-700 nm) & Far-Red (700-800 nm) Light Effects

Red light is generally associated with the growth rate and dry weight increase of plants. Red light can delay, or even completely inhibit, a plant's transition to flowering, allowing them to significantly increase their biomass [19]. The issue here is that although red light is proven to increase the total biomass of certain plants [20,21], it also increases elongation [22] and tends to deteriorate pigment [23], decreasing the overall value of many plants. Nevertheless, there are cases where this canon does not apply, with studies suggesting that monochromatic 660 nm light actually improves anthocyanin content and, in extend, the quality of certain plants [24].

One of the first studies exploring the effect of red/far-red wavelength LED light on plants was performed by Brown et al., displaying that the addition of 700–740 nm light increases the height and mass of sweet pepper (*Capsicum annuum*) plants [25]. A later study verified these results but showcased that the increased size had virtually no effect on the fresh and dry weight of peppers [26].

A study on cucumber transplants revealed that supplemental 622 nm LED light can increase the growth rate but, ultimately, has no effect on the total mass or yield [27]. Similar results were obtained by supple-

mental red light on spinach, which accelerated the formation of new leaves but was not optimal for the final weight of the plant [28]. A study on tomatoes suggests that 680 nm light will significantly increase yield [29], yet a newer study indicates that red LED light will cause leaf curling on several tomato genotypes, with virtually no tangible advantage [30]. More recent research found that the combination of red and blue LED light in 3:1 ratio assists the morphologic development of tomato plants and significantly improves the fruit yield and quality [31]. Red 640 nm light is also found to be important for the growth, pigment, and nutritional quality of kale [32].

The effect of red spectrum LED light on the growth and yield of lettuce (*Lactuca Sativa*) has been extensively studied, with conflicting results. Early studies claim that red light alone is unacceptable for the proper growth of lettuce [12,33,34] but more recent studies suggest otherwise. Stutte et al. studied the effect of multiple light wavelengths on red leaf lettuce, concluding that the application of far-red 730 nm light on red leaf lettuce elongated the leaves and significantly increased the dry weight of the plant [22]. A parallel study from Li and Kubota concluded that supplemental red and far-red LED light has similar results on the growth of baby leaf lettuce, considerably increasing the stem and leaf lengths of the plants, reducing, however, phytochemical concentrations when no other light is present [23]. The effect of red (660 nm) and far-red (735 nm) light on lettuce was also studied by Lee et al., who derived that it increased the number and size of the leaves on grown plants, whereas it also improved the shoot and root growth of red lettuce leaf seedlings [20]. These effects were more prominent as the wavelength increased. Pinho et al. [21] and Chen et al. [35] both verified that wavelengths longer than 700 nm significantly contribute to photosynthesis and considerably increase the growth rate of lettuce, warning however that the increased rate of growth decreases the fresh and dry weight of the plants, a comment that is in complete antithesis to the results of other studies [22,23].

Lettuce also seems to react positively to red light in terms of nutritional quality. The use of 620 nm to 700 nm has several positive effects on the nutritional value of lettuce, reducing ascorbic acid concentrations [36], increasing antioxidant properties [37], and stimulating the uptake of N, K, Ca, and Mg [21]. Another study showed that 620 nm light can increase chlorophyll and carotenoids concentrations [35], yet far red 735 nm light has the exact opposite effect [23].

Studies on cabbage suggest that monochromatic red LED light is not optimal for the growth or the properties of the plants. However, a red to blue 7:1 ratio provides adequate light conditions for the growth of non-heading Chinese cabbage, with no weight or nutrients loss compared to HPS lamp light [38].

Green (500-600 nm) Light Effects

Early research suggests that green light will repress the growth of algae and some plants [39,40]. However, more recent research suggests that several types of plants can greatly benefit from 510 nm to 585 nm wavelength light, yet mostly in conjunction with red and/or blue light. In nature, green wavebands are generally found in plant-shaded environments and, expectedly, affect organisms that populate such environments, such as fungi, algae, and bacteria [39,41]. For higher plants, green light regulates growth, usually negatively affecting the growth of plants if no red or blue waveband light is present, as it serves as a signal of unfavorable photosynthesis conditions [42]. Green light also signals the closing of stomata in several plant species, reducing stomatal conductance [43,44,45].

