LED professional Review

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LpR

The Global Information Hub for Lighting Technologies and Design

Sept/Oct 2021 | Issue 87

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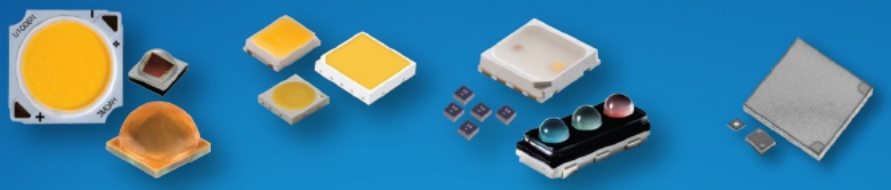

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Michael Huelskemper
Product Managtement – Electronic Systems for Luminaires, **OSRAM**

Michael Myer
Researcher, **Pacific Northwest National Laboratory**

Jan de Graaf
Product Architect, **Signify**

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More Than Trends

Currently, we and our planet are facing significant challenges. One of the greatest challenges is getting the greenhouse effect under control. In the lighting sector, this also involves the reduction of CO_2 emissions by reducing energy consumption. All new lighting solutions are required to offer intelligent solutions to support sustainability and energy efficiency.

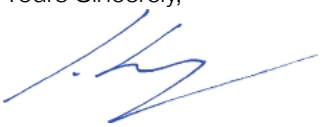
This issue of LpR shows some of the directions that lighting projects will take in the future. Pixel technologies are used in automotive lighting; dual systems for illumination and disinfection are used in general lighting, and UV light is used to optimize processes in production.

A particular focus is, again, the awareness of good light. This issue, together with the comic book, offers a new way to approach the topic. And finally, there is also an interesting article that deals with the simulation of light from sunlight.

But I'd like to go back to the environmental issue. This is an urgent topic that deserves more scope in the LED professional Review (LpR) and for this reason we want to invite you to send us information about sustainable projects, research activities, and solution ideas and concepts that can be published to a broad public. Please send your thoughts, ideas and information to our editors at editors@led-professional.com.

We hope you enjoy reading the issue LpR87 and thank the excellent authors for their great contributions.

Yours Sincerely,



Siegfried Luger

Luger Research e.U., Founder & CEO
LED professional, Trends in Lighting, LpS Digital & Global Lighting Directory
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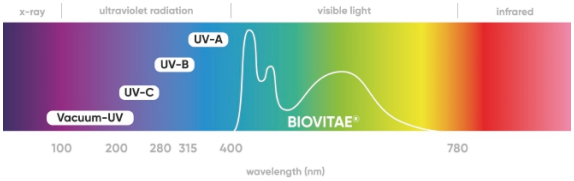
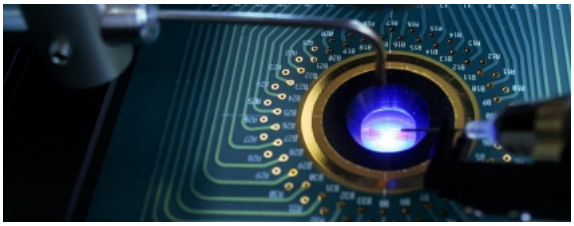
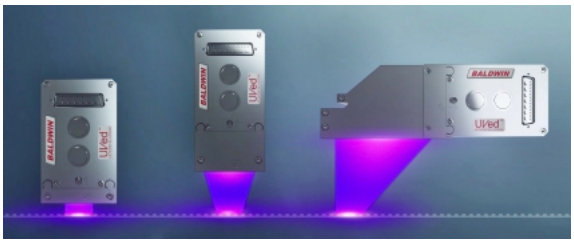
It delivers considerable benefits of significant vivid color, detail contrast, and homogeneous quality of light.





UV LED CURING



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LED professional Review (LpR)
Nov/Dec 2021

ADVERTISING INDEX

Stephan WEGSTEIN, DI

Mr. Wegstein graduated in communication engineering at the TU Darmstadt, Germany. His professional career started at Arrow, where he developed the European Go-To-Market Strategy and built up the LED Team. Afterward, Stephan was responsible for LED drivers at RECOM as VP for Marketing and Sales. Furthermore, he worked as an independent engineer consultant for renowned luminaire and component manufacturers such as Cooledge Lighting, Vestel, and ISSI Semiconductors.

He has been working for Cypress / Infineon Technologies for more than five years as the Business Development Manager for Flash Memories where he is responible for the European market. He also served on the Technology Board of the LED professional Symposium in Bregenz.

Lighting Future

One of the major barriers to enabling smart infrastructure is powering, communicating with, and managing sensors. Because of the cost of installing wired power, many sensors must be battery operated, limiting their computer capabilities, communications frequency, and operating range. They must also be within low energy wireless range of a gateway to connect to the cloud. More advanced sensors that are line powered, such as cameras, still need a place where they can be safely installed. Smart luminaires are the natural hub for both of these types of sensors. For example, streetlights are already widely spread through cities. By increasing the capabilities of these luminaires, cities can begin to deploy smart functionality using existing infrastructure. Cameras and other sensors can be installed in the streetlights themselves, providing them a high vantage point, power, a light source, and access to the cloud without requiring a wireless interface. Other sensors can be deployed within wireless range of the streetlight, which then serves as the sensor hub. Once the sensor gateway is in place, sensors can be deployed in stages. After basic sensors like light, temperature, and humidity sensors have been installed, more advanced sensors can be introduced. For example, with radar, streetlights will be able to track traffic and pedestrians. In addition to helping drivers find an open parking space, the streetlight network could alert nearby drivers when a child runs into the road after a ball. In retails spaces the same luminaires that confirm that social distancing guidelines are being followed could be used to track the shopping patterns of customers and personalize their experience.

To serve as a sensor hub/gateway, luminaires need a reliable way to store and secure both data and code. As processors migrate to 22 nm process manufacturing technologies, embedded Flash loses its ability to retain data sufficiently. Thus, there is a need for systems to utilize external Flash. This, in turn, increases the need for security to protect both the luminaire and the smart network at large. Security is important not only for keeping systems running reliably, but also to maintain the privacy of the individuals these smart luminaires are intended to serve. Today's NOR Flash provides a wide range of capabilities to secure data and code. Another important factor for OEMs to consider is capacity. With each new sensor, smart lights can provide increasingly complex functionality. Initially, luminaires will likely only need to support simple sensors, such as ambient light detectors or motion sensors. However, streetlights have an expected lifecycle of 15+ years. This means that as sensor gateways, they will need to be able to support sensors and capabilities that have not yet been developed. In short, they need to be extendable to accommodate new functionality years after they have been deployed.

Other important factors to take into account are standardization, consistency, and an open market. It can be argued that the smart home market was stalled by the lack of standards and products that work well with each other. Part of this issue arises from smart home equipment vendors who have tried to create closed systems operating through a proprietary gateway. Establishing luminaires as the sensor gateway for our cities, buildings, and factories would mitigate many of the issues associated with competing gateways and networks. Rather than build a standalone camera network, it makes much more sense to integrate the camera with existing lighting infrastructure. This would pave the way for accelerating innovation, enabling immediate deployment and speeding adoption of smart lighting technology.

The lights of tomorrow, and not just those that light our streets, will be much more intelligent than the lights we have today. By serving as the primary sensor hub for our cities – both outdoors and indoors – luminaires will enable us to enjoy the cost, health, safety, and ease of use benefits of smart lighting using existing infrastructure. And with the right technology, we'll be able to extend the operating life of luminaires while increasing our sustainability as we move into the future. ■

S.W.

Almost too beautiful just for the road – lighting design with PLEXIGLAS®.

What does PLEXIGLAS® have to do with car design? For over 60 years, PLEXIGLAS® molding compounds have been a driving force behind the auto industry. Why? Because the multifaceted ways in which PLEXIGLAS® can be formed open up virtually endless possibilities for design. One shining example is crystal-clear or colored PLEXIGLAS® whose top light-guiding properties and color stability make for innovative automotive lighting systems. For more inspirational PLEXIGLAS® products, go to **www.plexiglas-polymers.com.**

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THE ORIGINAL BY RÖHM

BUSINESS

EGLO Took Over the Majority of Bartenbach

EGLO's Rene Tiefenbacher (left) and Bartenbach's Christian Bartenbach (right)

On August 24, 2021 the company EGLO acquired the majority of the Bartenbach Holding. EGLO is a family owned business with more than 50 years of history and is credited as being the largest residential lighting supplier in Europe.

EGLO expects that with this acquisition they can further develop the lighting capacity of the EGLO group in the lamp industry. EGLO is also strong and established in the real estate industry and the entire group earns a turnover of approximately 700 million euros.

EGLO's strategic and financial background will contribute to Bartenbach's international growth. The brand and DNA of Bartenbach will remain. They will also stay true to their vision "Better Light for a better quality of life".

"This collaboration will enforce our capacity for research projects. Our R&D strength is key in the future strategic development for our clients and partners," said Mag. Wilfried Pohl, R&D Director

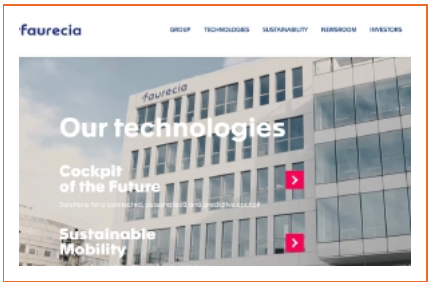
In this way, now more than ever, Bartenbach will provide higher quality light planning, overall lighting solutions, product development in the highest tier and Bartenbach will also research light applications. As an independent and neutral supplier Bartenbach will stay with their approximately 100 employees in Aldrans and will continue being a developing partner of the lighting industry." ■

Faurecia Acquires HELLA for 6.8 Billion Euro

The lighting and electronics specialist HELLA and French automotive supplier Faurecia recently signed an agreement on the combination of the two companies. As part of the transaction, Faurecia will acquire the 60 percent stake held by HELLA pool shareholders.

Faurecia has announced a voluntary public tender offer to acquire the remaining HELLA shares at an offer price of € 60 per share (gross offer price of € 60.96 including the expected dividend of € 0.96 per HELLA share). The closing of the transaction is subject to regulatory approvals and is expected in early 2022. The pool shareholders of HELLA will retain an up to 9% stake in the listed parent company via a reverse shareholding and therefore will continue to closely accompany HELLA in the future. A pool representative is also to join Faurecia's Board of Directors.

By combining their activities, HELLA and Faurecia will become the 7th largest global automotive supplier. This opens up significant potential for further profitable growth. HELLA and Faurecia are already global market leaders in their respective fields. By combining their respective strengths, HELLA and Faurecia aim to further expand their market position, particularly in key growth areas such as Electric Mobility, Automated Driving and Vehicle Interior Design, and to further strengthen their position across customers and regions.



"Faurecia and HELLA are a very good fit. This especially applies to product range and market coverage. In addition, both partners place a high value on consequent customer orientation, operative excellence and technology leadership," said HELLA CEO Dr. Rolf Breidenbach. "Therefore, it is only logical that we join forces to drive the future of mobility together. With Faurecia at our side, we will have even more opportunities to do so than before."

"As family shareholders, we are fulfilling our corporate and entrepreneurial responsibility for Hella by turning the company HELLA over to new owners early on, before our family pool agreement expires. This move will further improve the strategic positioning of the company – for the benefit of HELLA and its 36,000 employees. At the same time, the family will continue to accompany the development of this leading European company as a shareholder in Faurecia," said Dr Jürgen Behrend, Chairman of the family pool. "With Faurecia as the new majority shareholder, HELLA will be able to play to its strengths even more effectively. The competences of both companies complement each other perfectly. We have secured long-term commitments for HELLA's locations and its investments in future business areas. HELLA, thus, has the ideal prerequisites to continue to be successful in the long term."

"This combination is a unique opportunity to create a global leader in automotive technologies. I am convinced that Faurecia and HELLA are an outstanding fit as we share a common vision, values and culture," said Patrick Koller, CEO of Faurecia. "Our two talented teams have been cooperating very efficiently since the end of 2018 and have demonstrated their combined capabilities. Together, we will have the critical edge to benefit from the strategic drivers that are transforming the automotive industry. By combining the product portfolios and market reach, we will accelerate profitable growth, through innovation, with more electronic and software content and enhanced execution quality. Our financial profile will remain solid, with strong attention paid to sustained cash generation and deleveraging the company. I am confident that this acquisition will create sustainable value for Faurecia's and HELLA's customers, employees and shareholders."

Combination creates 7th largest global automotive technology supplier and a global market leader in high-growth technology fields

The combination of HELLA and Faurecia will create a global technology leader covering both a broad customer portfolio and significant future trends in the automotive sector. Faurecia's good access to key Chinese, Japanese and US original equipment manufacturers will create new growth potential for the business areas of HELLA. Further opportunities arise primarily in the areas of Electric Mobility, Automated Driving, Cockpit of the Future, and Lifecycle Value Management (including Aftermarket and Special Applications). Throughout these the two companies have complementary business activities which together offer a high-performance portfolio with broad market access.

The transaction will, for example, create a global supplier for Electric Mobility with a comprehensive range of services. HELLA will contribute its strong portfolio in energy management, sensors and actuators, while Faurecia will provide sophisticated hydrogen storage solutions and stacks systems. In Automated Driving, the combination will also create a global technology leader with a broad range of products and systems. To this end, Faurecia is contributing the expertise of its subsidiary Faurecia Clarion Electronics, among others.

Based on the close development partnership between the two companies regarding innovative lighting solutions for vehicle interiors, which has been in place since 2018, these activities will be further accelerated by incorporating Faurecia's competencies in

Seating and Interiors as well as the HELLA expertise in Interior Lighting, sensors and electronics for vehicle access systems. Further benefits will arise from combining the HELLA aftermarket activities and business with specialty vehicle manufacturers with Faurecia's Lifecycle Value Management activities.

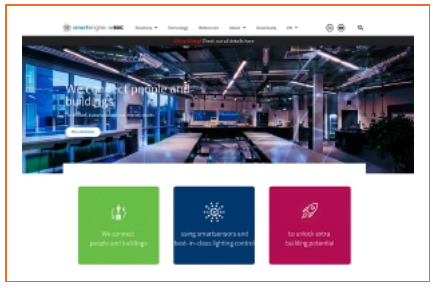
HELLA's focus areas are the continuation of significant investment in R&D and maintaining a high degree of operative responsibility.

To fully leverage the potential of both partners, the HELLA focus areas are to be integrated into the Faurecia Group while retaining a high degree of operative responsibility. At the same time, the business combination agreement between the two companies foresees the continuation of HELLA's multi-pillar business strategy and consistent investments in the development of future automotive technologies in order to secure its position as a technology and market leader. The established cooperation network of HELLA, consisting of numerous joint ventures and strategic partnerships, will also be further strengthened. Committees with equal representation will monitor implementation and ensure compliance with the business combination agreement. The agreement also includes far-reaching commitments to the HELLA employees. All works agreements and collective tariff agreements will be retained. No changes are to be made to the works council structure either. Employee co-determination on the Supervisory Board is also to be retained. According to the agreement between the two companies, the company headquarter in Lippstadt will remain a central location in the joint group.

"The agreements with Faurecia reflect that both partners share a great deal of common ground when it comes to general objectives and fundamental corporate values. In my view, these are important prerequisites for continuing our successful course", said HELLA CEO Dr. Rolf Breidenbach. "I am looking forward to the partnership with Faurecia. Together we will be able to generate even more added value for our stakeholders." ■

TRILUX is Investing 25.1% in the IT Expert wtec

Future-proof properties have a powerful building management system that brings together, monitors and controls all trades. In order to simplify the integration of lighting into the hardware and software infrastructure of digitalised buildings, TRILUX is investing in the IT expert wtec. The company specialises in building automation and IT infrastructure. One innovative solution in the portfolio is smartengine technology, with which the complete lighting network can be implemented via the data cabling and seamlessly integrated into the building management system. This makes complex building infrastructures obsolete and lays the foundation for individual Human Centric Smart Lighting that combines maximum efficiency with user orientation.



The progressive digitalization and networking of all trades in a building offers enormous advantages, especially through precise communication and coordination among each other. The spectrum ranges from the coordination of lighting and sun protection to the automated preparation of a meeting room (light, temperature, media) as soon as it is booked in the IT system. Up to now, however, most of the trades have acted separately from each other and had to be integrated into a higher-level building control system at great expense. With an investment of a total of 25.1 percent in wtec, a subsidiary of the largest German real estate developer Zech, TRILUX is further expanding its competence in the area of IT infrastructure and building automation

and strengthening its position as a provider of holistic room and building solutions.

With smartengine technology, the company offers a solution with which lighting can be implemented completely via data cabling. The classic RJ-45 data cable handles both the power supply to the luminaires via the network and the data communication via IP. Corresponding solutions reduce the hardware-related installation effort enormously and can also be integrated and controlled in the building management system without complex adaptations. In addition, the installation of smartengine technology significantly improves the ecological footprint and the CO_2 balance of a building.

Implementing the lighting via the data cable offers a clever alternative to the classic method, which requires five-core cabling - three phases for power supply, two for DALI control. For example, the luminaires themselves no longer require any ballasts; installation is simply done by latching the RJ-45 cable into the central data cabling. In addition, the luminaires all communicate via the IP protocol and can thus be integrated directly into the building management system without interface adaptations. Particularly in newly planned office buildings, the digitalisation and automation of the trades plays a central role. Through the integration of IoT system modules, lighting will increasingly take on tasks "beyond lighing" in the future, which go beyond the classic lighting tasks. "The lighting network acts as a flexible technology carrier that is responsible for communication and control of the other trades, thus becoming the backbone of digitalisation," explains Joachim Geiger, CSO at TRILUX. "Future-proof lighting provides high-quality and efficient light - and at the same time makes the room and building smart," said Geiger. The TRILUX lighting portfolio is already fit for the digital future thanks to "Smart Lighting Ready" and can also be implemented quickly and easily as an IP- and PoE-based solution. ■

Signify Joins HomeGrid Forum to Transform Wireless Communications Through LiFi

HomeGrid Forum has announced that Signify has joined the organization to expand the innovation and deployment of G.hn technology for Light Fidelity (LiFi) applications.

Trulifi by Signify provides a range of LiFi systems that ensure a fast, secure and reliable wireless connection. LiFi is a wireless communication technology that uses LEDs to transmit data at high speeds over the visible light, ultraviolet and infrared spectrums. LiFi provides network connectivity within the premises like Wi-Fi does, but uses light waves instead of radio signals.

LiFi enables data to be transmitted between multiple connected devices with the light spectrum providing low latency and avoiding the interruption that can often happen with congested radio frequency spectrum. As digital transformation accelerates to meet the growing demand for ultra-fast connectivity, LiFi will play a critical role in complementing Wi-Fi and providing a secure, reliable and spectrum-saving solution. However, for LiFi to reach its full connectivity potential for sensitive sectors such as financial services, healthcare and robotics, it will require a robust, reliable and proven physical layer encoding technology and a strong, solid backbone that connects the LEDs. G.hn technology is the perfect solution for both these needs.

"This is an extremely exciting time for the LiFi community, and we are thrilled to welcome Signify as a Contributor member. Together we will enable innovation and network infrastructure that are fully interoperable with a growing number of devices, at a time when demand for reliable and secure connectivity is increasing," said Livia Rosu, HomeGrid Forum President. "LiFi will build on an open standard to ensure full interoperability and widespread market acceptance. Signify's expertise will be instrumental as the Forum continues to innovate G.hn technology for LiFi use cases in airports, banks, factories, government and defense organizations – all of which require simultaneous high security and low latency connectivity."

With a presence in over 70 countries, Signify is the world leader in LED lighting innovation and is the frontrunner in the industry's expansion of lighting systems in both the professional and consumer markets. The portfolio of Trulifi by Signify systems is enabling the transition to Industry 4.0 by creating safer Internet highways for government and defense, office workspaces, hospitality locations, AR/VR devices and factory machines.

"Standardization is the cornerstone for LiFi interoperability, which is an essential condition for lowering barriers to adoption, encouraging competition and innovation, and building consumer confidence," said Musa Unmehopa, Head of Ecosystems and Strategic Alliances at Signify. "We join HomeGrid Forum to grow the LiFi ecosystem in which we collectively create and build a global market where we can all compete effectively and serve consumers."