Both the fresh and the dry weight of cucumber transplants, as well as their growth rate, were found augmented via the application of 505 nm to 530 nm green LED light [46,47]. In contrast to research suggesting that green light increases the hypocotyl length of plants [48], the addition of green light decreases the hypocotyl elongation of cucumber transplant seedlings [46]. In the case of tomato plants and sweet peppers, supplemental 505 nm LED light significantly increased the leaf area of the plants, as well as their fresh and dry weights, but the plants did not react positively to 530 nm light, suggesting a very selective wavelength behavior [47]. Green light wavelength was found to further improve the growth rate and quality of lettuce when combined with red and blue LED arrays [45]. Later studies discovered that partial green light, up to 50%, can increase lettuce growth but higher figures would cause a reduction of it [49]. The effect of green light wavelength on red leaf lettuce has been studied by Johkan et al., concluding that green light is an effective growth stimulant, with 510 nm high-intensity light displaying the most prominent growth effect [50]. A later study added that 518 nm light can also have a dramatic effect on the fresh and dry weight of lettuce, with the increase of fresh weight reaching 61%, but only in

conjunction with 655 nm light [51]. Green light also appears to have a significant effect on the nutritional quality of lettuce, increasing saccharide concentrations [52] and decreasing nitrate concentrations [53].

Blue (380-500 nm) Light Effects

Blue light is frequently researched as supplementary to red or polychromatic light, with few researchers solely focusing on the effects of blue waveform light alone. Blue light wavelength generally is responsible for the opening of stomata [43,54].

Supplementary blue light was found to be necessary for the proper growth of wheat, which was unable to fully develop with 660 nm red light alone. The addition of 10% blue light significantly increased fresh and dry weight, decreased the number of sub-tillers and spikes, and greatly increased seed yield, producing comparative results to plants grown in white light [55,56].

456 nm light also leads to the accumulation of antioxidants in lettuce [51,57], as well as an increase in carotenoids and chlorophyll concentration [58]. However, blue spectrum LED light on lettuce promotes leaf expansion and retards growth, leading to compact plant morphology [22,58]. Regardless, even though lettuce seedlings initially grow much faster with red 660 nm light, prolonged exposure to blue 470 nm light greatly increases the fresh and dry weight of lettuce, ultimately resulting to significantly heavier harvestable plants [57]. According to the same study, the combination of blue and red light has no further effect on the plant's ultimate weight but significantly increases chlorogenic acid contents. This is in agreement with earlier studies that suggest the supplementation of lettuce cultivations with blue spectrum light in order to enhance yield [33]. Finally, supplemental 400 nm to 500 nm blue light increases anthocyanins on lettuce by 31%, vividly improving the plant's quality [22,23].

In combination with red 660 nm light, 450 nm light was found to shorten the length of tomato seedling stems [59] and to increase the leaf area of the plant [47], as well as to improve the nutritional quality of their fruits [60]. Medium intensity 455 nm light also decreases the hypocotyl elongation of tomato plant stems but low and high intensities have the opposite effect [61]. Blue light was found to increase the tomato plant's biomass and quality [62] but some researchers report a negative impact on fruit yield [63]; however, the combina-

tion of blue and red LED light seems to enhance tomato plant biomass with ostensibly no effect on fruit yield, an effect that could not be achieved with red or blue light alone [30]. The introduction of blue LED light to tomato genotypes also increases chlorophyll and flavonol contents [30] and improves the disease resistance of tomato crops [62].

The addition of blue light appears to have several positive effects on cucumbers, with no adverse effects listed to this date. Hogewoning et al. found that a 7% - 93% blue-red light ratio is sufficient to prevent any overt dysfunctional photosynthesis and doubles the photosynthetic capacity of cucumber plants, effects that increase while blue light remains below 50% of the total irradiance [64]. The same research notes that the effect of blue light on the photosynthetic capacity of the plant also improved the weight of the plant, nitrogen and chlorophyll content, as well as stomatal conductance, improving the rate of passage of CO₂ and water vapors through the stomata of the leaves. Cao et al. obtained very similar results with 20% - 80% blue-red light on cucumber seedling growth [65]. More recent research claims that monochromatic blue light enhances the growth rate of cucumbers the most [66]. 455 nm light also improves cucumber photosynthetic pigment concentrations, bettering their overall quality [46].

Blue light is also beneficial for the growth and properties of cabbage. Mizuno et al. discovered that 470 nm light improves petiole elongation in both green and red leaf cabbage varieties but affects chlorophyll content only on the green leaf cabbage variety [24]. In the case of non-heading Chinese cabbage, blue light also increases their nutritional quality, benefiting Vitamin C, rising sucrose levels, improving soluble protein and soluble sugar concentration, and increasing chlorophylls accumulation [67].

Supplemental blue LED light also seems to accelerate the growth rate of certain plants, such as strawberries [68] and azalea [69], yet they still require red light wavelength in order to maintain their physical and nutritional quality. Spinach also displays a similar reaction to supplemental blue light, with researchers proving that cold white LEDs—LEDs with very high photon radiance on the 445 nm wavelength—advance the development of spinach plants by a full week, yet the research did not investigate what effect that has on the nutritional quality of the spinach plants [28,33].

Discussion

It can be surmised from the previous paragraphs that there is no one-size-fits-all solution, as different plant species react differently to each light wavelength and intensity. Certain studies showcase that the light intensity can greatly change the effect that a specific wavelength has on certain plants [61]. This warrants further investigation on how intense LED lighting needs to be in order to induce certain effects, as well as if other effects can be induced by the same light wavelength at different intensity levels. There are also plants that react to very specific wavelengths, such as, for example, tomato and sweet pepper plants that react very well to 505 nm green light but not at all to 530 nm green light [47]. Several studies find that the combinations of two or more wavelengths yield significantly better results. For example, the combination of red and blue light wavelength greatly increases both the size and the weight of peppers, while it offers easy modulation of capsaicinoids and carotenoids, as well as control over the fruit's color [26]. Basil and strawberries perhaps the most prominent example, with researchers identifying that the combination of red and blue LED light increases both the leaf yield and the nutritional quality of the plant [68]. There are also studies concluding that monochromatic or duochromatic LED light have poor results on the yield of certain plants, such as radish [33], suggesting that other wavelength and/or intensity combinations need to be investigated. Conversely, research on some plants has only been performed with polychromatic LEDs that include four or more light wavelengths, making it difficult to discern which wavelength affects what parameter and if any are unnecessary for the yield and/or the quality of the plants and fruits, warranting further research [70,71,72].

There are also a few studies investigating the effect of LED lighting on harvested plants during the storage period, suggesting that specific LED light wavelengths have interesting effects on the nutritional quality of fruits [73], with the researchers identifying that specific light wavelength can affect anti-oxidant concentrations, phenolic content, pigment, tocopherols, firmness, and more. Reviewing what effect which light wavelength has on plants, one can easily conclude that there are no formulae applicable to every plant species; different plants react differently to various light wavelengths and intensity. For example, although red light increases the harvest weight of lettuce [22], it seems to have no effect on the weight of peppers [26], and

while blue light increases the nutritional quality of cabbage [67], it decreases the nutritional quality of garlic seeds [74] and pea sprouts [75]. Researchers who examined the effects of supplementary lighting on several types of plants also found that reactions to specific wavelengths are species dependent [76]. Combining the above, we can assess that both light waveform combinations and light intensity affect how a plant develops, with different plants having a different optimal lighting configuration, suggesting that the optimization of LED lighting for horticulture is complex and needs to be a per-species approach. There are but a few detailed case studies currently published, such as the study for growing lettuce in plant factories with artificial lighting by Kozai et al. [77], but such holistic approaches seem necessary to optimize the characteristics and determine the cost-effectiveness of managing and improving horticultural crops via controlled LED lighting. Another seemingly viable application of LED lighting is for the protection of crops from disease. Depending on the plant species, it has been suggested that certain wavelengths can suppress disease or even prevent it altogether. Strawberry plant disease seems preventable by UV-B light [78], while blue-violet light wavelength seems to improve the resistance of tomato and other higher plants [79,80]. A more recent study suggests that UV light can very effectively increase resistance to insect and pathogens—the study is primarily focused on ornamental crops but suggests that could apply to edible crops [81]. Although this research topic has been only superficially studied, it represents a practicable indirect approach of using artificial LED lighting to improve the final quality of crops.