Dr. Leonard Dauphinee, Vice President and CTO of Broadband Products at MaxLinear added: "Signify's Trulifi product series is embedding MaxLinear's G.hn chipsets to modulate the light waves to transmit data and to provide backhaul over existing wires, such as powerline. By leveraging their lighting infrastructure, Signify customers get the best of both worlds: a great lighting experience and a high speed wireless G.hn-encoded LiFi connection with a reliable G.hn wired backbone."

Trulifi by Signify can also be retrofitted into existing luminaires to provide the future-proof network infrastructure.

"The capabilities of G.hn are critical success factors for enabling LiFi applications. By working together as an industry, we can ensure the end-to-end coexistence and interoperability that is needed to build the LiFi ecosystem on the solid G.hn foundation," said Rosu. ■

25th Anniversary Of The White LED

Established in 1956 to produce chemicals for the pharmaceutical industry, Nichia quickly evolved to become one of the world's largest phosphor manufacturers, a leadership position Nichia held into the 2000's. After significant investment into a technology believed impossible, in 1993 Nichia commercialized the very first high luminous blue LEDs. With these high luminous blue LEDs and its then 30+ years of phosphor expertise and history, Nichia created a revolutionary technology. In September of 1996, Nichia combined Yttrium Aluminum Garnet (YAG) phosphor with its innovative blue LEDs to officially produce the first ever white LEDs. The world suddenly had a new trajectory for applications utilizing white light, one with many significant benefits.

White LED Adoption

White LEDs present significant benefits vs. traditional technologies. Perhaps, the most important contribution to society is white LED's enablement to achieve a quicker path to carbon neutrality with its reduced energy usage. Several additional benefits have been delivered, including a small form factor which enables devices to utilize light in a manner that never previously existed. Complementing the

energy savings benefit, white LEDs also offer very long lifetime and an environmentally friendly light source without any hazardous materials, such as mercury.

Many applications have benefited from white LEDs and could not have been created without Nichia's invention, including smartphones, tablets, thin LCD TVs and Notebook PCs, slim stylish automotive LED headlights, LED light bulbs, lighting systems with dimming and color tuning, bright and comfortable outdoor lighting on highways, and many more. People could not see and enjoy these products if Nichia had not invented the white LED. A historic invention generated through a miracle marriage of Nichia's competence in blue LEDs and phosphors has truly changed the world. ■

TRILUX: Hubertus VOLMERT Took Over Leadership from Michael HUBER

Left to right: the TRILUX executive board with Mr Huber. Johannes Huxol (CFO), Michael Huber (general representative and Chairman of the Supervisory Board), Hubertus Volmert (COO and Chairman of the Board), Joachim Geiger (CSO & CMO). Photo: TRILUX

Change of leadership at the top of TRILUX: Hubertus Volmert took over as Chairman of the Board of the Arnsberg-based luminaire manufacturer on 1 July 2021, replacing Michael Huber. "It's good to know that the company's fortunes will remain in the capable hands of an experienced company and market expert," stated Michael Huber. The long-standing general representative will also continue to accompany the company in accordance with the shareholders' resolution. From now on, he will focus on the active, strategic orientation and management of TRILUX as Chairman of the Supervisory Board.

"Our market strength means customer orientation, many years of lighting expertise and a strategic culture of innovation – this is what TRILUX stands for with its entrepreneurial management," stated Michael Huber regarding the guideline for the personnel realignment. In his 16 years of management within TRILUX, Michael Huber as general representative of the Arnsberg-based (Germany) company's shareholders has succeeded in realigning the traditional family business and making it fit for the future. "The ever-changing technology pushes have been challenging but have also shown how dynamically a family-owned company can distinguish itself in the high-tech sector," said Huber. Ideally prepared: his successor Hubertus Volmert (48), who has been part of the TRILUX family since 2006 and has actively promoted the technological transfer process in recent years. As Chairman of the Board, he will lead the three-member board in the future. He is joining Johannes Huxol (59) who is also experienced in the company and the market and has been in charge of the commercial division for two decades as Chief Finance Officer (CFO). Joachim Geiger (53) as the third board member will be responsible for the tasks of Chief Sales & Marketing Officer. The TRILUX board is also supported by Michael Blum (52), Managing Director Sales Germany, and Klaus Röwekamp (57), Managing Director Technology. Michael Huber (71) sees the personnel points for the decade that has just begun manned with technology and market expertise: "All our entrepreneurial power is combined in a proven management team – this creates good prospects for the future!" ■

New EnOcean CEO: Raoul Wijgergangs Supersedes Andreas Schneider

Raoul Wijgergangs

Raoul Wijgergangs was appointed EnOcean's new CEO, starting from 1 August 2021, succeeding co-founder Andreas Schneider. In this role, Wijgergangs will further expand EnOcean's position as a market leader in the field of battery-free radio technology and wireless solutions for the Internet of Things (IoT).

After 20 successful years, the last five of them as Managing Director of EnOcean, co-founder Andreas Schneider has left the company at his own request on 31 July 2021 to take on new entrepreneurial challenges. Since 1 August 2021 Raoul Wijgergangs is EnOcean's new CEO. He has over 20 years of experience in the IoT industry and is also a co-founder of the Z-Wave Alliance.

Dr. Peter Klein, CFO, EnOcean: "I would like to personally thank Andreas Schneider

for his constant commitment and tireless dedication to the company and every single employee. Under his leadership EnOcean has been able to expand and consolidate its market position even further. The fact that we as a company have successfully come through the Corona crisis confirms this. The entire EnOcean team and I wish him all the best for the future. At the same time, I am looking forward to the upcoming collaboration with Raoul Wijgergangs as the new CEO and I am sure that together we will build on the outstanding work of Andreas Schneider."

Raoul Wijgergangs, new CEO, EnOcean: "I am honoured that the Management Board puts so much trust in me as the new Managing Director, and I am very much looking forward to this new professional chapter. As the world leader in sustainable IoT, EnOcean will certainly be even more in demand in the coming months and years. With that in mind I see great opportunities not only in the commercial real estate but also in the industrial IoT. What's more, the company's focus on interoperability with products supporting the EnOcean radio standard, Bluetooth Low Energy and Zigbee Green Power makes it a real IoT power house. I thank Andreas Schneider for his successful work over the last years, without him EnOcean would certainly not be where the company is today. And of course I'm very much looking forward to be working with such an innovative team with a strong expertise and great technical know-how."

Before joining EnOcean, Wijgergangs was CEO at Disruptive Technologies in Oslo and worked as Vice President/General Manager at Silicon Labs as well as Vice President/General Manager of the Z-Wave business unit at Sigma Designs in Copenhagen, to name but a few positions.

Raoul Wijgergangs studied Electrical Engineering and Computer Science at H.T.S. 's-Hertogenbosch, Netherlands, and completed his MBA at the Twente School of Management, University of Twente, Netherlands. ■

Bob Bohannon Joins the Lighting Industry Association

Bob Bohannon has joined the management team of the Lighting Industry Association (LIA) in the role of Head of Academy and Policy. This is a key role for the LIA and will provide strategy and leadership in the Academy, as well as enabling a forward-looking handover, of Peter Hunt's excellent work in his role as Chief Policy Officer.

Bob will oversee and coordinate all those supporting policy within the LIA, head up many of the key relationships, create wider and effective cross-industry links and work closely with the newly created Government Affairs committee, chaired by Dave Ribbons.

Bob Bohannon

Passionate about good lighting, sustainability, knowledge sharing and competence, this move brings Bob's career full circle, as his 35 years in the industry started like so many others with a LIA Certificate Course. Bob brings a wealth of experience to the LIA. As the immediate past president of the Society of Light and Lighting, he spent 20 years in manufacturing, working on major projects such as St Pancras Station and Heathrow T5, before returning to lighting design and sustainability and recieved prestigious industry awards for both.

Matt Sturgess (The LIA's CEO) commented "I am excited to have Bob join us, strengthening our management team, spearheading growing the Academy and representing our members in key industry and government forums".

Terry Dean (President of the LIA) added "Having Bob come on board, takes us a big step forward on our journey to develop the LIA and support our member's businesses." ■

New Ecodesign & Labelling Rules Become Applicable

The Ecodesign and Energy Labelling Regulations for light sources adopted in 2019 and revised in February this year become applicable in all EU Member States. Updated LightingEurope Guidelines are available for the market.

The two regulations published in 2019 and revised in February 2021 bring major changes for producers and end-users of lighting products.

New in the Energy Labelling Regulation (ELR) is the enlargement of the scope to cover all light sources placed on the EU market and the rescaling of the energy label for light sources to the new A – G scale. The energy label for luminaires was discontinued already in 2019. The ELR also clarifies the new requirements for registering light sources in the EU EPREL database.

The Ecodesign Regulation for light sources and separate control gear, also known as the Single Lighting Regulation (SLR), introduces energy efficiency requirements that will ban some fluorescent and halogen lamps as of today and T8 linear fluorescent and other halogen lamps in two years' time. It also introduces new functional requirements, such as those to regulate flicker and stroboscopic effects, and new circular economy requirements on the removability and replaceability of light sources and separate control gears and on durability for LED and OLED light sources.

LightingEurope has worked closely with regulators on both laws and their amendment to share our members' technical expertise and market experience.

"The new laws are complex and create new obligations for manufacturers. LightingEurope is now concentrating our efforts on helping companies understand and apply the new requirements to their products and to help authorities enforce the new rules," states Ourania Georgoutsakou, LightingEurope Secretary General. "We've been getting questions every week from companies on how to apply the rules to specific products and applications. That's why we regularly update the LightingEurope Guidelines on the new Ecodesign and Energy Labelling rules and on the EPREL Database, based on our member's latest understanding and on discussions with Member States authorities and the European Commission," Georgoutsakou adds.

The LightingEurope Guidelines on Ecodesign and Energy Labelling are already in their Fourth Edition in less than two years and a Fifth edition is in the pipeline. A second edition of the EPREL Guidelines was published in July 2021. ■

DOE Announces Nearly $83 Million to Increase Building Energy Efficiency and Cut Consumers' Energy Bills

US Secretary of Energy Jennifer M. Granholm

The U.S. Department of Energy (DOE) awarded $82.6 million in funding to 44 projects that will lower Americans' energy bills and help meet President Biden's goal of net-zero carbon emissions by 2050 by investing in new energy efficient building

technologies, construction practices, and the U.S. buildings-sector workforce.

"Americans spend about $100 billion every year on wasted energy from buildings, heating and cooling units, and more – increasing energy bills and needless emissions that dirty our air and worsen the climate crisis," said Secretary of Energy Jennifer M. Granholm. "By pursuing advancements that make both existing and newly constructed buildings more energy efficient, we can save consumers money and reduce the climate impacts of the places we live and work."

Currently, residential and commercial buildings account for more than one-third of the climate-altering carbon pollution America releases each year, and consume 40% of the nation's energy and 75% of its electricity. Pursuing energy efficiency innovations is one of the most cost-effective means to keep the growth of energy consumption from spiraling upwards as society's energy needs grow.

The 44 projects across 20 states will improve building energy efficiency through innovations in thermal energy storage, building envelopes, lighting, heating, ventilation, air conditioning, refrigeration, and water heating – as well as by bolstering America's energy efficiency workforce with trainings, educational programs, and other technical support.

"Technology serves as the third economic wave in our state's economic growth and today's funding to North Dakota State University will be used to advance innovative ways to store energy," said U.S. Senator John Hoeven (ND). "Investments in research to develop cost-effective, more efficient technologies is key to meeting our growing energy needs while leveraging existing resources and with improved environmental stewardship."

"I am grateful for the Energy Department's consistent investment in North Dakota and its energy efforts," said U.S. Senator Kevin Cramer (ND). "Today's award will help NDSU advance its research of efficient energy storage and sustainability."

"As the strain of extreme heat and wildfires continue threatening to overwhelm California's electric grid, the funding and support of these pivotal projects are crucial to improving the efficiency of our energy grid and reduce demand," U.S. Senator Alex Padilla (CA) said. "This is one of the many steps we need to take in order to combat the worsening impacts of climate change. Through these various research projects, we are one step closer to being able to conserve more energy and save billions of dollars in yearly energy costs."

"Just yesterday, I had the opportunity to bring Secretary Granholm to Central Virginia to demonstrate how our region is leading the way in building new clean energy technologies, constructing energy-efficient buildings, and creating good-paying clean energy jobs," said U.S. Representative Abigail Spanberger (VA-07). "Today's announcement is an exciting moment for Project Haystack and the Commonwealth as a whole. I look forward to following this project's progress very closely, and I would like to thank the U.S. Department of Energy for their continued confidence in Virginia's clean energy future."

"If we are going to address the climate crisis we must take steps to reduce emissions in every sector of our economy," said U.S. Representative Teresa Leger Fernández (NM-03). "This investment will help New Mexico deploy energy-efficient building technologies and advance our ever-growing clean energy workforce."

"Georgia's Fifth Congressional District is home to innovators working toward environmental justice for everyone," said U.S. Representative Nikema Williams (GA-05). "The Southeast Energy Efficiency Alliance is one of those innovators and today's award will allow them to help consumers make the informed decisions they need to create a greener planet. I thank Secretary Granholm and the Department of Energy for recognizing this work."

Among the 44 projects are:

- North Dakota State University (Fargo, North Dakota) will develop a novel absorption material that will efficiently store thermal energy.
- Baryon Inc. (Wilmington, Delaware) will develop an innovative air-conditioning system based on a new method of evaporative cooling combined with dehumidification that can consume 50 to 85% less energy than traditional air conditioning systems.
- Emerson Commercial and Residential Solutions (Sidney, Ohio) will design, fabricate, and validate a highly efficient refrigerated display case for use in supermarkets.
- New Jersey Institute of Technology (Newark, New Jersey) will design, prototype, install, test, and evaluate a high-performance residential wall retrofit that can achieve estimated heating and cooling energy savings of 30% or more.
- The Southeast Energy Efficiency Alliance (Atlanta, Georgia) will develop training resources on electrified building systems such as electric heat pumps, heat pump water heaters, electric vehicle charging systems, and battery storage systems. These resources will help members of the workforce learn how to educate consumers on the benefits of these technologies.

The DOE's Building Technologies Office competitively selected from its Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT) funding opportunity announcement. For more information about DOE's work to improve buildings, visit the Building Technologies Office website.

The mission of DOE's Office of Energy Efficiency and Renewable Energy is to accelerate the research, development,

demonstration, and deployment of technologies and solutions to equitably transition America to net-zero greenhouse gas emissions economy-wide by no later than 2050, and ensure the clean energy economy benefits all Americans, creating good paying jobs for the American people—especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. ■

SOLUTIONS

EDEKA Equips Its Latest Store Entirely with Advanced LED Technologies

LED manufacturer NICHIA is a technology leader in highly efficient human centric lighting and the replication of natural light. Its innovative LED technologies are increasingly being used in retail to push the shopping experience to the next level. The most recent project is an EDEKA store in Wiesbaden-Sonnenberg, Germany, which opened its doors in May and is equipped with a lighting solution entirely based on NICHIA technology.

The owners of the store engaged Prof. Dipl.-Phys. Werner Lorke and his interdisciplinary team of experts to plan and implement the project. As part of his consulting work with iO Interdisziplinäre Objekte, the physicist focuses on product and exhibition design and brings together the fields of architecture, technology, and art. He was tasked with developing and employing a lighting concept that presents the store's merchandise in the best possible way and creates a positive shopping experience for the customer. To do this, he selected NICHIA's 'Light so Good' technologies, which significantly enhance the quality of light: 2-in-1 tunable white, Optisolis, and Vitasolis.

For the Wiesbaden-Sonnenberg project, Lorke drew, among other things, on the experience he had already gained over several years with another EDEKA branch in Wiesbaden. Above average sales figures in this store prove that the influence of light on people is enormous. Thus, lighting generally represents a great opportunity for retailers. "We are proud to say that all our activities here, in terms of introducing new illumination, have more than paid for themselves within a few months," he emphasizes. "Based on this experience, our advice to retailers, in general, is to look at lighting as a sales tool rather than as an expense."

In the confectionery department, for example, a solution with adjustable color temperature has proven successful. Thanks to 2-in-1 tunable white LED and COB, it is possible to create good contrast between the merchandise on display and the aisles, as well as to install dynamic lighting in which the color temperature changes throughout the day. Optisolis products are ideal for illuminating goods such as fruit and vegetables. They can be used to produce a light spectrum that comes closest to that of the sun, while at the same time UV emission is essentially non-existent. As a result, it has a positive effect on perishable goods while fruit and vegetables shine in the best possible light. Vitasolis provides brilliant white light and a wide wavelength spectrum for pleasant illumination. A strong cyan component compared to other products has a positive effect on the human circadian rhythm. Aisles illuminated with Vitasolis in combination with Optisolis product provide shoppers with an image that is inspiring and very pleasant – a solution ideally suited, for example, in the dairy section. High CRI Optisolis illuminating the dairy products presents the merchandise more naturally while the natural white light coming from Vitasolis is suitable for illuminating the aisle. Lorke applies Vitasolis for two reasons: one, it allows for a good contrast between space and merchandise thanks to its broad spectrum and low contents of yellow spectrum. Two, its quality of light is extremely easy on the eye. As such, the technology also perfectly meets the needs of any counter areas. Here, the comfortable lighting makes waiting times more pleasant for visitors. A total of around 500 luminaires from all three 'Light so Good' technologies have been installed at EDEKA in Wiesbaden-Sonnenberg. "Ultimately, each product group in the store requires its own lighting concept," states Lorke. "The secret lies in the optimal mix of color temperature, color spectrum, and contrast. At the moment, I don't see any alternative on the market to NICHIA products for achieving such a high quality of light as we have managed to create here." ■

Lufthansa Improves Travel Experience with Innovative Cabin Including HCL

Lufthansa passengers can now enjoy a whole new flying experience on short and medium-haul routes. Thanks to a new innovative cabin, the airline is noticeably improving travel comfort. Recently, the first Airbus 321neo with the modern Airspace Cabin will take off from Frankfurt for Fuerteventura.

In addition to Lufthansa, the new cabin will also be used by Swiss, Brussels Airlines and Eurowings in new aircraft of the Airbus 320 family. And it has a lot to offer: The huge new overhead bins have a forty percent larger volume and can even hold sixty percent more suitcases, as they can be stowed vertically in the bins. The cabin design and the entrance area have been extensively redesigned and now appear brighter and friendlier. So-called Human Centric Lighting, a specially programmed, flexible lighting system, illuminates the cabin in warm red light, graduated intermediate tones to colder blue light. Depending on the time of day or night, the light in the aircraft cabin is thus geared to the passengers' biorhythms. Seating comfort has also been improved: the side walls of the Airspace Cabin will in future offer passengers

more space in the shoulder area. In addition, the modern washrooms are even more usable for people with limited mobility.

"Regardless of the crisis, we continue to focus emphatically on a premium offering for our guests," emphasizes Heike Birlenbach, Head of Customer Experience, Lufthansa Group. "For us, premium means providing high-quality, individualized and relevant offers for all our passengers at all times. With the new Airspace Cabin, we are significantly improving the travel experience on short-haul routes." ■

Signify Introduces Philips LED's First Most Energy-efficient A-class Bulbs

Signify introduces the first Philips LED A-class bulbs that meet the more stringent EU Ecodesign and Energy labeling regulations that came into effect on September 1, 2021. The new Philips LED bulbs with a longer lifespan provide consumers with a smart investment for both the planet as their purse. The more sustainable LED bulbs, available in 40W and 60W equivalents, hit the shelves on September 1, 2021.

For an A-class rating under the new regulations, lighting products have to reach an energy efficiency of 210lm/W. Signify has developed and designed four regular A-shape light bulbs that meet these criteria, meaning they consume 60% less power to achieve the same light output and quality as standard Philips LED bulbs. Thanks to this technological breakthrough, the new products are the first in a range of new Philips LED A-class bulbs meeting the highest level in the new EU energy labeling legislations.

The bulb that can last half a century

The new Philips LED A-class bulbs - which meet the high-quality Philips EyeComfort1 criteria - are the brand's most energy-efficient lamps in this shape yet. Consumers can benefit from a 3.5 times longer life span than Philips LED's regular A-shape equivalents as the new bulbs are able to shine light for approximately 50.000 hours. This translates into an average lifetime of 50 years2 , which provides consumers with a smart investment in the long run, for both the planet as their purse.

"Our passion for a better and more sustainable world pushed us to further innovate and increase the energy efficiency of our LED lighting. With this technological breakthrough, we created our most energy-efficient lamp in this shape yet, while maintaining the same high quality of LED lighting that our customers are used to. This innovation puts us well ahead of new EU regulations and this is just the beginning. We will continue to provide consumers the best quality of LED lighting, while we relentlessly work on further product improvements to contribute to a better world," said Michael Rombouts, Business Unit leader LED Lamps and Luminaires at Signify. ■

LUXEON 7070: For High Light Output & Efficiency Applications

More lumens, higher efficacy, and lower system costs are the driving forces behind new designs for a broad range of indoor and outdoor high light output applications. Lumileds new LUXEON 7070, introduced today, is designed to outperform similar lead-frame and ceramic high-power solutions with leading efficacy and light output in a robust, small surface mount package. For any new or redesigned street light, high/low bay, horticulture, or other application that requires many thousands of lumens, LUXEON 7070 will be the clear choice.

"Across seven critical parameters, lumens per emitter, lumens per Watt, lumens per dollar, system cost, optical compatibility, ruggedness and lumen maintenance, LUXEON 7070 is the clear best overall value for new designs," said Noman Rangwala, Product Line Director at Lumileds. "We've worked in advance with Future Lighting Solutions, LEDiL and Carclo to develop asymmetric and symmetric optical systems available at launch so that manufacturers can immediately take advantage of LUXEON 7070's power and robustness."

Engineers from Lumileds and Future Lighting Solutions have already established a comprehensive ecosystem including drivers, heatsinks, optics, and technical know-how to support LUXEON 7070 solution design and production. Evaluation kits are available with driver and optics for turnkey evaluation.

LUXEON 7070 is a game changer. Compared to a typical 5050 LED, a LUXEON 7070 delivers three times the light output. This allows for lower LED density that can reduce the size and cost of the PCB, optimize the heatsink, and potentially the optical system as well.

LUXEON 7070 utilizes a special treatment designed for superior lumen maintenance and corrosion resistance in punishing conditions like atop a high mast, or in high humidity. It is hot color-targeted (85°C), binned for 3 and 5 step MacAdam ellipse and is immediately available in a full range of CCTs: 2200K to 6500K and 70, 80, or 90CRI.

LUXEON 7070 is immediately available from Future Lighting Solutions and Lumileds distribution network. ■

Lumileds Expands the Color Portfolio and Extends its LED Phosphor Conversion Program

Lumileds announced its latest phosphor converted (PC) LED, a PC Red-Orange LED that is part of the LUXEON 2835 Color Line. Like PC Amber, phosphor conversion of a blue InGaN chip brings many advantages compared to its direct AlInGaP counterpart, most significantly, simpler engineering when mixing colors, equivalent forward voltage to

other InGaN LEDs, stabler, higher output at operating temperatures, and common form, fit and optical height. With the addition of PC-Red Orange, the LUXEON 2835 Color Line now includes 12 color options and 3 different white CCTs.

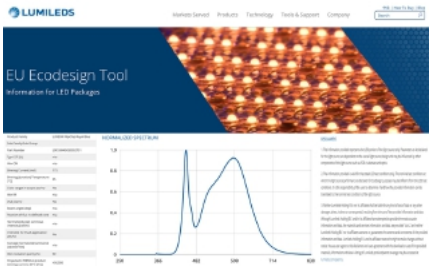
“Illumination possibilities are driven, in part, with color, and the more colors that are available, the more exciting, interesting, engaging or comfortable lighting can be,” said product manager LP Liew. “From architectural lighting to landscape lighting, pool lighting, emergency vehicle lighting and even general illumination, we continue to see increased interest and demand for an expanding palate of color options.”

Side-by-side and in application, the two red-orange LEDs appear virtually identical and have similar saturation. However, light output performance at operating temperatures is significantly higher and with lower variance than is seen with the direct red-orange version. LUXEON 2835 PC-Red-Orange is immediately available from Lumileds distributor network and complete product information can be found on the LUXEON 2835 Color Line web page. ■

Lumileds’ New EU Ecodesign Information Tool Makes it Easier for Light Source Manufacturers to Comply to New Regulations

Lumileds has introduced a first-of-its-kind web-based tool – the EU Ecodesign Tool – that provides detailed LED performance data lighting manufacturers need in order to comply with the European Union’s Ecodesign Directive. LUXEON LED users can view the data and a normalized spectrum on screen or choose to download a .csv file containing the same data seen on-screen.

Lumileds’ new EU Ecodesign Tool supports lighting manufacturers that must comply with two new regulations taking effect September 1, 2021. Regulation 2019/2020 (on Ecodesign) establishes a set of performance requirements for light sources and Regulation 2019/2015 (on Energy Labeling) specifies information that must be provided to consumers. Compliance with both regulations is required as of September 1, 2021.



“Suppliers of light sources for the EU market must comply with Ecodesign and Energy Labeling regulations that include the declaration of various parameters that relate directly to the properties of the LED packages used in the light source,” said Dr. Wouter Soer, Director, Illumination Product Development. “Suppliers need this LED package information in order to determine the declared values for their light source. Though most of the relevant LED package information can be found in the respective product datasheets, Lumileds new Ecodesign tool provides additional information to give a full description of LED package properties relevant to the regulations.”

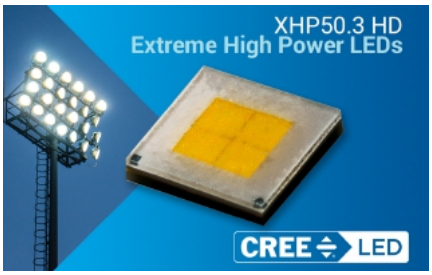
Users can quickly search on a partial or full part number. Each on-screen report details 16 key parameters and presents a graph of the normalized spectrum for the part. The accompanying .csv file contains the same 16 parameters as well as the raw data of the normalized spectrum.

Lumileds new EU Ecodesign Tool is live on the company’s website and can be accessed by anyone at any time. ■

XLamp® XP-G3 S Line LEDs Shine Brighter

XLamp® XP-G3 LEDs are optimized for directional, high-lumen lighting applications where efficacy and optical control are critical, such as roadway, portable and horticulture. The compact and proven 3.45 mm XP platform has an excellent ecosystem of optics and system solutions available, enabling lighting manufacturers to simplify their design process and shorten time to market. XP G3 LEDs are available in Royal Blue and two different White and Photo Red versions: Standard & S Line. The White Standard version delivers best in class TM 21 lifetimes and color stability over time. The S Line versions of White and Photo Red deliver improved efficiency, best in class sulfur resistance and better system level reliability through switching and dimming cycles. With these S Line versions, Cree LED delivers high power LED technology that is optimized for both general and horticulture lighting applications where sensors and switching are becoming common. ■

Extreme High Power LEDs Deliver Best Optical Performance



The XLamp XHP50.3 LEDs are the third generation of Extreme High Power LEDs that deliver the best lumen density, reliability and optical control available in their size. By leveraging the XHP family advantages, lighting manufacturers can significantly reduce their system cost by using fewer optics, PCBs and heat sinks than possible with standard LEDs.

The third generation XHP family LEDs deliver improved optical performance versus the previous generations, along with a new High Intensity version of the XHP50. The XHP50.3 High Intensity provides double the intensity for existing XHP50 designs. XLamp XHP50.3 LEDs are optimized for outdoor and premium indoor lighting applications that require large amounts of light output from small luminaires, such as stadium, outdoor area and architectural spotlight. ■

ams OSRAM Presents New Quantum Dot LED

ams OSRAM presents a new Quantum Dot LED. LED technology has been on the rise for many years and the demand for high-quality and energy-efficient solutions for general lighting is growing. The Osconiq E 2835 CRI90 (QD) pushes efficiency values, even at very high color rendering indices and warm light colors. The special 2835 package offers further system benefits for luminaire manufacturers. Quantum Dots (QDs) are special semiconductor particles that emit light in different wavelengths depending on their

size when blue light hits them. Their unique properties allow very precise adjust- ment of the desired color temperature and outstanding efficiency values in the warm white color spectrum. “With our specially developed Quantum Dot phosphors, we are the only manufacturer in the market that can offer this technology for general lighting applications,” said Peter Naegelein, Di- rector Product Management Illumination at ams OSRAM. “The Osconiq E 2835 is also the only available LED of its kind in the established 2835 package and impresses with extremely homogene- ous illumination.”

The Osconiq E 2835 CRI 90 (QD) is available in a color temperature range of 2200 to 6500 K and achieves outstanding efficiency values of over 200 lm/W. The space-saving dimensions of the 0.5 W component of 2.8 mm x 3.5 mm enable particularly compact and efficient luminaire designs. The good absorption behavior of the Quantum Dots reduces the amount of nanoparticles required. Unlike other phosphors in general lighting, Quantum Dot-based solutions are still in their infancy in terms of development – with a very promising future of what can be achieved in upcoming product generations.

A special feature of Quantum Dots from ams OSRAM is that they are encapsulated in a protective package that makes them more robust, protecting them from moisture and other external influences. This special encapsulation technology makes it possible to use the small particles in demanding “on chip” operation within an LED.

The LED also meets the strict requirements of the Single Lighting Regulation (SLR) regarding the energy efficiency of light sources, which will become mandatory in Europe in September 2021. Part of the new guidelines is, among other things, a value >50 for saturated red, the so-called R9 value. R1 to R8 is used to determine the CRI. Each R-value stands for a specific color. The Osconiq E2835 is also available in two other versions: a CRI 80 component for office and retail lighting solutions and the Osconiq E2835 Cyan, which produces a spectral peak in the blue wave- length range that surpresses melantonin production in the human body, making it ideal for Human Centric Lighting solutions. ■

LUXTECH Launches Fingerboards: 4 Versatile Area LED Modules

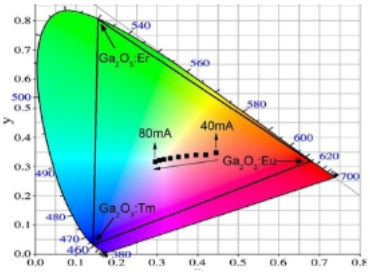
Fingerboards are designed to make it easier than ever to fill area fixtures with architectural-grade light; available in White, Tunable White, RGB, and RGBW to suit the demands of any lighting application. Filling large areas of light specifying custom edge lit assemblies or wiring together dozens of rigid boards for back lighting is a pain; Fingerboards combination of poke-in connectors with cuttability between every LED make it a breeze to trim and connect boards to fill any shape fixture. The constant current static white (CC Batwing) module is even integrated with wide angle batwing optics to minimize the required diffuser depth.

“We are a collection of engineers, designers and researchers based out of Philadelphia, PA and proudly work with architectural fixture manufacturers and teams around the world. Besides being inquisitive and inventive thinkers, we are also personable – we make sure our customers’ needs are heard and their expectations exceeded.

We believe lighting has the power to define our world: it can elicit a mood, improve appearances, enhance performance, and influence our behavior. By pushing the latest lighting technology and manufacturing exceptionally built modules with the utmost customer care, we believe we can elevate illumination to foster a better world,” said Graham Merrifield, LUXTECH Senior Applications Engineer. ■

RESEARCH

Phosphor-free White LEDs – Saga University, Japan



Saga University in Japan has reported work towards white light-emitting diodes (WLEDs) based on rare-earth (RE)-doped gallium oxide (Ga_2O_3) [Yafei Huang et al, Appl. Phys. Lett., v119, p062107, 2021].

Artificial lighting technology is of vital importance because it has involved in almost every aspect of modern society. As the next-generation light source to replace traditional incandescent and fluorescent lamps, white light-emitting diodes (WLEDs) are of crucial significance for illumination and displays owing to their excellent merits, including small size, environmental friendliness, high reliability, low power consumption, longevity, and high luminous efficiency. So far, the commercially available strategy for WLEDs is to utilize blue-emitting InGaN LED chip with yellow-emitting phosphors coating. However, WLEDs produced in this strategy remain controversial owing to the innate deficiency of red and green components in the spectral region.

Furthermore, the usage of phosphors compromises the device reliability due to unavoidable shortcomings, including Stokes energy converting loss and decreased thermal stability. In order to achieve the ultimate potential of solid-state lighting (SST) to be smart and ultra-efficient, it has been pointed out that the phosphors must be ultimately replaced by multi-color semiconductor electroluminescence in the blue, green, and red. ■

LpS Digital: Lighting Conference & Exhibition 2021

LpS Digital is the unique and first digital lighting conference and exhibition available to viewers 24 hours a day, 7 days a week. LpS Digital presents current, high-quality content about lighting technologies, design and applications, and acquaints the viewers with the latest trends in product developments and applications.

Experience the Future of Light

Like the LED professional Symposium +Expo and Trends in Lighting Forum &Show that took place at the Festspielhaus in Bregenz/Austria every year since September, 2011, LpS Digital is meant to approach and support the complete value chain in the global lighting industry. When it comes to Technological Design, LpS Digital's goal is to provide Corporate Managment, Technical Management, R&D and Production/QM within the global lighting manufacturing industry with top notch technical knowhow, primarily on a component level. In terms of Lighting Design, LpS Digital will show best practice for Architects, Lighting Consultants, Electrical Consultants, Lighting Designers, Lighting OEMs, IT/IoT System Integrators and students. The editors focus on Human Centric Lighting, Connected Lighting, Smart Controls, Internet of Things, Light as a Service and much more.

Unique Global Reach in the Lighting Sector

VIRTUAL CONFERENCE
The authors of contributions accepted by the program management will be invited to give a presentation and, if appropriate, to write a qualified article. Each presentation will be announced to the industry and/or design channel contacts and followers immediately after publication.

VIRTUAL EXHIBITION
Virtual exhibitors have the possibility to present their products and/or services. The maximum length of the presentation is 20 minutes. Each product/service video is announced to the industry and/or design channel contacts and followers immediately after publication.

Lighting Industry & Technology Channel

With the Industry/Technology channel, over 30,000 contacts in the lighting sector are targeted and addressed. The opt-in databases are highly selective, highly qualified and address key persons in the respective channel.

- Magazine: 30,000
- Newsletter: 27,000
- Online: 30,000/month
- Twitter: 22,000
- LinkedIn: 11,700

Lighting Design Channel

With the Design channel, over 30,000 contacts in the lighting sector are targeted and addressed.

- Magazine: 30,000
- Newsletter: 15,000
- Online: 5,000/month
- LinkedIn: 4,600

Benefits for Conference Authors

- Global, highly-qualified target group
- Knowledge transfer at a high level
- Ideal platform for expanding the network

Benefits for Virtual Exhibitors

- Global, highly-qualified target group
- Immediate promotion of innovations and novelties
- Participation in the LpS/TiL Awards
- Highly efficient promotion at no risks

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“Powering Customer Growth Through LED Innovation”

Claude DEMBY, President of Cree LED

Claude DEMBY
Claude Demby, president of Cree LED, joined Cree in 2014 where he was responsible for the materials, semiconductor, and LED chips businesses followed by moving into mergers and acquisitions and corporate development. His time as the CEO of a global holding company, and, before that, working for GE and Proctor & Gamble, were ideal for learning the unique skills he needs to take businesses through transformational processes. Today he is responsible for the Cree LED business, a position he finds particularly exciting.

LED professional had the opportunity to interview Claude Demby, president of Cree LED. We asked him about himself and, of course, the newly formed Cree LED. We found his strong focus on his customers and solutions as well as the simultaneous concentration on the strengths of the company very interesting. Claude also shared his views on the industry challenges with us as well as the Cree LED roadmap, going forward. After the challenges of the past two years, there is a focus on innovative application-specific lighting solutions. We were happy to recognize a positive trend for the lighting sector again.

LED professional: **Hello Claude, thanks for agreeing to give this interview.**

Claude DEMBY: My pleasure!

LED professional: **If you don't mind, I'd like to start by asking you a little about yourself. Could you tell us about your career, background, and how you got into the LED business?**

Claude DEMBY: I have worked at Cree since 2014. When I started, I was responsible for the LED Chips and Semiconductor Materials Business. In 2014, that market was going through a down cycle, so we developed a strategy to reinvigorate growth. That was an exciting time that lasted for several years. After that, I moved into mergers and acquisitions and corporate development at Cree and worked on the divestiture of Cree Lighting to Ideal Industries. That situated me very well for my current role leading the Cree LED business during this exciting and challenging time.

Before my time at Cree, I was CEO of a global holding company that manufactured synthetic materials for many industries. And before that, I was President and COO at a global automotive supplier. I started out with both Proctor & Gamble and GE, where I learned many other skills associated with business transformation. I enjoy taking businesses through transformational processes, either turnaround or through fast growth periods. Given all the challenges we see globally, especially in the LED industry, it is an exciting and challenging time with the global pandemic and the geopolitical issues surrounding international trade.

LED professional: **I see how your background makes you uniquely qualified for today's global situation. If we move on to Cree LED that was established recently, could you explain the structure behind it to our readers? There is Cree itself, Cree Lighting, and now Cree LED as well as Smart Global Holdings. How do all of these Cree enterprises come together?**

Claude DEMBY: Yes, that's interesting. Of course, the Cree brand is renowned around the world for everything related to LED lighting. Cree started the LED lighting revolution, primarily focused on chips and then expanding into components. Cree extended into the lighting area to drive further adoption in the lamp and fixtures business. Cree's LED business was unique because it was based on the silicon carbide substrate, which is also advantaged in power, electric vehicle, communication, and infrastructure applications. Cree in the 2010's contained three distinct technology divisions: LED Components, LED Lighting and Wolfspeed, which was focused on these non-LED applications. In 2019, the LED Lighting division was sold to Ideal Industries. Under new leadership, the Cree board decided to focus on the non-LED applications. So, while the LED division is a solid foundational technology company in the industry and leader in LED, it was no longer a part of their growth strategy. In the LED division, we looked at several players who wanted to develop the LED business as a core piece of their strategy. The sale of Cree's LED division was completed in March of this year. Our new name is Cree LED and we are now a part of SMART Global Holdings, a holdings company headquartered out of California. SMART has several businesses: a Memory Solutions business, an Intelligent Platform Solutions business focusing on high power computing, and now the LED business. We're excited about being a key part of SGH's growth and diversification strategy.

LED professional: **What are the focal points for Cree LED?**

Claude DEMBY: First of all, it's not just about components. We're focused on delivering application-optimized solutions to enable our customers to have a differentiated value proposition in the market. We fundamentally believe that if we deliver the right kinds of solutions to them, they'll be able to add value. The by-product is that all stakeholders will do well. We're focused specifically on high power in general lighting – our fundamental strength. Our very foundation, our technological innovation, stems from that platform. We believe we can then extend this platform into the mid-power space. Especially as performance in mid-power is becoming more demanding, this also creates a robust platform and a solid base allowing us to lean into and to invest in other fast-growing areas.

One of the vital fast-growing areas that we're very interested in is the video space, especially the ultra-fine pitch video space. The reality is, "The world

is a stage," and everything is playing out through video. Whether you're at Piccadilly Circus or Times Square or at a large football stadium, the visual effects of these video screens add to the excitement for the audience. We believe we can make a difference in this space. Transformations that impact how you put component technology together in a modular fashion will simplify how those screens are put together. Additionally, there are other specialties where we think we can excel. Firstly, the horticulture area and secondly, the architectural area where not only colors, but also lumen density and intensity per given square area are going to be important. So, our focus is on how our customers are working to add value to their customers and how we establish application-optimized solutions to help them make a difference in the marketplace.

LED professional: What is the critical technology that makes Cree LED unique in the high-power range?

Claude DEMBY: It's a combination of things. The first thing that made us unique before I came was our substrate and what we could deliver off the substrate in terms of our brightness. But it wasn't and isn't about the substrate technology – it's about scientists working with that technology and getting every bit of light out of the silicon carbide. You could argue that getting light out of a silicon carbide substrate is more challenging than sapphire. I would say it's probably the case, and at the same time it sharpened the capabilities of our scientists to understand the technology deeply. So, it's not about the substrate, but all the technology that our people put into place. And then, back in 2014 or even before that, we started looking at how to more effectively bring the best products to market on an alternative platform that delivers more value to our customers. We started looking at how sapphire would enable us to further differentiate our technology from our competitors.

"One of the vital fast-growing areas that we are very interested in is video space. Especially the ultra-fine pitch video space."