It is interesting to note that there is a shortage of studies on the economic impact that supplemental LED lighting may have on crops, asserting whether the gains from installing such lighting systems will overcome the capital costs of the system, or even the energy cost from running the LEDs. Recent research suggests that the replacement of HPS lamps with LED lighting may be economically feasible only in regions where the energy cost is high or if the capital cost of the LED systems decreases significantly [82,83]. Still, the efficacy of LEDs increases exponentially with each passing year and the economic feasibility of LED-based horticultural designs, such as dense vertical canopies, has not been adequately investigated yet. With studies suggesting that certain high-intensity configurations probably are unrealistic [69], the practical application of LED lighting for crops warrants thorough investigation. Finally, it has been proven that the place-

ment of the LEDs can also be optimized in order to minimize energy use [84], which suggests that not only the correct light wavelength for each intended excitation must be identified for each type of plant but the placement of the lighting must also be researched for the optimization of energy use.

Conclusion

LED lighting has great potential either as a supplemental or the sole lighting source in horticulture. Due to the technical characteristics of LEDs, such as their small size and excellent efficacy, the design of very dense farming canopies is possible, greatly improving the feasibility and yield of cultivation in artificial constructs. This is exceptionally important for locations or constructs where space for food production is very limited and energy is a costly commodity. What is equally important, however, is to gain a better understanding of how different plants react to different wavelengths and intensities of the light spectrum. Only a handful of plants and lighting configurations have been explored to this date, leaving colossal research headroom toward the lighting optimization for every horticultural plant species. The optimization of controlled cultivation environments can have a very significant impact on the yield, quality, and cost of horticultural products. ■

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TUNABLE WHITE TECHNOLOGY INTRODUCTION OF ON-BBL TUNABLE WHITE TECHNOLOGY

Introduction of On-BBL Tunable White Technology

In a traditional tunable white solution with a combination of warm white LEDs and cool white LEDs, the chromaticity point moves linearly on the xy chromaticity diagram, while the black body locus (BBL) is curved. Due to the curvature of the BBL, especially under 3000 K CCT, the emission color withdraws from "white" with a certain range when adjusting the emission color, and it is impractical to prolong the range of correlated color temperature (CCT) toward 2000 K CCT. Tomokazu Nada, Managing Director at ZIGEN Lighting Solution, proposes a new "On-BBL Tunable White" technology that makes the chromaticity point draw an upward curve along the BBL by 2-channel control. This technology expands the possibilities of tunable white LEDs by allowing the CCT range to be set from 2000 K sunset color.

Introduction

After LED technology was adopted in lighting, a tunable white feature that can adjust emission color from warm white to cool white was provided in various lighting applications. And now, a tunable white feature is being increasingly adopted for circadian rhythm lighting.

Generally, emission colors of tunable white LEDs are achieved with a combination of a warm white LED and a cool white LED. The generated chromaticity points are located on the straight line between the chromaticity points of light source.

On the other hand, the set of white points draws an upward curve called the black body locus (BBL), on which the chromaticity points of natural light, like the sun, fire and stars are located. Thus, the farther away the chromaticity points of the two light sources are, the more difficult it is for the chromaticity points of the mixed light to follow the BBL.

For example, if a warm white LED is 2000 K CCT and a cool white LED is 5000 K CCT and both are located on the BBL, the generated chromaticity points in the middle range are more than 7 steps away from the BBL, as shown in Figure 1. Such chromaticity points are no longer "white".

In order to keep an emission color white, a chromaticity point of a tunable white LED is

required to trace the BBL on the xy chromaticity diagram as closely as possible. For this reason, a color range of a tunable white is usually set to the range where the BBL is relatively linear on the xy chromaticity diagram, such as from 2700 K CCT to 6500 K CCT or a narrower range.

However, these days, dim to warm LED technology is becoming popular in lighting and people are now aware of the importance of the 2000 K CCT Sunset Color for comfort and sophisticated lighting effects. Not only that, 2000 K color is said to be very important for circadian rhythm [1]. Thus, it is ideal to implement 2000 K CCT in tunable white lighting applications, despite the problem of the chromaticity point.