CLAUDE DEMBY

We were able to overlay all the things we learned foundationally from a technology standpoint onto that platform that I think will provide game-changing and market-leading performance in our products. If you look at the continuum of components in general lighting, you have $1-2 billion of that in high power and $4-5 billion of that in mid-power. The definition of what mid-power and high-power are is changing. But why is it changing? It's not because people want less light or more light. It's because we're shifting from just trying to get light out of a box to developing the light for specific applications. We found that we needed to look at our product portfolio – we needed to create a technical foundation that enabled us to play throughout the space. I think we've gone out and done that.

Figure 1: Cree LED Headquarter in Durham, North Carolina, USA.

LED professional: You recently announced a high-power product for stadiums and high-power applications, and it seems to fit perfectly into the strategy you just described. You mentioned horticultural and general lighting as two critical applications you're looking at. Are there others?

Claude DEMBY: There are several different applications. In high-power general lighting we're looking at stadium, outdoor, and industrial applications - you'll see that in some of the new products we've introduced. Our flagship XLamp XP-G3 S Line LED has increased sulfur resistance, intensity, and light output. Or, if you look at our XLamp XP-P LED **[3]** with higher intensity, greater lumen density coming out of a smaller area for very specialized applications. So, we look at horticulture, outdoor, stadium, and video lighting. We're interested in the invisible spectrum as well. If you look at the market today where the invisible spectrum is, between now and 2024, we expect UVC to grow to about $1 billion. We ought to play in that market. I want us to play in that market, not just because it's growing, but I think it's essential in the context of the world that we live in today and some extreme applications in terms of helping our customers and helping communities. So those are the areas that I think we'll focus on.

LED professional: What do you think are the key challenges and opportunities facing the lighting business today? You mentioned the pandemic before, but isn't it more than that?

Claude DEMBY: Yes. Several challenges are facing the industry. Going back to 2018/2019, there have been significant disruptions in the marketplace. In phase one and phase two of the United States Section 301 tariffs against China, companies in the industry were driven to reconfigure business systems and infrastructure to continue to deliver value throughout the world. Add to that situation the pandemic and supply chain constraints that further constricted the market. If you look at the total market for general lighting and our component business, in 2018/2019, it was approximately $16 billion. Without any fundamental changes in how we're delivering technology today, the market probably sits at $13 billion. That's a three billion dollar market erosion just from structural and geopolitical/trade issues outside of the

Figure 2: A 3-meter integrating sphere for fixture analysis in Cree LED labs.

Figure 3: Die bonder in a Cree LED Pilot Production Facility.

market's control. Now we have a smaller market for a ton of players in the marketplace. You have ten huge players, and hundreds of small players trying to determine how to deliver application-optimized solutions to the market. I distinguish that because the LED industry, except for maybe the automotive sector, has gone a long way down the adoption curve so it is no longer about replacing sockets. The key challenge – and opportunity – is working with downstream players to produce the kinds of products that will help them solve critical problems. And so, there's a host of things that we have to focus on ahead. One is lumen intensity and lumen density. How do you get more light out of a smaller surface so that you can use it? Whether it's in automobiles, or architectural applications or high-end retail, that's always going to be the case, so we have to continue to push the envelope on technical product performance.

"There's a host of things that we have to focus on ahead. One is lumen intensity and lumen density."

CLAUDE DEMBY

Second is Human Centric Lighting. How do we match the natural light that comes through our windows?
Third is UV - the full potential around disinfection is essential.
Last is micro LEDs, video screens, and the whole mass transfer challenge it presents. When you think about the industry grappling with all those ideas, there must be the right strategic relationship across this industry if we genuinely want to deliver robust solutions to our customers.

LED professional: What do you think about all the interference with the digital systems? Does this affect the components in any way?

Claude DEMBY: I sure hope it does! Our components need to interact with this digital space that will ultimately drive the benefit to the customer. We think that every component we make ends up in some form or fashion on a level 2 board or a module. Those modules, whether they have ASICs or other controllers, interact with the environment

Figure 4: CV94D – a unique RGB LED created for the next generation of variable message signage. Size: 9 mm x 4 mm. [C2]

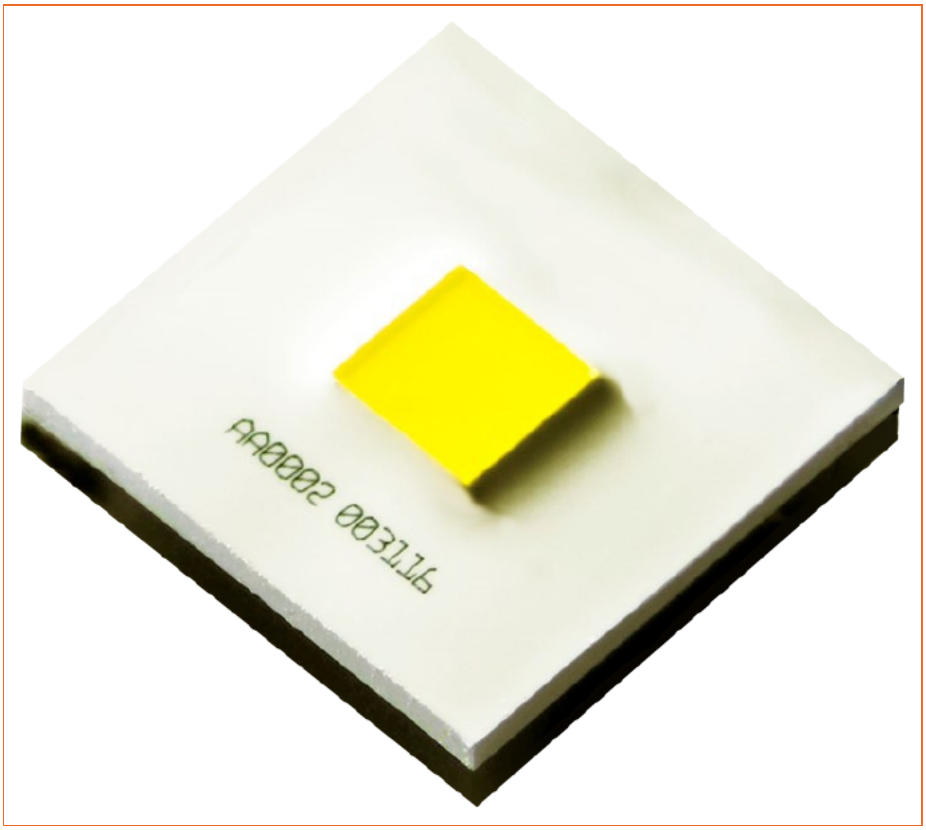

Figure 5: XLamp XP-P extreme high intensity LED for torch and narrow-beam spotlighting applications in the industry standard 3.45 mm XP footprint. [C3]

around them. We desire to work with the right partners or invent the technology inside that enables the digital world. The big challenge with the digital world is that nobody knows what standard is going to play out. The lighting people thought that because lighting is ubiquitous, it would come out of that world. Well, that hasn't fully evolved. The building control folks said it would come out of that world, which hasn't fully evolved, either. Where is that marriage going to come together where we can develop the proper standard to create breakthroughs in this digital space? There's more to come on that. We're certainly not driving that, but we're looking for the right partners where our componentry can plug into their level 2 or their modules that will drive the digital transformation.

LED professional: And what do you think about laser technology in lighting?

Claude DEMBY: We looked at laser technology, but we are focused on improving our LED products. We can leverage LEDs to get similar output from a highly pixelated light source, whether it's in automotive or not. We decided that we don't see a lot of potential in laser lighting for us at the moment.

LED professional: We see a dramatic situation in terms of climate change worldwide, especially over the last few months. So it's still vital to reduce power consumption, especially when it comes to high-power systems. You mentioned before that that is still something you're going forward with – but many of these systems are already mature. Is there still a significant potential there, or how do you see that?

Claude DEMBY: We are doubling down on high-power and mid-power LEDs for lighting applications because we believe that we can maintain a technology advantage in that space. It's not one piece of the environmental chain that will impact the overall direction of climate change. It's going to be across the entire application chain that we will see the technology leaps. So that's why we discuss application-optimized solutions and the right strategic partnerships with our customers to drive greater efficiency. And that's parallel to the challenges that we're having in the world. Until we all figure out how to collaborate on it, we're

just not going to make any in-roads. We're thinking about how to do that, and that's what we're focused on.

LED professional: I read that, e.g., 70% of European street lighting is ancient and inefficient. And that means that there is room for specific applications to improve the systems, as you already mentioned, and I feel that that is a perfect approach. So if we look at the Cree roadmap, what can our readers expect soon in the area of innovations from Cree LED?

Claude DEMBY: I'm not going to give away all of our secrets, of course! First, one of the key items that we continue working on is our manufacturing transformation. We're driving our business to produce brighter, more intense components specific to applications, moving from our silicon carbide legacy to a sapphire future. Changing the component substrate enables us to create greater intensity, higher lumen density products. On top of that, you're going to see a series of significant performance improvements to existing products as we go through the manufacturing transformation.

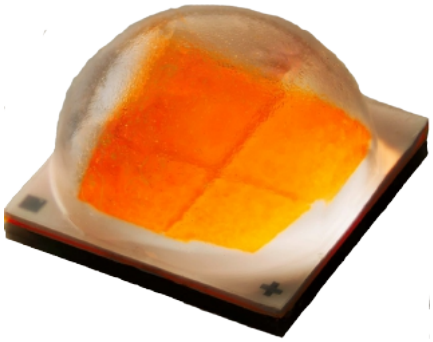

Figure 6: XLamp XHP-70.3 – improved color over angle and leading efficacy in the newest generation of high power LEDs. [C4]

Second is the extension of our mid-power product line to solve several problems we see out there in the world. Third, we continue to push the envelope on how we present 3-in-1 and 4-in-1 solutions in the video space and in a modular way to simplify that. Lastly, you're also going to see us continue to develop our technology for specialty lighting applications, including horticulture and architectural. The key to all of it is how focused we are on these markets – not being distracted by anything else. We understand that when we're focused on those markets, we help our customers solve their problems and better meet their application needs in the field.

LED professional: When will the 3-in-1 and 4-in-1 products be on the market?

Claude DEMBY: It will be a continuous rollout between now and the end of 2022.

LED professional: How do you organize all of that? How do you find out about all of the requirements? Do you talk to or collaborate with designers or architects, or people in the field? And, on the other hand, you need to have a profound knowledge of specific applications, so how do you help design-in for the engineers?

Claude DEMBY: It comes down to our employees and our customers. Cree LED has a global presence with 2000 employees across 13 locations on three continents. A significant number of those people are scientists and engineers who wake up every day and go to bed every night thinking about LEDs! If you had told me ten years ago, I wouldn't have believed you. But when you come into our environment, you see how passionate our people are about the LED market and how they want Cree LED to lead in the market.

We have over 24,000 customers that are dispersed in 101 countries. To service those customers, we have strong marketing, sales, distribution, and application engineering networks. We have distributor partners worldwide connected to the right markets; we educate our distribution partners on the new technology and developments that we have today. But more importantly, or equally importantly, they educate us on the applications, trends and opportunities in the market. And that's rich ground for us to not only solve problems but to share information with our technologists and work on the fundamental and foundational technologies that help us address existing and future opportunities.

We work with the influential and innovative leaders in the marketplace to understand their challenges, using our direct salesforce and marketing team to link them to our engineers, enabling us to design leading products. We also stay connected by doing what we are doing right now in this interview. Participating in and networking at industry events is a key component for us to understand the pulse of what is going on in the industry and how we integrate into it.

"We want to make sure that we can help our customers have a differentiated value proposition for their customers."

CLAUDE DEMBY

LED professional: Is there a key message you like to share with our readers in terms of Cree LED?

Claude DEMBY: We want to help our customers power their growth through our LED innovations enabling them to deliver a differentiated value proposition to their customers. We're fully invested in LED technology, we're invested in our people, we're focused on delivering application-optimized solutions to the market, and we continue to believe that there are still LED innovations that we will drive in this marketplace together to make an overall difference.

LED professional: Thank you very much for taking the time for this interview.

Claude DEMBY: Thank you for giving me the opportunity! ■

About Cree LED:
Over the past two decades, Cree's LED division crushed all arguments against LEDs as the best light source available. Now part of SMART Global Holdings, Inc., the new Cree LED offers the industry's broadest portfolio of application-optimized LEDs that lead the industry in lumen density, intensity, efficacy, optical control and reliability, backed by expert design assistance and superior sales support.

References

[1] Cree LED – https://cree-led.com
[2] CV94D Series RGB – https://cree-led.com/products/smd-s/cv94d-series-rgb
[3] XLamp XP-P – https://cree-led.com/products/xlamp-leds-discrete/xlamp-xp-p
[4] XLamp XHP – https://cree-led.com/products/xhp-family-leds/xhp-leds

Faster Automotive Lamps Approval

Advertorial by GL Optic, www.gloptic.com

New Player in the Market

GL Optic, a light quality control company, is entering the automotive lighting quality control market with its new photometric systems. Now, the new car revolution, forced by electro mobility and autonomous systems, changes the design styles of vehicles. Engineering teams are in need for speedier photometric systems in order to improve the approval process. For this purpose, new photometric instruments are being introduced to the market.

Lamp Design is Getting More Complicated

Multiple functions of modern vehicle headlights make the testing process more sophisticated. Repositioning of the lamp under test to measure low beam, high beam, position light, daylight running light and direction indicator is time consuming. Adaptive headlights with more functions being defined are the latest trend. Also the tail lights are composed in a similar manner in order to integrate various functions. Additionally, new lamps are getting longer and more complicated. Their elegant form puts specific requirements on the testing equipment. As a part of this process, vehicle manufacturers require the right tools for testing during the R&D phase and approval while manufacturing. Everyone wishes to do it precisely and quickly with respect to the existing standards. Due to both the new shapes and sizes of car lamps and in-vehicle lighting there is a growing need for more sophisticated and larger measuring systems.

Meet the Game Changer for Vehicle Lights Approval

For fast and reliable vehicle lamps approval, GL Optic presented a preconfigured, turn-key photometric system – GLG A 50-1800 (**Figure 2**). It is built to help solve testing challenges on a daily basis and get prepared for future developments as well. The main features of the type A goniophotometer are 3 mechanized H,V and Z axes and a DUT moving x,y mechanical mounting table (**Figure 1**). The Goniophotometer GLG A 50 -1800, with increased load capacity, allows the measurement of lamps weighing up to 50 kg, with a width up to a 1.8 m and extended angular positioning. The large 50 cm×50 cm mounting table is adjustable and has 80 cm adjustment in the vertical plane.

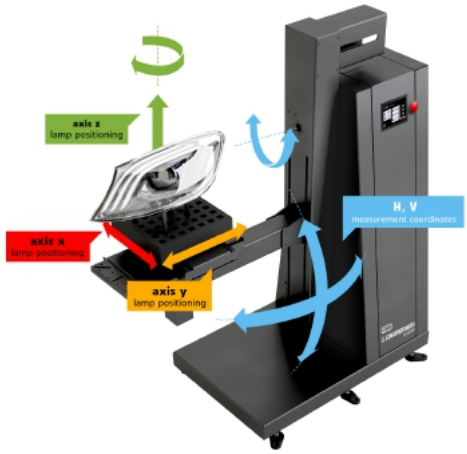

Figure 1: GLG A 50-1800 with precise alignment protocols and extensive automation capabilities.

The measurement of the light signal is provided by GL Photometer 3.0 LS. Its high sensitivity and dynamic range allows the measurement of illuminance from 1/10th of millilux up to 1000 kilolux. Sampling rate of 125 kHz allows quicker measurements of illuminance and light modulation (flicker). It has been developed in cooperation with the industry leading suppliers such as Panasonic and Hamamatsu Photonics to ensure the highest accuracy and reliability. A new level of performance and usability is supported by completely new and easy to use software including precise alignment protocols and extensive automation capabilities for the entire system.

The GLG A 50-1800 goniophotometer systems are compliant with the conformance testing of lamps and signals to UN/ECE and SAE /FMVSS Regulations and the CIE 121-1996 and IESNA LM-75-01 standards regulating far-field photometric and colorimetric measurement systems.

What About In-vehicle Lighting?

Touch screen displays indicating LEDs and LED line illumination must be verified in order to fulfil the quality standards while maintaining consistent. The optical performance of displays and backlit elements requires a dependable luminance testing solution. The GL OPTICAM 2.0 4K TEC is a new high resolution Imaging Luminance Measuring Device (**Figure 3**). This is a laboratory performance optical camera system featuring a high resolution 9M pixel CMOS image sensor with a dedicated V-Lambda correction filter. Selection of high class lenses is available for the system depending on specific luminance measurement requirements. The system features a unique RFID lens recognition system and a thermal stabilization of the image sensor, which compensates measurement errors resulting from changing temperature conditions.

With this new optical instrument all the touch screen control panels, backlit buttons, displays, keyboards and indicating lights can be easily and precisely verified during the R&D and production stage.

One Provider – Many Different Solutions

Fast changing design and increasing number of new technical solutions for in-vehicle and exterior lighting creates a challenge in quality verification for system engineers, development teams and QA/QC staff. Starting from single LED emitter or OLEDs, through modules and component testing up to the final lighting assemblies, GL Optic offers comprehensive optical instrument systems for tests and measurements of any kind of lighting in the transportation industry. ■

Contact GL Optic

- https://gloptic.com
- mailto:office@gloptic.com
- +48 61 102 47 21

Figure 2: GLG A 50-1800 a preconfigured, turnkey photometric system.

Figure 3: The GL OPTICAM 2.0 4K TEC a new high resolution Imaging Luminance Measuring Device.

Projected Safety with High-resolution LED Headlamp Concept

by Dipl.Ing. Stefan GROETSCH and Dipl.Ing. Joachim REILL, ams OSRAM

When it comes to automotive lighting, there are several attributes which immediately come to mind: brightness, safety, reliability, quality. During the evolution of solutions for automotive exterior lighting, manufacturers needed to clear a lot of different technological hurdles. Therefore, it was quite a long way from the first headlamp to matrix headlights. But evolution never stops. Besides the classic task to light up the road, the latest technological developments enable way more than this to further increase safety on the streets. Think about projected warnings with symbols like a snow flake to show you that the road ahead is icy, or a visual, light-based assistance that guides you through a tight construction site. Thanks to the latest developments, scenes and use cases like these will soon become reality.

The main goals regarding the development of automotive lighting solutions are more safety, visibility and comfort for the driver and other road users. When you have a look at the latest car generations it is more than to see and been seen on the road. Suppliers need to address the trend towards new slim headlamp designs, higher brightness values and very precise and at the same time highly energy efficient lighting solutions. High-resolution headlamps will now be the next milestone, combining illuminating the road and communication with the environment via light at the same time. ams OSRAM's Eviyos 2.0 LED **[1,2]** with 25,600 individually controllable pixels is capable of realizing Advanced Driving Beam (ADB), Advanced Front Lighting System (AFS) functionality as well as road projections in High Definition with the same LED component. Thanks to two different aspect ratios of $3:1$ and $4:1$ the LED offers flexibility for various lamp architectures generating HD-quality projections.

The realization of high-resolution headlamps with different challenging functionalities leads to different demands regarding the optical and thermal system setup – which will be investigated in the following article.

Pixelated LED Array Concept

Multifunctional, intelligent headlamps enhance the drivers' visibility while simultaneously reducing glare for other road users. As soon as oncoming traffic is detected the appropriate pixels – which would light into the windshield of the other car – are automatically switched off. In addition, it is also possible to dim the pixels that would dazzle the driver himself when a traffic sign is illuminated.

Thanks to the special LED design a certain number of pixels within the component can be run at a higher brightness level than others – enabling, for example, an overlap of the usual glare free high-beam combined with the projection of certain symbols into the defined FoV as shown in **Figure 1**. Besides this, it is also possible to mark special objects with a marker light – for example a crossing cyclist – to further increase the drivers' perception and safety of all road users.

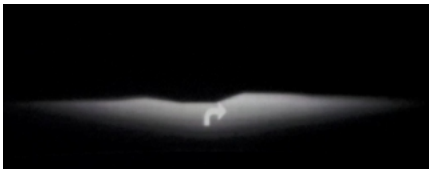

Figure 1: The screenshot from the setup in the ams OSRAM laboratory shows the combination of the classic glare free high-beam function with the projection of certain symbols.

The Pixelated LED Array of 41 mm^2 is soldered onto the top of an LED pixel driver IC. The gallium-nitride on silicon stack is directly bonded to the thermal conductive base of the package substrate. The phosphor layer on top of the 320×80 LED pixels converts a part of the emitted blue radiation into yellow emission to generate white light. The fundamental concept of the new lighting technology is shown in **Figure 2**.

Architecture

To fill a defined field of view e.g. 40° horizontally and 10° vertically it is proposed to use two Pixelated LED Arrays and lenses with different magnifications addressing the base FoV of 40°x10° and a center FoV with

20°x5° to 24°x6° (**Figure 3**). This results in high angular resolutions of less than 0.075° and moderate efforts for the active LED area. The Pixelated LED Array is the core of the light engine in **Figure 3**. The system in **Figure 4** includes the interfaces from the ECU: RGB8, UART and SPI which are used to deliver video data. UART over CAN, I^2C or SPI interfaces are used for diagnosis and control access. With a highly parameterizable diagnosis scheduler the Pixelated LED Array system relieves the ECU and minimizes diagnosis access.

Thermomechanical Setup

Figure 5 is a cross section of a headlamp mockup showing one of the two optical units. The aluminum heatsink also acts as the fixing unit for optics and the LED printed circuit board (PCB). In addition to their primary function as mechanical substrate and electrical contacting element, circuit boards also have the task to efficiently dissipate the heat which is generated. A fan forces air through the heatsink fins which form an enclosed channel since they are also covered from the backside to enhance heat transfer. And especially in highly complex system designs, like the Pixelated LED Array, the thermal management is essential to increase the LED's light output. To achieve this, the p-n junction temperature of the LED (T_J) should be as low as possible to achieve a high optical output, high efficacy and also high LED lifetime and reliability. Therefore, the selection of appropriate materials and designs for circuit boards is essential. Additionally, junction temperature is the determining factor for the suitability of the whole thermal management system. For the Pixelated LED Array the maximum LED junction temperature (T_Jmax) can be even up to 150 °C.

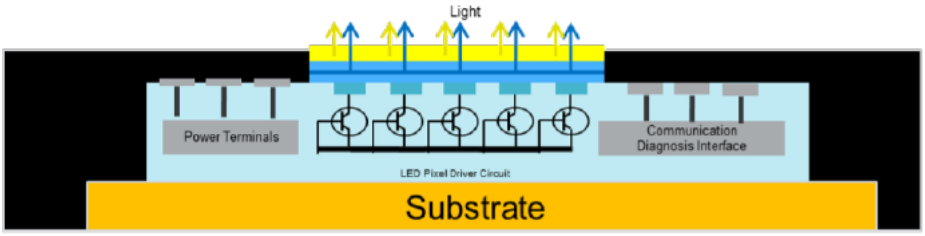

Figure 2: Concept of the light source device. The GaN-LED array is placed on top of the pixel driver IC in the package.

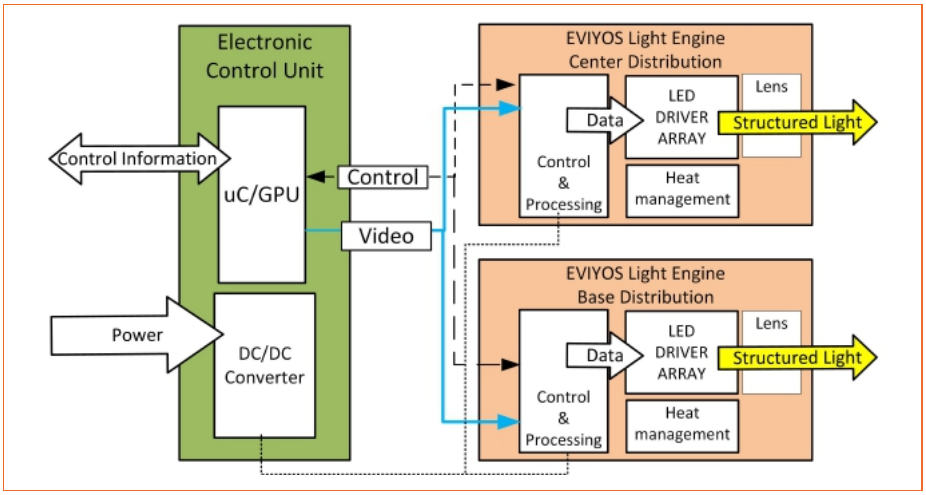

Figure 3: Architecture for one headlamp consisting of two Eviyos light engines and one ECU.

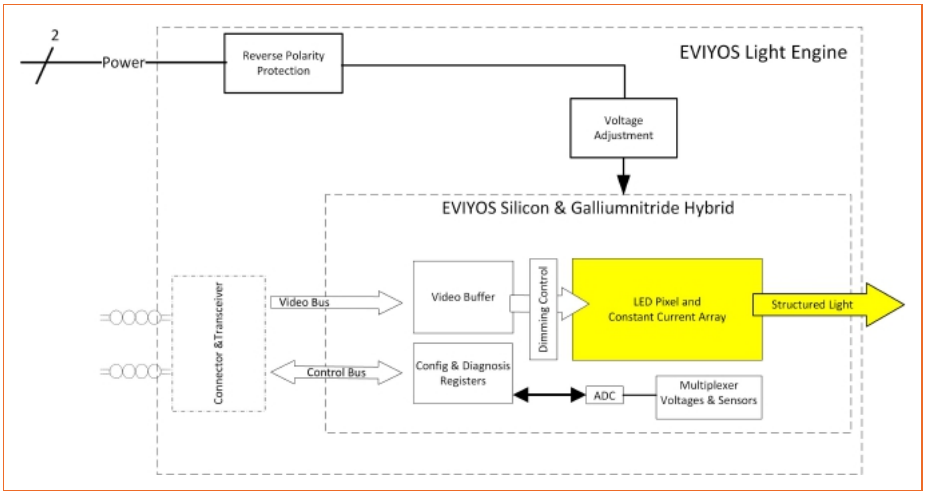

Figure 4: Eviyos LED pixel array light engine.

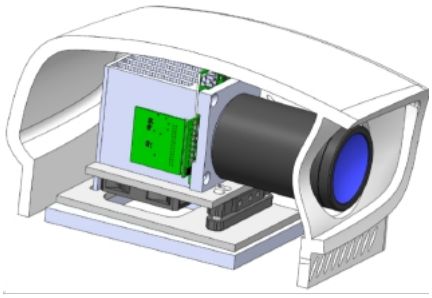

Figure 5: Cross section of a Dual System with one Unit.

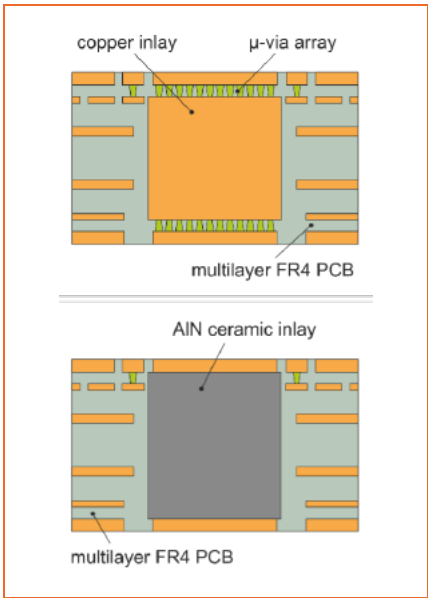

Figure 6: Multilayer PCB technologies with copper or aluminum nitride inlays.

The operation of the Pixelated LED Array requires a special PCB that fulfills all of the component's requirements. A good thermal performance as well as multi-layers for the necessary technology are essential in this regard. Investigations showed that the new lighting technology can be operated thermally stable with an FR4 PCB with copper inlay and μ-vias in addition to appropriate cooling. But also other PCBs with ceramic inlays are a suitable solution.

Optical Lens Designs

The optical system consists of two projectors with different fields of view (FoV). The smaller FoV covers a horizontal range of $\pm 12°$, the larger one $\pm 20°$. Both systems achieved a numeral aperture of approximately 0.7. The system for the small FoV consists of eight lenses, while the other one comes with seven lenses. All those lenses are made from glass with spherical surfaces. Both systems have a length of 125 mm and a diameter of approximately 70 mm (small FoV) or 65 mm (large FoV) and achieve an efficiency of 48%.

Whereas the system for the larger FoV achieves measured luminous intensities of 25 300 cd up to 30 900 cd in the central area, the system for the small FoV even achieves 77 000 cd up to 81 000 cd. The superposition of both systems would achieve a luminous intensity level of more than 100 000 cd.

Outlook

This new lighting solution shows where the technological journey for automotive exterior lighting is headed in the coming years: multifunctional, intelligently controllable headlamps that can do more than just illuminate the road. The market launch for the LED is planned for 2023.

With more than 25,000 individually controllable pixels, the Pixelated LED Array has a light emitting area of 41 mm^2. The individual pixels are brought together to a pixel pitch of 40 µm, creating a particularly space-saving component. The Pixelated LED Array enables an active distribution of light. Only the light pixels that are needed are energized and switched, others are not active. This makes the LED very efficient and ideal for energy-saving concepts or electric vehicles. Additionally, it can be configured to cover different fields of view depending on the application area. For example, only the central section can be filled with high resolution and the remaining field of view can be supplemented with discrete LEDs. Finally, it provides a fine-resolution ADB system to be implemented in a small space and delivers outstanding performance. A part of this work is funded by the German Federal Ministry of Economic Affairs (Bundesministerium für Wirtschaft und Energie) in the frame of the “Important Project of Common European Interest” (IPCEI). ■

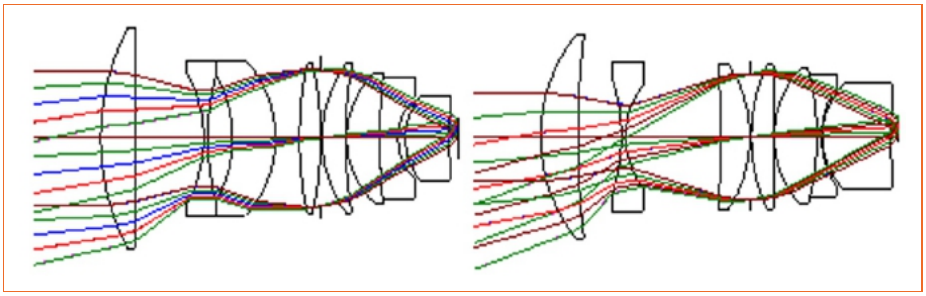

Figure 7: Structure of the lens systems. Small field of view (left) compared to a large field of view (right).

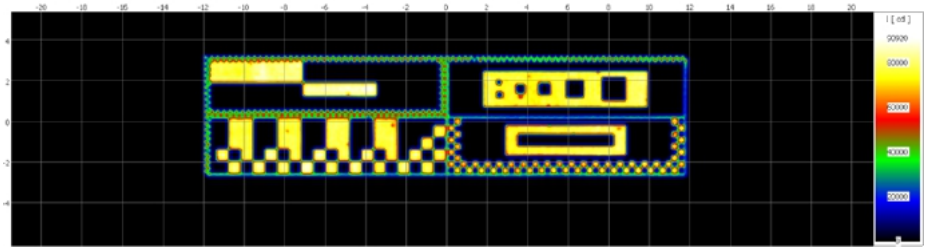

Figure 8: Measured luminous intensity for small FoV.

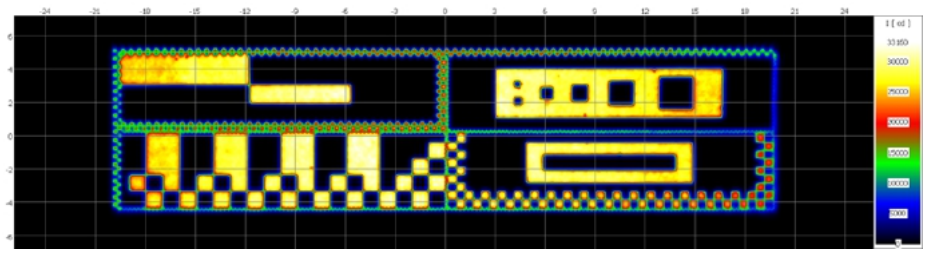

Figure 9: Measured luminous intensity for large FoV.

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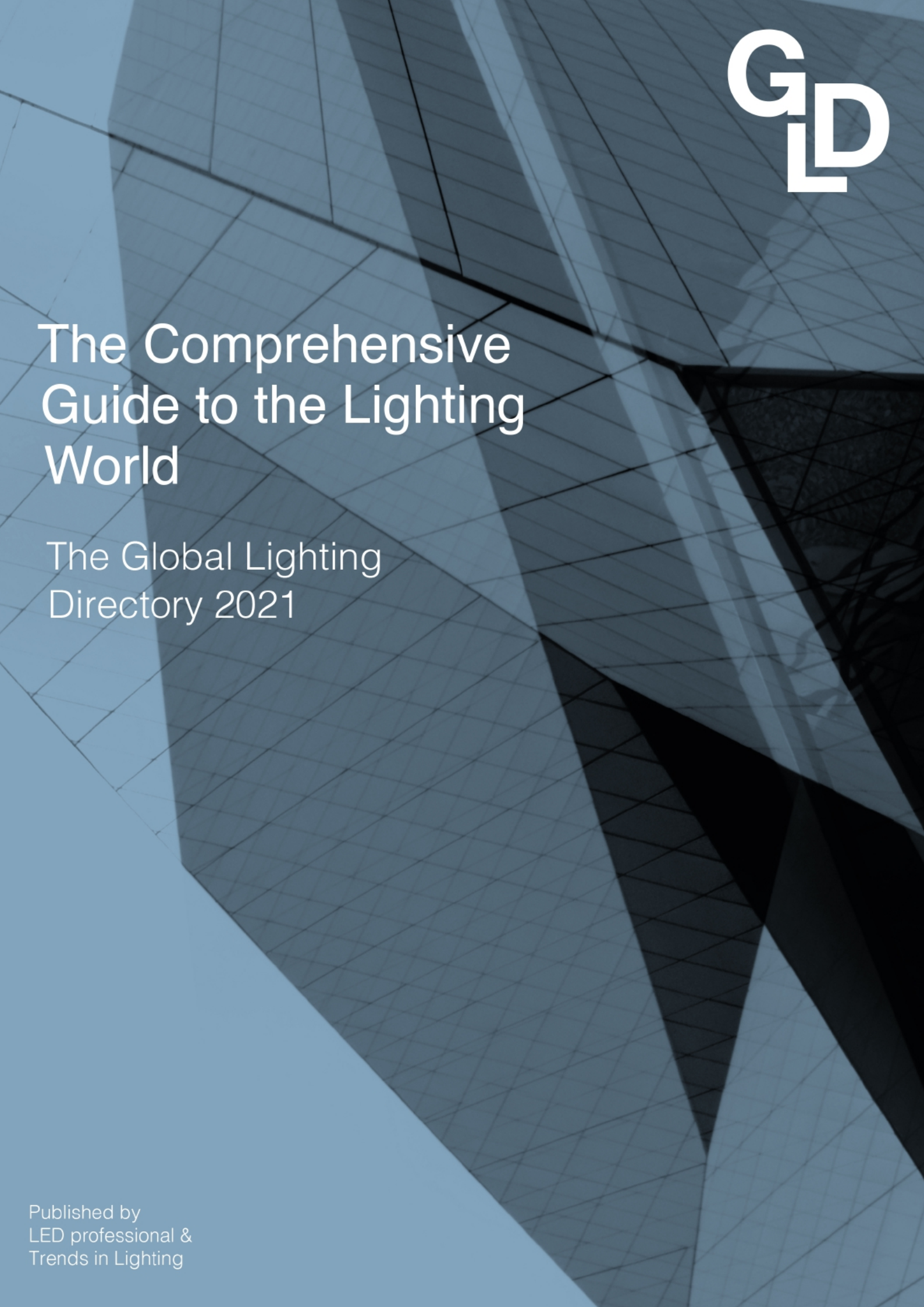
[1] https://www.osram.de/os/applications/automotive-applications/eviyos-digital-light.jsp.
[2] https://youtu.be/ZhHaibDzUVs.



The Comprehensive Guide to the Lighting World

The Global Lighting Directory 2021

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Trends in Lighting

Illumination and Simultaneous Germ Reduction with Light

by Thomas WALENTOWSKI, Dipl.-Ing.(FH); AURORA Lichtwerke

Light creates emotions and since the introduction of LED technology, it has become easier to realize these emotions, e.g., with infinitely variable color control, color temperatures from cold to warm that can be adapted to the mood, and the integration of lighting into smart home and building management systems. However, light also has biological aspects, such as health, well-being and human performance, which have been pursued for years with the Human Centric Lighting approach, for example.

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Mr. Walentowski studied Precision Engineering at the University of Applied Sciences in Munich. He is Head of Business Unit Light & Sanitization at AURORA Lichtwerke and has been intensively working on the new desinfective technology with the combination of purple and white light in close cooperation with the Italian partner NextSense S.r.l. Formely Mr. Walentowski had held various management, sales, marketing and productmanagement functions in the European lighting industry. From 2013 to 2016 he was a Board member of LightingEurope.

Illumination and Sanitization

With the new sanitizing technology, which sounds almost too fantastic to be true, an important health aspect is now added: The dual function illumination with integrated preventive germ reduction by combining white with purple (blue-violet) light. Light, mind you, not UV-C radiation. It is based on the invention of the Italian company Nextsense S.r.l. (European patent applications EP3442603 and EP3491290) [1].

It involves the combination of different wavelengths with varying intensity in the purple range between 400 nm and 430 nm and white light up to 700 nm, i.e. within the visible range of the electromagnetic spectrum. When the light is switched on, the germ reducing effect also begins, and it is completely harmless for both people and animals that are present in the room without any time limit.

By combining different purple wavelengths (**Figure 1**), the effectiveness is significantly increased compared to solution approaches that work with only one wavelength, and at the same time the range of action is extended, i.e. many types of bacteria and viruses can be combated with the new sanitizing light technology. A ratio of approximately 1 W of sanitizing purple light and 800 lm luminous flux has proven to be particularly effective. The germ reduction starts when the light is switched on and increases continuously with the exposition time, and the risk of infection decreases accordingly. The microbicidal effect of the sanitizing light is due to so-called photosensitizers, which occur naturally in microorganisms, absorb the purple wavelengths of light and subsequently produce oxygen radicals in the cells, which then destroy membranes, proteins and DNA, killing the cells from inside [2] (**Figure 2**). The mechanism is not reversible, so that no resistance can develop.

Microbiocidal Efficiency and Evidences

The effectiveness of the new sanitizing technology against bacteria and the SARS-CoV-2 virus has been confirmed in several studies, e.g. by the Finnish research institute VTT[1], the French CEA (Département Médicaments et technologies pour la Santé)[2], and studies by La Sapienza University in Rome, as well as the University of Salerno[3]. Another multicentric study within the European Bio-Defense Laboratory Network, involving the Italian Celio military scientific department, the Swedish military research institute and the microbiological institute of the German Armed Forces, is to be published soon. In the CEA study, conducted in a BSL3 laboratory, the concentration of SARS-CoV2 viruses was reduced by over 99% in one hour.

Photobiological Safety According to IEC 62471, Harmless for Humans and Animals

Since sanitization is always active when the light is on, photobiological safety according to IEC 62471 is of crucial importance in addition to effective germ reduction. In tests performed by TÜV Rheinland, for example, the BIOVITAE A-60 household lamp was classified in the lowest risk group 0, i.e. the light is completely harmless to both humans and animals even when switched on for long periods of time.

[1] Mr. Satu Salo, Mrs. Hanna-Leena Alakomi, VTT Technical Research Centre of Finland Ltd.: Field study on the microbicidal efficacy of the BIOVITAE® lights installed in the first aid of the Leonardo da Vinci airport, Rome.

[2] Mr. Laurent Bellanger, CEA France, Direction de la Recherche Fondamentale, Département Médicaments et technologies pour la Santé, Service de Pharmacocinétique et d'Immunoanalyse, Laboratoire Innovations Technologiques pour la Détection et le Diagnostic: Study report assessment of the inactivation of the SARS-CoV2 by the BIOVITAE® lamp.

[3] Prof. Anna Angela Barba, Universita' degli Studi di Salerno, Impianti & Processi - Difarma Microbiologia - Difarma: Protocolli per l'irraggiamento a LED di alimenti per il prolungamento della conservabilità.

Differentiation and Differences to UV-C

In contrast to the new purple sanitizing light, the significantly shorter wavelength UV-C radiation (usually 254 nm, less often 222 nm and 273 nm), damages the DNA and RNA of microorganisms in a short time and thus prevents their reproduction, but also harms human cells. Therefore, almost all UV-C disinfection devices available on the market work with disinfection chambers hermetically sealed from the environment, because the open application of UV-C radiation is very dangerous.