One technology to solve this problem is RGB+W LED solution.

Note that W (white color) is necessary on top of RGB (red, green, blue) for a lighting application. Because the spectrums of the RGB LED are separate from each other, the combined spectrum and color quality of the generated light become poor. This means that RGB solutions cannot be used for general lighting applications. By using the RGB+W solution, the chromaticity point can be set at the farthest point on the xy chromaticity diagram, including along the BBL by controlling each R, G, B and W LED output. However, when using the RGB+W solution, each LED output must be precisely controlled to generate

a white color. Therefore monitoring intensity from each LED and adjusting output is necessary during operation. The monitoring and adjustment of each LED output is quite complicated and costs are high. Thus, most tunable white LED solutions have, so far, used a combination of warm white LEDs and cool white LEDs, but this is still a compromised solution.

In this article a new technology of tunable white, which starts from 2000 K CCT without the problem of the chromaticity point, even by 2-channel control is presented.

Basics of Color Mixing

A white LED device typically emits with a single CCT and is stable over temperature or current, because

- The wavelength of emission light from a blue LED chip is less susceptible to heat and operating current.
- Phosphor is improved to emit stable spectrum over temperature.

And stable emission color is actually one of the advantages of LED lighting. On the other hand, for achieving tunable white characteristics, it is necessary to arrange at least two sets of white LEDs with different color temperatures (typically, a combination of warm white LEDs and cool white LEDs). By adjusting the current balance between

the two sets of white color of the mixed

The chromaticity point of the mixed light can be expressed by the following formula, using the chromaticity point $(x, y)_{warm}$ and the luminous intensity L_{warm} of the warm white LEDs, the chromaticity point $(x, y)_{cool}$ and the luminous intensity L_{cool} of the cool white LEDs.

In practice, the chromaticity point of the mixed light can be expressed by the following formula, using the chromaticity point $(x, y)_{warm}$ and the luminous intensity L_{warm} of the warm white LEDs, the chromaticity point $(x, y)_{cool}$ and the luminous intensity L_{cool} of the cool white LEDs.

$$(x, y)_{mixed} = \frac{(x, y)_{warm} \cdot L_{warm} + (x, y)_{cool} \cdot L_{cool}}{L_{warm} + L_{cool}} \quad (1)$$

As can be seen from the above formula, the chromaticity point of the mixed light moves linearly between the chromaticity points of the cool white LEDs and that of the warm white LEDs.

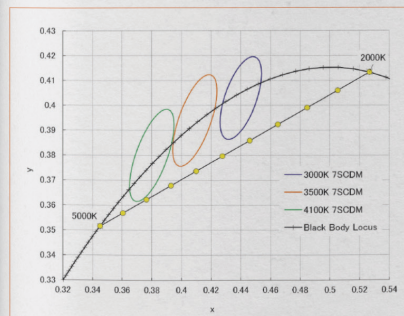


Figure 1: Chromaticity points of conventional tunable white LED together with Mac Adam Ellipse (step-7) on the xy chromaticity diagram

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Dive into the **Future of Lighting** with our upcoming issue that promises to be a treasure trove of insights and innovations. Join Prof. **Shuij Nakamura**, the esteemed **Nobel Prize Winner** from Santa Barbara University, as he shares his profound commentary on the evolving landscape of technologies and lighting. Get an exclusive peek into the mind of **Monica Luz Lobo**, the President of **IALD**, as she unveils the latest trends shaping the world of lighting designs. **Bronwen Rolls**, a renowned marketing expert, takes us on a journey with the lighting maestros at **StudioZNA**, delving deep into luminaires, sustainability, and transformative user experiences. Dr. **Oliver Stefani**, founder of **Chronolight** and affiliated with the University of Lucerne, poses the pivotal question, "What is Good Light?" and explores the tools and techniques that will define our luminous future. **Nichia** presents a compelling case study, showcasing the application of cutting-edge lighting technologies in real-world scenarios. And, **Arno Grabher-Meyer** challenges us to think **Beyond Efficiency** in lighting, emphasizing the importance of sustainability and environmental protection in the modern era. This issue promises to be a beacon of knowledge, innovation, and inspiration for everyone in the world of **Solid State Lighting**.

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