Purple sanitizing lamps are absolutely safe, in contrast to open UV-C disinfection lamps with timers and motion sensors. For example, if someone falls asleep while watching TV in the evening under purple sanitizing lights, this is totally harmless; but with UV-C lamps this can be very dangerous if the motion sensor does not respond due to lack of movements and the UV-C lamp therefore does not switch off; the person who fell asleep would then wake up with severe skin burns.

Another great advantage of the new purple light technology compared to central UV-C disinfection devices, and also room ventilators, is the decentralized arrangement of the lights in the room (for example above the desks, or at home in the floor lamp next to the sofa): germ reduction takes place exactly where people are.

And finally, commercially available UV-C lamps usually have to be replaced after 8000 hours to 12 000 hours, while BIOVITAE lamps and luminaires have lifetimes of between 20 000 hours and 50 000 hours.

Applications and Reduction of the Risk of Infections

Therefore, the purple sanitizing light is predestined for simple, efficient germ reduction and at the same time completely harmless for humans and animals in all indoor spaces with many people. Thus, germ reduction with purple light as an integrated part of normal room lighting covers a very wide range of applications; like school classrooms, kindergartens, hospitals, doctors' and dentists' offices, hairdressers' salons (**Figure 3**), government offices (e.g. registration office, vehicle registration office) and last but not least in family homes.

The use as a pure purple supplementary light would also significantly reduce the risk of infection in public means of transportation (for example, buses, trains, cabs). All these applications can be perfectly addressed because the new sanitizing technology is already commercially available in different lamps and luminaires. For example in LED tubes, linear fixtures and LED panels 600×600.

A pilot installation at St. Walburg School, Eichstätt, Germany, has just been finalized; and another school project in Baden-Württemberg will be scientifically accompanied by the Institute of Medical Engineering and Mechatronics, Ulm University of Applied Sciences, Ulm, Germany. Therefore, a logical approach worth considering would be to include lamps and luminaires based on germ reduction with purple light sanitization technology as an alternative to room ventilators and UV-C disinfection devices in corresponding public support programs aimed at reducing indoor infections. ■

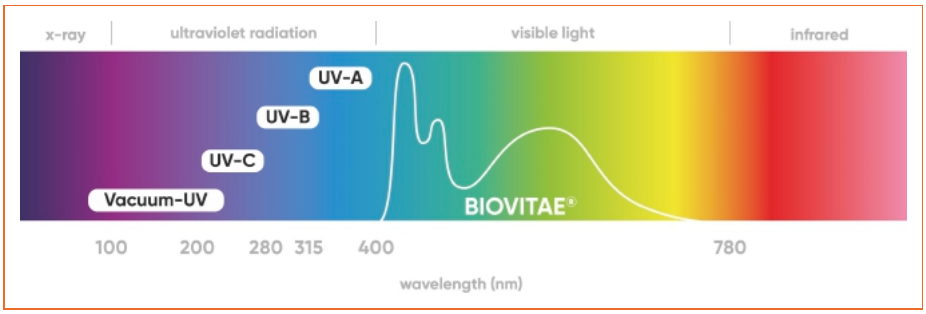

Figure 1: Sanitizing spectrum (BIOVITAE), Source: Nextsense S.r.l.

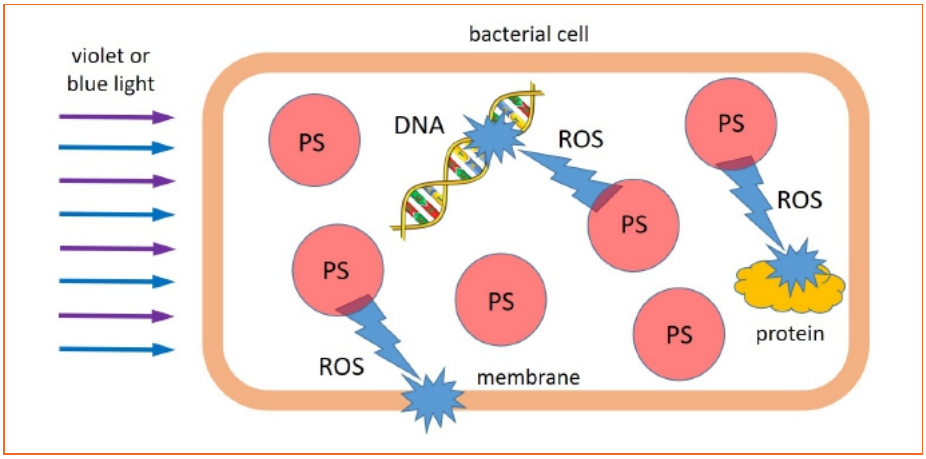

Figure 2: Scheme of the desinfection mechanism of blue and violet (purple) light for bacteria [2] (PS: Photosensitizer, ROS: Reactive Oxygen Species, DNA: Deoxyribonucleic acid).

Figure 3: Barbershop by Kardasch Berlin, Grunewald. Photo: Why-5, M. Wurzer.

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[1] European patent applications EP 3442603 and EP 3491290 Nextsense S.r.l., Carmelo R. Cartiere, Rosario Valles.

[2] Buehler, J., Sommerfeld, F., Meurle, T., Hoenes, K. and Hessling, M., "Disinfection Properties of Conventional White LED Illumination and Their Potential Increase by Violet LEDs for Applications in Medical and Domestic Environments." Advances in Science and Technology Research Journal 2021(15 (2)) (2021).

Measurement Systems and Calibrations for UV Radiation

The pandemic situation caused by the COVID-19 virus has inspired many companies, research institutes and lighting designers to adopt UV radiation as a new tool in their projects and research. The promising germicidal effect of UV-C radiation, also on the coronavirus, raises the question of the reliable measurement of UV radiation. However, this complex task needs expertise and the appropriate equipment. Conventional radiometers are easy to use, but limited only to the very narrow spectral range, typically around one emission line.

The system best suited for UV measurements consists of a high-precision spectroradiometer with stray light correction and irradiance probes or PTFE-coated integrating spheres for total radiant flux measurements. However, the reliable and traceable calibration of the system is the challenging factor. So far, no national metrological institute has been able to offer a reference standard for the total radiant flux in the UV-B and UV-C spectral region. Therefore, we have realized traceable UV LED calibration standards that complete the measurement system for UV radiation presented here.

The UV LED calibration standards were developed for the typical peak wavelengths of 280 nm (UV-C), 305 nm (UV-B) and 365 nm (UV-A). The traceability of the radiant flux is ensured by the precise calibration of the spectroradiometer with the irradiance probe and a subsequent integrative measurement using a goniospectroradiometer. Such UV LED calibration standards can be used for monitoring and for absolute calibration of UV measurement equipment consisting of the stray light corrected spectroradiometer and the integrating sphere. The largest contribution to the measurement uncertainties of the systems containing integrating spheres is the fluorescence of the reflective material. A special manufacturing procedure with optically pure Polytetrafluorethylen (PTFE) enabled us to produce new integrating spheres with permanently low fluorescence.

Introduction

Ultraviolet (UV) radiation covers a wide wavelength range between 100 nm and 400 nm and is divided into three main areas according to the standard ISO 21348: UV-A between 315 nm and 400 nm, UV-B between 280 nm and 315 nm and UV-C between 100 nm and 280 nm. Typical applications in the UV-A range are UV curing or UV ink printing. Light sources in the UV-B range are mainly used in medical skin treatments. The main application in the UV-C range is water and surface disinfection, which is currently of great importance in the fight against pathogens such as the novel coronavirus COVID-19.

In the light source industry, there has been an increased demand for UV-C radiation sources since the outbreak of the SARS-CoV-2 pandemic. UV-C radiation between 255 nm and 265 nm has been recognized as a highly efficient method for inactivating the DNA or RNA of microorganisms such as the coronaviruses, effectively preventing their replication and ability to actively infect other cells.

Because of their specific areas of application, all UV radiation sources should be characterized very precisely with regard to their radiant flux and spectral distribution. This requires reliable and accurate UV measurement systems over the entire UV range. The use of radiometers, however, is restricted to a very narrow range of wavelengths, typically only around one spectral line. The system, which meets all requirements for UV measurements, consists of a high-precision spectroradiometer with stray light correction and either coupling optics for measurements of the irradiance [W/m^2] or integrating spheres made of polytetrafluoroethylene (PTFE) for radiant flux measurements [W].

However, a reliable and traceable calibration of the measuring system is a challenge. So far, no national metrological institute has been able to offer a reference standard for the radiant flux in the UV-B and UV-C spectral range. For this reason, we have developed traceable UV-LED calibration standards that complete the UV measurement system. The special test procedure for determining the radiant flux in the UV is accredited according to ISO 17025 (D-PL-19052-01-00).

Optimization of Measurement Systems for UV

The main limitation of the performance of an array spectroradiometer in photometry and radiometry is the occurrence of stray light in the instrument, especially in the sensitive UV range. This means that a particular element of the array detector registers radiation from a different spectral region than the designated one. The reason for the occurrence of stray light can be found in various mechanisms:

- scattered light from the diffraction grating due to manufacturing inaccuracies in

the shape and spacing of the lines, or roughness of the surface of the grating,
- higher diffraction orders, particularly for detectors with a wide spectral range,
- double diffraction of the light reflected back on the grating,
- inter-reflections between the detector and other optical components,
- reflection and scattering from surfaces, especially from the inner wall of the spectrograph,
- fluorescence of optical components,
- the way the light is coupled into the spectroradiometer.

Thus, the total amount of the measured radiant power contains a partial amount of incorrect radiation that causes an error in spectral power distribution. The main approach to improve the radiometric performance of the spectroradiometer is to avoid, or at least largely suppress, the stray light by design measures of the spectrograph. When further suppression is technically not possible, the residual stray light can be effectively corrected to a great extent, for example by applying the NIST method **[1]**.

The main idea of this method is that monochromatic radiation can be attributed, for the most part, to a certain pixel of the CCD array detector. The entire radiation that is measured outside the bandpass function for this wavelength is the stray light contribution of this pixel that is seen from all other pixels in the detector. In the practical realization, the stray light correction is achieved with a tunable optical source that emits narrow (<1 nm) spectral lines over the entire spectral range. Excitation wavelengths are tuned within the measurement range of the spectroradiometer in 10 nm steps and a spectrum is recorded for each laser excitation wavelength. The set of all recorded spectra over all excitation wavelengths results in a device-specific matrix. If the band-pass function of the real signal is subtracted, one obtains a stray light distribution matrix. The inverse of the stray light matrix can be numerically multiplied with raw spectra in order to obtain stray light corrected spectra.

Figure 1 shows spectra of a UV-C LED with and without stray light correction in logarithmic presentation, as an example. The suppression of the stray light in the spectral curve by more than one order of magnitude in the UV range is clearly recognizable. The impact of the stray light correction on an array spectroradiometer is almost as high as the stray light level of a double monochromator, which is the best spectroradiometer worldwide, that can be reached. A direct benefit of the stray light correction is higher precision in radiometric evaluation, especially in the UV-C range.

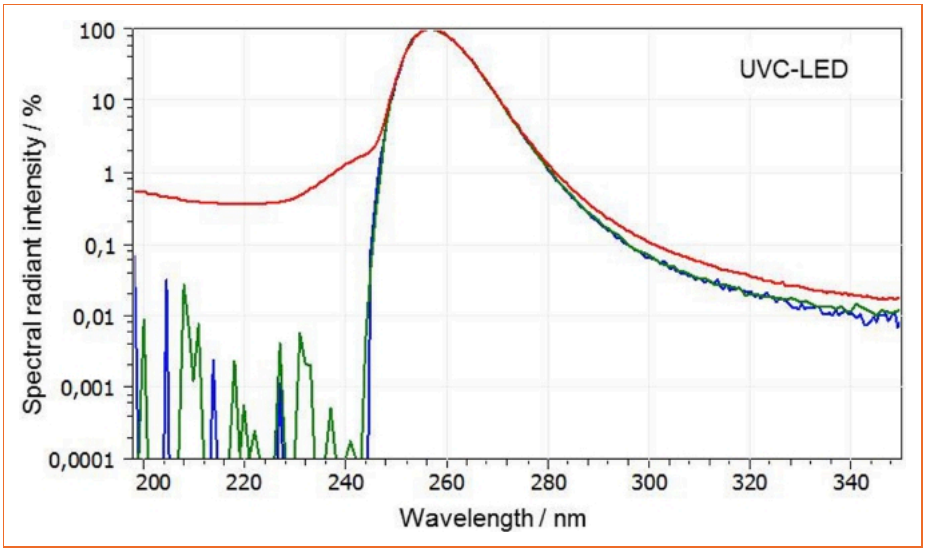

Figure 1: Logarithmic display of the spectra of a UVC LED with (blue) and without (red) stray light correction of an array spectroradiometer, measured with a double monochromator (green).

Figure 2: Integrating spheres made of optically pure polytetrafluoroethylene (PTFE) for low-fluorescence measurements of the radiant flux in the UV.

For measurements of the irradiance [W/m^2], simple coupling optics can be used, which are connected to the spectroradiometer via a UV-optimized fiber bundle. A special diffuser element is used for UV applications, which ensures homogeneity in the detection of the radiation. The fiber bundle allows flexible handling in combination with a high throughput. The traceable calibration to the spectral irradiance [W/m^2/nm] is realized directly using a deuterium lamp as a reference standard.

Reliable Measurements of Radiant Flux

For measurements of the radiant flux [W] in the UV, integrating spheres made of polytetrafluoroethylene (PTFE), which is also highly reflective in the UV range, should be used (**Figure 2**). The reflection index of barium sulphate ($BaSO_4$) drops sharply towards the UV range so that integrating spheres made of barium sulphate can only be used to a limited extent in the UV range. Depending on the size of the source, spheres of different sizes can be used, but the lateral sphere opening should not exceed 1/3 of the sphere diameter. Since the sources themselves absorb part of the emitted radiation, depending on their size and body color, a so-called self-absorption correction should be carried out over the entire spectral range, e.g. with a combined deuterium-halogen lamp.

The greatest contribution to the measurement uncertainties of the measurement systems with integrating spheres is the flu-

orescence of the reflective material. The portion of the fluorescence in the spectrum can be made visible with a blue LED measurement. Much higher fluorescence is visible on the right flank of the blue LED for poor quality PTFE than for the PTFE material with optical quality (**Figure 3**). A special manufacturing process with optically pure polytetrafluoroethylene (PTFE) enabled us to manufacture new integrating spheres with permanently low fluorescence. These PTFE spheres can be audited and recalibrated with the newly developed UV-LED calibration standards.

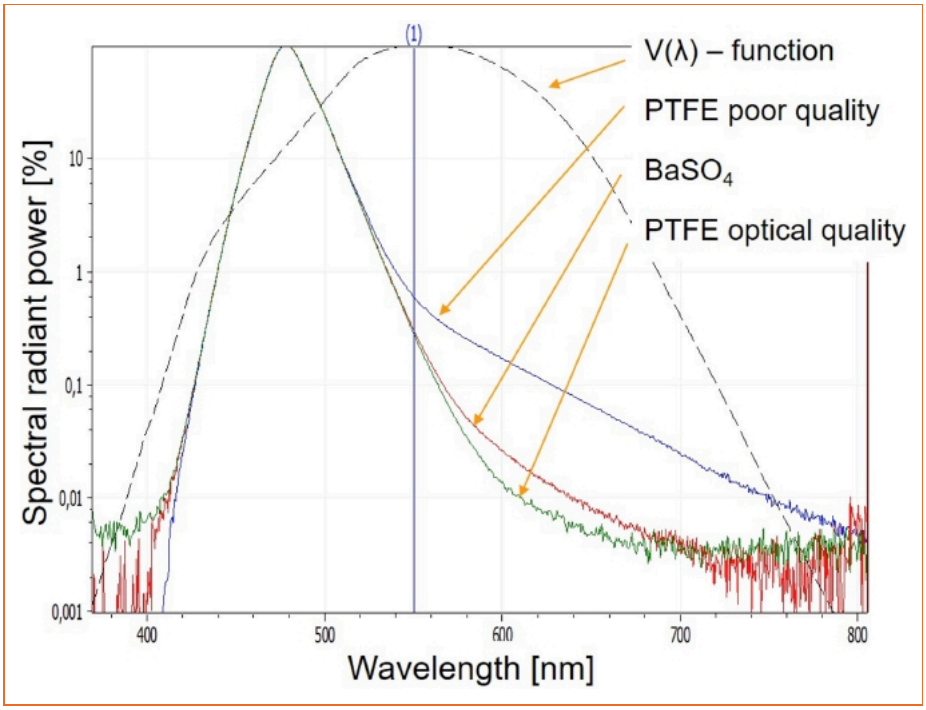

Figure 3: Blue LED measurements show higher fluorescence on the right flank for poor quality PTFE and lower fluorescence for the PTFE material with optical quality compared to barium sulfate ($BaSO_4$).

Calibration Chain

A defined calibration chain must be maintained for traceable spectral characterization and calibration, as shown in **Figure 4** top line (blue). National metrology institutes (NMIs) create the national standard of an SI unit, in this case the definition of the candela or a derived radiometric quantity. The standards of national institutes are compared globally on a regular basis. The NMIs create calibrated reference standards for interested companies or institutes that can use them to create calibrated transfer standards. The transfer standard is used to calibrate or characterize other light sources, the so-called working standards. These are then used for the factory calibration of measuring systems. Each of these steps brings a certain contribution of the measurement uncertainty into the budget.

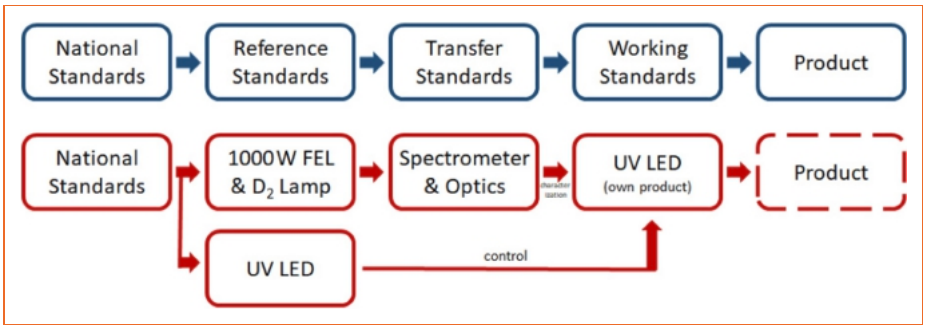

Figure 4: Calibration chain at national metrology institute (blue) and at Instrument Systems (red).

Figure 4 lower line (red) shows the characterization chain at Instrument Systems. The NMI (e.g. Physikalisch-Technische Bundesanstalt in Germany) supplies a calibrated 1000 W FEL halogen lamp, a deuterium (D2) lamp and a UV LED. All standards are calibrated to irradiance E [W/m^2] at certain intervals. With the lamps FEL and D2, a spectroradiometer with the connected coupling optics is spectrally and absolutely calibrated and set as the transfer standard. This can be used to calibrate other light sources (e.g. UV LEDs) and define them as a new working standard. The third PTB-calibrated standard (UV-LED) is used as a control unit. This double control system guarantees the highest precision in the traceability of the standards, which in turn are used for further quality control and product characterization.

Realization of UV-LED Calibration Standards

The most important requirement for the UV-LED calibration standards is the audit of the radiant flux of UV measurement systems with integrating spheres and their characterization. At a certain distance, UV-LED standards can also be used to check the irradiance. So far, international metrology institutes such as the Physikalisch-Technische Bundesanstalt (PTB) and the National Institute for Standards and Technology (NIST) have not offered such a reference standard for the UV-B and UV-C spectral ranges.

As a result, Instrument Systems has developed its own UV calibration standards, namely the Advanced Calibration Standards of the ACS series (**Figure 5**, **Figure 6**). These are regulated and actively temperature-stabilized UV LEDs on a heat sink in an insulated housing. The UV-LED calibration standards were developed for the typical peak wavelengths of 280 nm (UV-C), 305 nm (UV-B) and 365 nm (UV-A). As for any type of calibration or characterization of light sources, essential requirements must be met: low drift of the wavelength, low drift of the optical power, stable mechanical interface and robustness against environmental influences. Internal qualification tests (e.g. long-term optical characterization, heat, humidity and mechanical tests) are required to ensure the quality of the sources. In addition to the light sources, measuring devices must also meet these requirements in order to achieve precise and reproducible results.

The traceability of the radiant flux of UV-LED calibration standards was achieved through a traceable factory calibration of the spectroradiometer with the coupling optics for irradiance and a subsequent integrative measurement with a goniospectroradiometer. The test object is rotated step by step in two mutually orthogonal angles: C in $[0, \Pi]$ and γ in $[-\Pi/2, \Pi/2]$. The measuring system measures an irradiance $E\,(r_0, C, \gamma)$ in [W/m^2] at a known distance r_0 at each specific angle. The radiation characteristics of the light source

are recorded and the total radiant flux is determined through numerical integration of the measured irradiances at each angle. This procedure is accredited by the DAkkS (German accreditation body) according to ISO 17025 (D-PL-19052-01-00). Since goniopectroradiometric measurements take a little longer, the long-term stability of the optical characteristics is implemented in the basic requirements on the LED calibration standards (<0.2% in 12 h and <1% in 100 h).

A major aspect of the reliability of this system is the control point at $E\,(r_0, C = 0°, \gamma = 0°)$. Before a new UV LED is characterized, a PTB reference UV LED can be measured as a control unit. Its irradiance is precisely known and any major deviation would lead to an incorrect calibration of the transfer standard. Thus, a double check with differently calibrated standards is done.

Figure 5: Advanced Calibration Standard (ACS) on UV-LED basis.

Each measurement process contributes a measurement uncertainty to the total budget. The measurement uncertainty contributions of various influencing variables are based on statistics and are either determined by many measurements or simulated by the so-called Monte Carlo method. The overall measurement uncertainty of the three UV-LED calibration standards with different peak wavelengths results in these very low measurement uncertainty values ($k = 2$):

- UV-A (≈ 365 nm): 2.0%
- UV-B (≈ 305 nm): 3.5%
- UV-C (≈ 280 nm): 4.5%

Conclusions

Stray light corrected spectroradiometers with different coupling optics are the best suitable measurement systems for the entire UV range. When using PTFE integrating spheres, a low level of fluorescence should be ensured. Suitable self-absorption correction for the entire spectral range should be carried out with a combined deuterium / halogen lamp. UV-LED calibration standards can be used to check the radiant flux or the irradiance and, if necessary, for the absolute recalibration of the system.

The factory calibration of the UV standards, which is accredited according to ISO 17025, is a combination of several precision steps:

- All measurements are traceable to national standards.
- The light source itself is manufactured with the highest requirements in terms of optical properties, mechanical tests and thermal stability in order to guarantee a long calibration period.
- Spectral measurement setups (UV spectroradiometer, coupling optics and UV fiber bundles) are optimized in order to minimize the effects of fluorescence and stray light.
- The mechanical setup (goniospectroradiometer) enables not only the determination of the radiant flux of the test object, but also its radiation characteristics.
- When using a double test with separately calibrated light sources (both with devices that are traceable to national standards) a maximum of reliability and a minimum of uncertainty is achieved.

The very low measurement uncertainties ($k = 2$) of the UV-LED calibration standards are comparably low with those in the metrologically unproblematic visible range. Therefore, we are a global pioneer for radiant flux calibration in the UV-B and UV-C range. ■

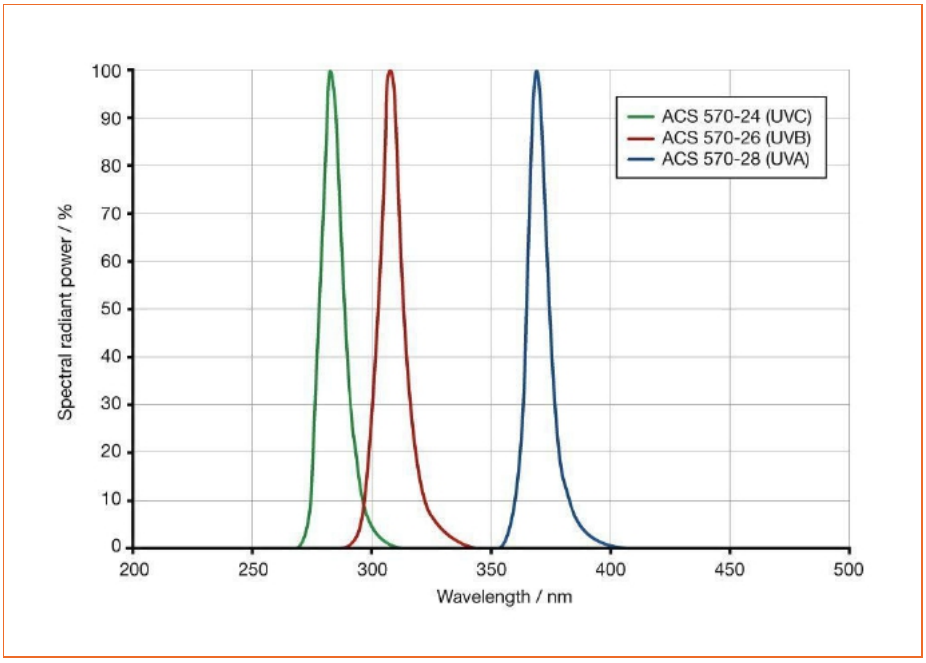

Figure 6: Typical spectra for UV-LED calibration standards.

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High Performance LED Sources Enable Innovation in Manufacturing

by David Armitage, Baldwin UV, UK

Think of virtually any product you have around you and the vast majority will have applied some sort of coating for decoration or functional performance somewhere with its makeup. If it is electronic, almost certainly, radiated light will have been applied in the manufacturing process of the components inside. Accelerated drying is used in nearly all manufacturing processes. It is important to realize that this does not have to exclusively mean light in the UV spectrum. Accelerated drying of all forms is simply the movement of energy from a source to a surface or body that uses this energy to perform the necessary action to improve productivity.

All drying processes involve a liquid material to change to a solid through:

- Physical Processes – solvent/water removal
- Chemical Processes – cross-linking or polymerization
- Combination Processes – dual-cure

UV curing, which can include wavelengths into the visible blue, works by activating photoinitiators which are light reactive components within the coating formulation and which break apart on absorption of the light. These form highly reactive free radicals that drive a polymerization reaction, turning the liquid coating into a solid.

IR or thermal drying (note the terminology drying): IR does not provide enough photon energy for photoinitiated chemical reactions; it works based on removing a solvent (increasingly water) by evaporation and then a slower chemical oxidative interlocking occurs over several hours or days. Typically, additional air exhaust and directed hot air is required to remove the solvent efficiently.

Both accelerated processes have their place and are well established.

Basic Considerations

For any energy driven process there are three key parameters which define the curing or drying performance.

The first parameter is the total energy or radiant flux density arriving at the surface over time. This is typically referred to as the dose in UV curing and it is measured in J/cm^2. Dose is dependent on exposure time. If you double the line speed or shorten the exposure time for a fixed process you get 50% less exposure time to the UV lamp resulting in 50% of the total UV dose. If you add a second source you will double the dose.

The second parameter is the peak power density or Irradiance. This is the radiant power arriving at a surface from all forward angles, per unit area. It is expressed in watts per square centimeter or milliwatts per square centimeter (W/cm^2). It will increase with the input current in the case of an LED source. It does not accumulate with multiple sources; it only defines the maximum peak value.

The third parameter is the output spectrum of the source. This is important because Photoinitiators have different absorbance responses with wavelength so the source must have output peaks where the photoinitiator absorbs. The wavelength of the radiation also affects the penetration depth into the UV curable material. In general, shortwave radiation will have a much shorter penetration depth than longer wavelengths. The exact penetration depth depends on the exact nature of the material but generally UVC may only penetrate a couple of microns while UVV or UVA may penetrate 30 microns or more.

All three parameters are required to fully define the curing process. Most processes require a threshold of Irradiance for the curing to activate efficiently and to allow penetration to the deeper layers in the coating. Once over this threshold the dose will determine the speed a process can run and the state of cure achieved. Because the dose is integrated with respect to time of exposure, the faster a process runs the more dose is required. Most fast processes are always ultimately limited by available dose.

Both Dose and Irradiance are affected by the distance from the curing surface and any optical arrangement used to focus the light. As the source moves further away from the surface both dose and irradiance will decrease.

With no optical arrangement to manage this, the irradiance will reduce as in inverse square of the distance. The dose will often reduce less because for processes that involve motion underneath the UV source, the curing surface will collect the wide-angle light but usually there can be only one point for the peak power density which is normally directly under the source.

How the light is managed with distance depends on the distance and what is important for the process. Within a few millimeters, normally the best solution is to have no optics. Every optical arrangement, be it a lens or reflector, causes an insertion reduction of the dose output. This loss can easily be as much as 10 – 30%. The only reasons to have optics is if they are used to even out the light output or to reduce stray light to an absolute minimum.

At greater distances there typically needs to be some sort of optical arrangement to manage the light. Optical arrangements can generally be put into two classes. Focused where the Irradiance is designed to be maximized with a certain range of distance, and flood where the Irradiance is designed to be as uniform as possible but will be much lower than can be achieved with a focused solution at the same distance.

As an example of how optics increase and extend the performance can be seen below. The standard light engine has different optics available for optimum curing in different situations. A close-range small optic where the optic is solely there to even the

light output, mid-size optic where a combination of glass and reflector optic maintains high peak irradiance and a larger optic for longer distance applications. Generally, the optical arrangement will get larger as the distance to focus the light gets longer.

In the early years of UV LED curing, the main aims were to apply the technology to traditional applications where the existing sources had been in use since the early 1970's. The hardware was deployed in similar form factors to those that already existed, even for new applications where design was much more open.

The first systems were, and to a large extent still are, limited by the availability of the full traditional range of UVC, UVB, UVA and UVV generated by mercury-based arc systems.

This required some innovation in the UV materials and the coating manufacturers made great efforts to formulate coatings that would cure acceptably with the limited range of output wavelengths spanning the upper UVA to UVV (365 nm to 450 nm). There are a number of photoinitiators in use for UV LED curing and more are being developed. None is currently particularly perfect, and all are more expensive than the ones in use for conventional UV because of the lack of powerful, cost effective UVC LED. ITX has a good response but has issues with curing byproducts in that it gives a yellowing tinge to the cured product. BAPO and TPO are relatively low absorbance but still significantly better that the photoinitiators used for traditional arcs such as DMPA.

In some applications such as printing, metal decorating, and adhesives, UV LED has now claimed the greater part of new systems sold. In this region of the spectrum the availability of low-cost powerful LEDs has completely transformed the initial higher costs of LED systems when they were first introduced to the point where they are now generally cheaper than the traditional arc lamp systems they are replacing.

However, there remains quite a large set of applications where LED, for all its success in the region from 365 nm to 450 nm, has struggled to gain full traction in manufacturing processes. The chief missing link has been the region below 365 nm. The reason why this region is so important is because many of the traditional photoinitiators that are responsible for the curing chemistry, respond strongly in the shortwave UVB and UVC.

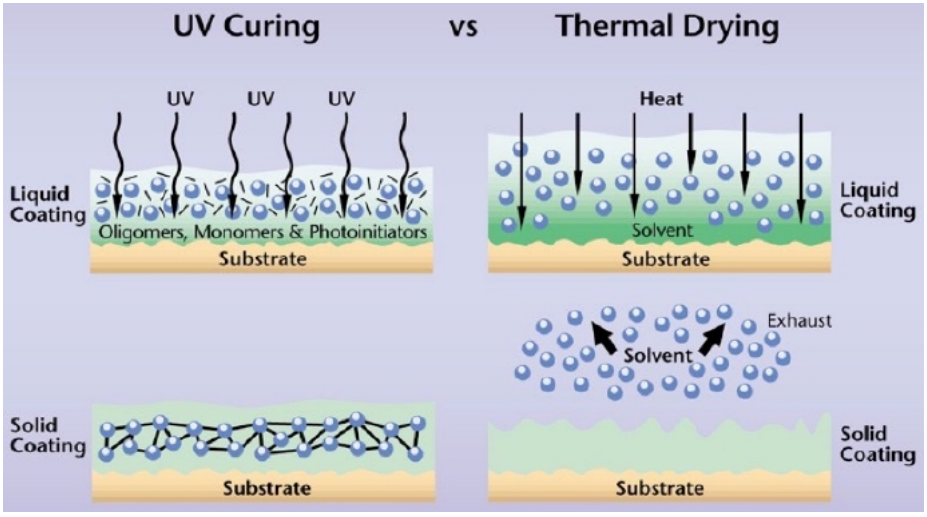

Figure 1: Comparison between UV Curing and Thermal Drying.

UV curing process: • low capital cost • low running cost • lower maintenance • improved quality • inline finishing operations • reduced space • clean & efficient	UV material performance: • wet equals dry film thickness (no solvent removal) • rapid cure • good light fastness • good heat-fastness • sufficient flexibility • good adhesion for plastics • high process resistance	UV environment: • low odour • low residual volatiles • no solvent • no VOC • reduced energy
IR drying process: • lowest capital cost • lowest running cost • widest range of consumables • best for water-based products • best for ink keying into substrate • best flow out • better with shadow areas for 3D products	IR drying performance: • slower final cure • good light fastness with coating • good heat-fastness • best flexibility	IR environment: • water-based coatings have replaced solvents • low migration • lower toxicity • less odour • suitable for food packaging

Table 1: Comparison between UV Curing and IR Thermal Drying.

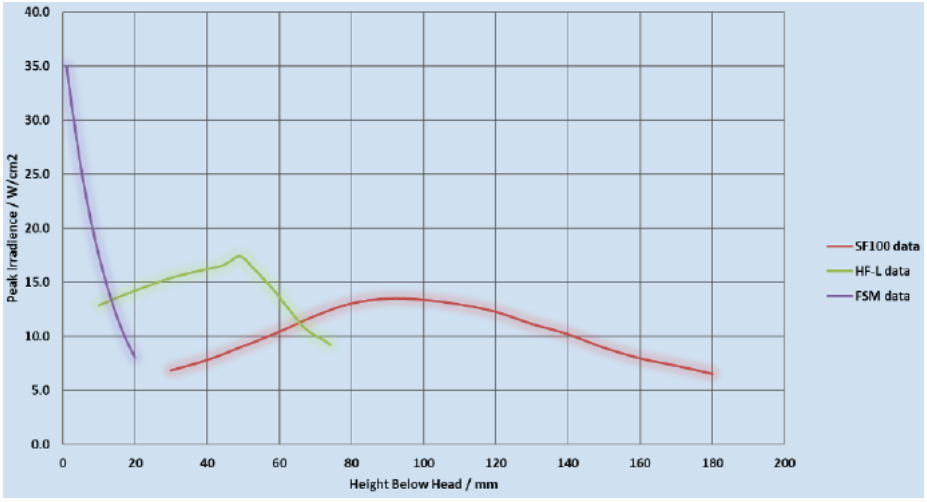

Figure 2: UV Output FSM, HF-L and SF100 UVed2 Reflector Systems (385 nm to 395 nm) measured with EIT LEDR-R395.

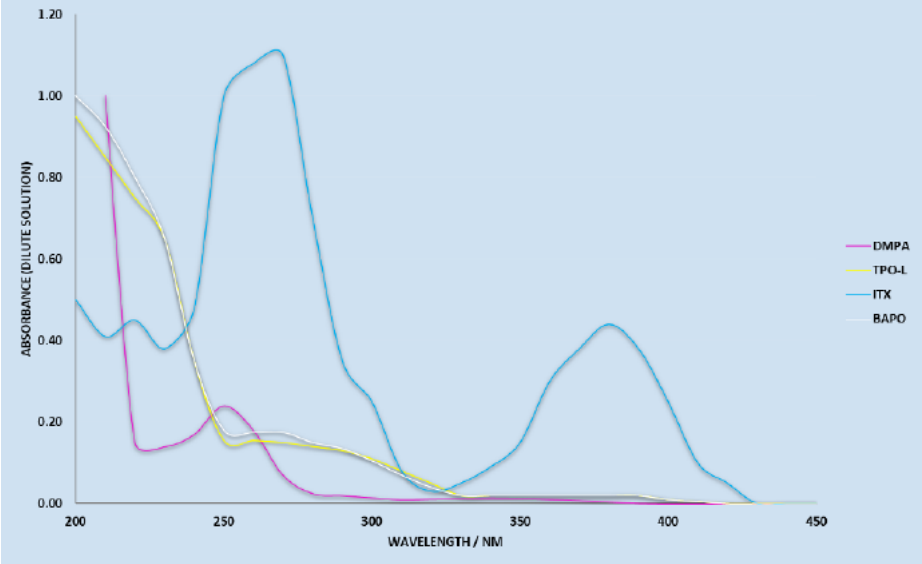

Figure 3: Absorbance of common UV LED photoinitiators in the UV region.

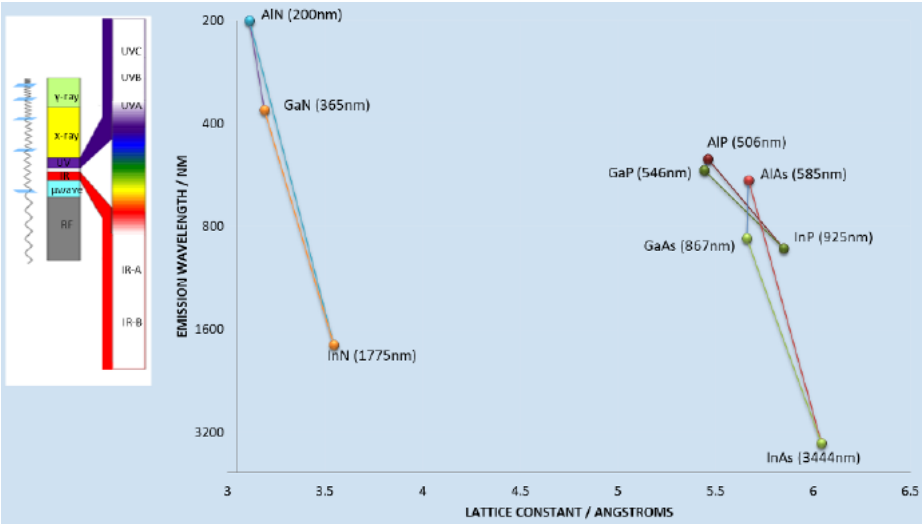

Figure 4: Group III-V Ternary Material System $Al_xGa_yIn_zN$, $Al_xGa_yIn_zP$ and $Al_xGa_yIn_zAs$

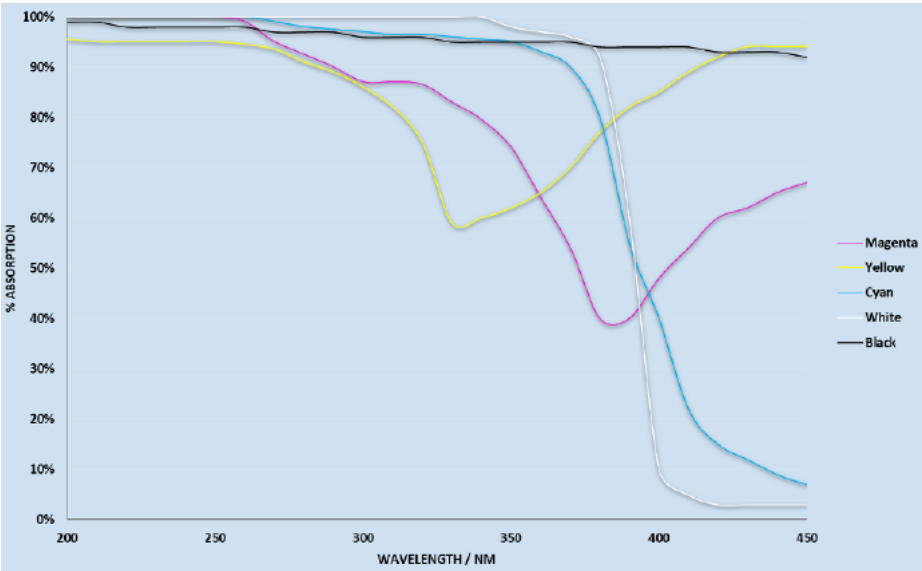

Figure 5: % Absorption of common process pigments in the UV region.

These are also the photoinitiators that are the lowest cost, do not produce colored byproducts (very important for clear coatings) and importantly, for applications such as food packaging or medical applications, these are simpler molecules with lower toxicity than the more complex photoinitiators that respond to the longer wavelength UV. The other main importance of the shortwave UV is it tends to produce better surface cure because it naturally has enough energy to overcome the oxygen inhibition of the surface that exists for any coating cured in air due to surface peroxy radical formation that blocks the continued polymerisation reaction at the surface. The coating manufacturers made large strides in formulating chemistries such as isothiolene and tri-amine chemistries that could produce better resistant surfaces without UVC but ultimately many manufactured products requiring very hard surface cure still run with mercury arc chemistry today because the addition of anything in the formulations often degrades other key properties and raises costs.

These initial UV applications also ignored the fact that UV curable coatings were not the only accelerated technology in use for converting wet applied coatings to dry coatings, finished coatings. Thermal drying is also a very large market and initially little effort was made on the use of LED for these areas because the existing technologies were cheap. In the case of IR lamps, they had quick on - off and were mercury free, two of the often-quoted advantages of UV LED over traditional technologies.

Recent developments of the Covid pandemic have accelerated efforts to bring more powerful and affordable UVC LED sources to market and developments such as LIDAR has started to push the near IR end of the LED spectrum. This is to the point that we now have reasonable coverage in a wide band of emissions from 265 nm up to 1650 nm. All the current commercial products are based on the Group III-V Binary, Ternary or Quaternary system. As can be seen from the chart below this potentially covers an emission range from 200 nm in the UVC to 3400 nm in the mid IR by simply varying the material composition.

This situation is not so straightforward in practice because the material composition in each group has regions where good performance can be realized and regions where there are significant chemical and physical challenges. Some areas of the phase diagrams may have indirect bandgaps where the electron angular momentums of the conduction and valence

bands do not coincide, so emission has a low probability and practical devices are not possible.

Table 2 gives an overview of the current state of the art for various wavelength ranges based on nominal 1 mm^2 LED bare die. The way dies are packaged, materials used, any optics and the measurement equipment used means that great care needs to be taken comparing products directly, so bringing everything back to a standard die size or package is the preferred way of making comparisons.

The performance gap for wavelengths below 365 nm is all too obvious. The other gaps of note are in the green area of the visible spectrum and wavelengths beyond 1050 nm. The production of practical curing systems is not as simple as just choosing a LED die of a particular wavelength.

There are three fundamental constructions of LED chips used in curing applications. The vertical die with electrode connections top and bottom, which generally have the highest efficiencies due to the superior thermal transfer possible, the flip chip die with electrical connections both at the bottom, which typically has lower performance as the efficiency decreases, and finally the lateral die that tends to only be used in lower power or cost sensitive applications due to its lower efficiency that vertical dies. The LED's themselves generally have a Lambertian output with a natural emission angle of around 120 degrees. Things get slightly more complex for flip chip dies, especially in the UVC, where increasingly more emission occurs from the die sides. Vertical dies only emit from the top surfaces.

As visible LED manufacturers well know, using RGB LEDs to generate white gave all sorts of consistency issues. This was due to the fact that even in the relatively narrow wavelength range from 450 nm to 660 nm the red, green and blue die's different short term and long-term properties meant controlling optical performance for CRI and color shift was extremely challenging and product prices could not match blue + phosphor, which is the most dominant method of white light generation for LED today.

For full range curing the difference in the die's properties are even more marked as to cause major design headaches. The Vf of UVC power dies are typically of the order of 6.5V whilst IR can be as low as 1.7V. The maximum drive currents possible through the most efficient dies to the least efficient dies vary by a similar order of difference. Electrically, this means they cannot be arranged in the same way. Currently, dies below 365 nm are exclusively flip chip in architecture, meaning different packaging requirements and they also have the twin issues of increasing environmental sensitivity and the nature of the light wavelength itself starts to become more and more destructive to organic materials.

Curing systems are high power sources and along with this comes an amount of heat generation. One of the early fallacies of LED curing was it did not heat the curing surface like traditional UV curing systems. That was true to an extent when LEDs were less efficient but with the level of efficiency now, they are fully capable of causing significant heat damage to sensitive products if care is not taken.

Table 3 shows the comparison between a typical arc system with heat reducing dichroic reflectors for the energy being directed towards the curing surface for a typical 1 m wide source. Despite needing less input energy to cure than arc systems, the LED system is still directing a considerable amount of energy especially when, for long distances, this energy can be more tightly focused than for the arc system due to the smaller source width.

Spectral Region	Nominal Wavelengths /nm	Typical Power @ current	Max Current /mA	Epi	Average Efficiency %
UVC	265	70 mW 500 mA	700	AlGaN	2.0%
	275	70 mW 350 mA	350	AlGaN	4.9%
UVB	308	75 mW 350 mA	350	AlGaN	3.6%
	325	65 mW 350 mA	350	AlGaN	3.7%
UVA	340	90 mW 350 mA	350	AlGaN	4.9%
	365	780 mW 500 mA	700	AlInGaN	44%
	385	1100 mW 500 mA	1000	InGaN	61%
UVV	395	1100 mW 500 mA	1000	InGaN	61%
	405	1060 mW 500 mA	1000	InGaN	61%
	425	860 mW 500 mA	1000	InGaN	65%
Blue	450	675 mW 350 mA	1500	InGaN	62%
	470	530 mW 350 mA	1500	InGaN	53%
Green	527	270 mW 350 mA	1500	InGaN	23%
Red	620	320 mW 350 mA	1500	AlInGaP	44%
	660	410 mW 350 mA	1500	AlInGaP	56%
	730	310 mW 350 mA	1500	AlGaAs	42%
IR-A	810	535 mW 350 mA	1500	AlGaAs	51%
	850	630 mW 350 mA	1500	AlGaAs	60%
	940	535 mW 350 mA	1500	AlGaAs	55%
	980	400 mW 800 mA	2000	AlGaAs	29%
	1050	300 mW 500 mA	2000	GaAs	38%
	1100	240 mW 1000 mA	2000	GaInAsP	17%
	1200	160 mW 1000 mA	2000	GaInAsP	12%
	1300	140 mW 1000 mA	2000	GaInAsP	11%
IR-B	1450	70 mW 1000 mA	2000	GaInAsP	5.4%
	1550	45 mW 1000 mA	2000	GaInAsP	3.2%
	1650	25 mW 1000 mA	2000	GaInAsP	2.0%

Table 2: Overview of the current state of the art for various wavelength ranges based on nominal 1 mm^2 LED bare die.

Much focus was made on UV LEDs that were emitting only UV, but it was being ignored that when UV is absorbed by a curing surface it is not simply disappearing benignly by absorption of the photoinitiators. There are many other mechanisms possible by which the UV photons can be absorbed and many of those result in the heating of the curing surface.

All materials have an absorption spectrum throughout the electromagnetic spectrum and the level of absorption will usually vary with the wavelength of the radiation trying to pass through it. If a material absorbs the radiation, the energy gained will result in scattering down to longer wavelengths of emission, if that is possible, or ultimately to dissipation in vibrations or rotations of the atoms and molecules resulting in heating of the material.

In coatings, one of the chief UV, visible and IR absorbing materials are pigments. Plastics may have UV absorbers to stabilize their resistance to UV.

Applications in the UVA and UVV Regions

These regions of the spectrum were the first to be applied for UV curing. The first tentative steps were taken around 2002 but it wasn't until 2008 really, that sufficient output existed to demonstrate a rate of cure and cost that started to drive adoption into manufacturing. Crucially it was then that sufficient coatings were available with a suitable formulation to address the inherent lack of surface cure.

Early applications with printing and adhesives where the curing tasks were less demanding. The technology developed rapidly as the market grew and prices reduced. The chart below shows how the performance increased and the die cost per W of UV reduced over time.

By around 2015 the tipping point had been reached in that most applications that could use UVA LED's, the mercury arc was not the favored choice. The upper UVA die costs and wall plug efficiency have now largely reached that of the blue LED, so a period of stability is likely as they effectively become a commodity product.

By 2015, systems had all the power they generally needed for the tasks they we were being used for and if more power was required the cost of simply adding more dies and more power supplies could be commercially justified.

At this point the industry started to see a change as LED's started to rapidly move into new applications that historically had not used UV. The other benefits and unique benefits of the technology started to be looked at.

The small form factor, low energy requirements and the ability to have no air movement are attractive to operations carried out in clean environment.s These include electronics and medical applications which make use of UV for:

- Resist and conformal coatings
- Sealing
- Component adhesive bonding
- Product marking
- Display sealing

The Automotive industry which had always been a user of UV curing started to see it as a much more viable tool for general use. For formed in place adhesive bonds and gasketing it increased productivity still further. Many more of the interior parts now have UV curable surface coatings for decoration and function. The energy saving for UV curing in place of larger ovens for drying coatings became very attractive. Because many of these parts were not flat it required much more use of light modelling software to optimize the illumination so there were not shadow areas on the parts or for the parts to be jigged in a way that allowed uniform exposure. The compact size also helps mount the curing units onto automated robots more easily.

Following the initial success in the printing industry, many industrial coating processes started to look at UV LED. There was still a barrier for entry for specialized, low volume coatings if the cost of reformulation for LED was justified, but where the volume was sufficient, metal decorating, wood coating, plastic laminating, plastic and film decorating along pressure sensitive adhesives applications where precise control and sta-

		Arc System	UV LED System (385 nm)
Power In	W	24000	18000
UV Output (200–450 nm)	%	29%	38%
UV Output	W	6960	6840
VIS + IR Output	%	20%	0%
VIS + IR Output	W	4800	0
Combined UV + Vis + IR	%	49%	38%
Total Energy onto the Curing Surface	W	11760	6840

Table 3: Comparison between a typical arc system with heat reducing dichroic reflectors for the energy being directed towards the curing surface for a typical 1 m wide source.

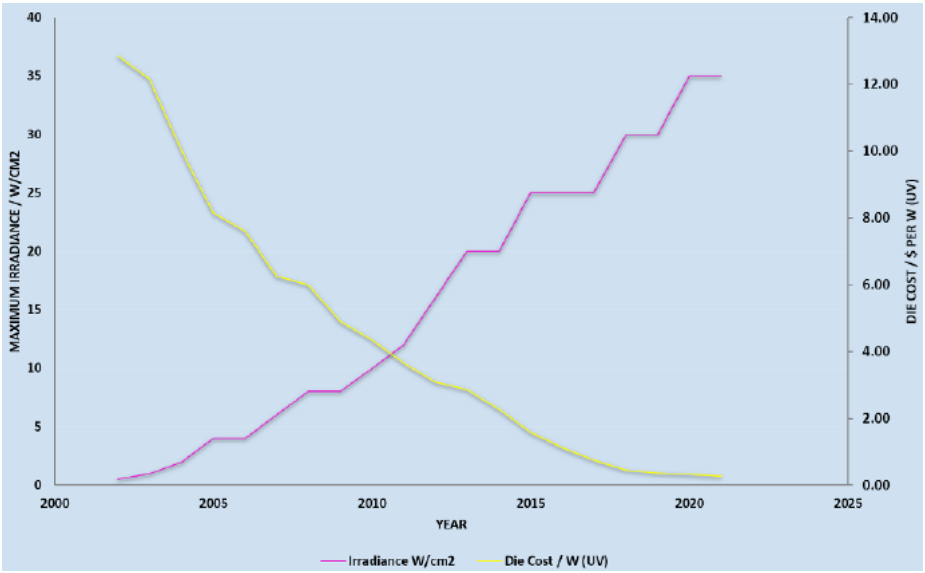

Figure 6: Evolution of UV performance and die costs for 395 nm.

bility of the UV output have always been important.

Latterly new industries such a photovoltaic cells coating and testing, Li-ion battery cells electrical isolation and sealing production and printed electronics for RFID, resistors, organic LED's have started to adopt UV curing. One of the latest growth industries has been 3D printing where UV gives different possibilities to the other additive techniques based on thermal or laser sintering. Ultimately, the desire for 3D printing is to bring metals to an affordable possibility. UVA certainly has the available power density to be of interest but currently it is just one of several technologies in R&D.

Finally, since the output achievable is now generally more than what is needed for many applications, other ways of driving the LED's such as PWM dimming, are becoming more interesting. How a particular process may benefit from operating in different modes is going to be particular to the process and its chemistry. Bimolecular curing processes or synergistic reactions may behave in different ways under the pulsed output rather than the UV being a continuous wave.

Applications UVB and UVC Regions

As mentioned previously, there is a significant region of the Arc lamp UV spectrum that LED has struggled to penetrate and there are some significant applications still using other technologies.

Food facing and medical products have much more stringent regulations for materials that can be in contact with the product. Unfortunately for UVA LED, most of the photoinitiators that have been in use such as ITX or BAPO give byproducts that are not considered safe enough or for the curing byproducts to be sufficiently low migration for use in these applications. There is a lot of effort going into developing solutions but currently, competing technology such as EB or thermal cure is used.

While the UV LED companies can point to increasing take up of UVC LED for sterilization applications brought on by the SARS Cov-2 pandemic, the reality is industrial curing applications are normally consuming 10's of kW of power and thousands of LED dies so efficiencies and cost metrics of UVC have some way to improve before being generally applied in these applications. Going back to the performance increase graph of UVA curing the die cost / W of output was a little under $13 back in 2002.

Currently we are a few years in to UVC dies being available and the comparative die cost per W is $107. It's for this reason you will only see UV LED suppliers giving $/mW. One of the key things to enable progress is to have increasing volume so sterilization and disinfection applications will drive the technology forward. It is quite a step, and no one should expect prices and performance to get near where the upper UVA is today at least not with conventional dies based on the III-V material system.

As the cost metrics and performance of UVC dies continue to improve there will be adoption. It is important to note that for most curing applications, UVC will be alongside UVA. For applications with anything but the thinnest layers and anything containing pigments need the longer wavelength to penetrate deeper into the coating. UVC alone cannot achieve this. It means that UVC will be needed only to cure the surface layers. However, even this task requires a lot of output for the fastest processes. A fast process may be running at 5m/second. A typical LED output footprint may be 20mm, so that means the exposure time is only 4 milliseconds. From current UV arc data, it is reasonable to suggest that we will need at least 10 mJ/cm2 of UVC dose per head. So that means the dose for 4 milliseconds exposure is 2.5 W of UV. A powerful UVC die may have 70 mW currently, so that is 33 dies along the curing direction. If you multiply that by 1 m wide and factor in the current UVC die cost per W, it isn't remotely commercially viable yet for these sorts of applications.

However, for sterilization and disinfection, it is viable in certain situations. These are often stationary exposures so the dose can accumulate for many seconds so the necessary output requirement can be met. The form factor of the UVC LED allows more freedom to put into places that conventional technology simply could not go. Masks, water bottles, point of use water treatment systems, personal air filters, personal hygiene products, washing machines and fridges are all applications that have increased dramatically in the last year.

In time we will move towards large commercial sterilization such as municipal water treatment. Inline process sterilization is then the same commercial reality that exists in UV curing applications in that the cost to purchase and the ongoing running cost must be viable against the current technology. Not every process is a fast extreme output requirement and UVC LED will penetrate through early adopters. Indeed there are some large-scale water treatment installations, but these are still very much gathering data to make the case.

Currently 265 nm marks the shortest wavelength that has any practical use or is commercially sold. There are a few groups that have produced 255 nm and even 235 nm dies but the output from these is measured in microwatts and lifetimes in the 100hr range at this time.

Applications Visible and IR regions

There are photoinitiators that will respond up into the blue / green region but generally the difficulty of working with the chemistry in this region is the light stability of formulations and the need to shield from the ambient light.

LED in the blue region is, however, equally as efficient as the near UV and even lower cost. Several applications have looked at using sources in this region to produce a high energy density output for thermally heating a surface. LED's can achieve continuous operation energy densities much higher than the other typical sources in this region and with reasonably good wall plug efficiency.

In the IR region there are well-established low-cost elements and lamp-based products, and given the size of many of them the cost metrics of trying to displace this technology with LED is not there, so like UVC LED, IR LED needs to look for unique form factor or operational possibilities. Certainly the choice and performance of IR LED has expanded significantly in the last few years with the arrival of the double heterojunction structure. Just like with the early UVA LED we have a source that delivers its output in a much narrower more intense band than the existing technology. It is not up to process engineers and the theoretical modelers to see what benefit such sources may enable.

Some UV curing processes, such as metal decorating, have always benefitted from the IR that arc systems delivered along with the UV from coatings to flow out better. We may see IR LED appear alongside UV LED sources for these reasons.

Summary

LED's have successfully moved into industrial production. While the coverage is not yet complete across the wavelength range, it has proved itself to be highly adaptable across a wide range of applications. LED's now drive most innovations because the larger part of new UV applications are being developed with UV LED from the get-go. One of the biggest changes from the traditional lamp technology was moving to a full electronics product where typically innovation rates and technology change cycles happen more quickly. There are a number of directions the technology make take and not all of them are necessarily based on the current LED structures. There are still competing technologies in the UV to IR ranges of the spectrum and LED is not always going to be the best fit but this is where companies that have all the technologies can advise on the best solution, be it a single technology or a combination of technologies. ■

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Safe and Stable Connection with the SMD PCB Terminal Block from WAGO's 2065 Series

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Due to its flexible substrate and individual cut options, Tridonic's LLE Flex CC LED module offers a high degree of design freedom when used in profile and linear luminaires. WAGO's 2065 Series SMD PCB terminal block is also on board to ensure stable and safe wiring.

Light has a central importance for human beings. After all, it is used everywhere: at home, when working, during shopping, and at recreational facilities, among others. Linear LED modules permit the placement of targeted accents in lights. Due to their uniform illumination, LED modules are optimally suited for any workplace: from the office to the restaurant trade or even in production and beyond. As a supplier of intelligent and efficient lighting solutions, Tridonic developed the LLE Flex CC, a flexible LED module that includes WAGO technology: specifically, a 2065 Series SMD PCB terminal block to insure fast and safe wiring of the LED module to the LED driver.

The history of Tridonic, an Austrian firm, began in 1956, when they developed a compact, magnetic control gear. Today, the company sells interior and exterior lighting solutions in more than 50 countries around the world. Tridonic's slogan – more intelligent, exciting and sustainable – is always included on their agenda for designing professional lighting.

High Degree of Design Freedom due to Flexible Substrate and Cut Options

The LLE Flex CC LED module is used in profile and linear luminaires made from extruded aluminum or sheet metal, as are commonly found in office buildings and educational institutions. The light strips are particularly well suited for decorative lighting in furnishings, as indirect or accent lighting. The LED strip can be cut every 140 mm, allowing it to be cut to the optimal length for the respective luminaire. Due to the flexible substrate and adaptable length of the LED module, it can be fixed in luminaires with round, oval or irregular shapes. This guarantees a high degree of design freedom. 16 LEDs are attached to the substrate per 140 millimeter segment, which ensures a homogeneous light image. By using an LED driver from Tridonic, or any other supplier, the linear LED module can be linked into and controlled by a smart building system or building automation system.

Color Temperatures from Warm to Neutral White

The linear LED module, which is up to 25 meters long and 14 millimeters wide, can be easily installed at the desired location using the integrated adhesive tape, which is both long-term stable and weatherproof. When installed, the LED provides 1250 lumens of light in the space. It is available in different color temperatures of 2,700, 3,000, 3,500 and 4,000 degrees Kelvin, which ensures warm to neutral white light, adjusted for the respective installation location. The LLE Flex CC guarantees a high color rendering index between Ra > 80 and Ra > 90, and a small color tolerance in a 3-step MacAdam ellipse. The light from the LED module is uniformly distributed in all directions due to the small luminous flux tolerances.

Two wiring options are available for electricians for connecting to the LED drivers. The wires can be soldered to the LED module, or the variant with the pre-mounted, low-profile WAGO – the 2065 Series SMD PCB terminal block – can be used for easy, safe and shadow-free wiring.

Minimizing Shadowing

Tridonic and WAGO are connected by a long-term, successful partnership, in which WAGO's proven technology is regularly incorporated into Tridonic products. "When developing our LLE Flex CC LED module with a flexible substrate, the WAGO 2065 series was the logical solution for bringing our new product to the market at a reliable level of quality," Hristo Ganev, Product Manager Office and Education at Tridonic, praises the compact SMD PCB terminal blocks from WAGO.

The WAGO SMD PCB terminal blocks are pre-mounted every 280 millimeters on the Tridonic light strip. This enables fast and easy wiring, without requiring soldering. Due to the very low, flat installation height of only 2.7 millimeters, undesired shadows are prevented by the 2065 Series, which is a clear advantage in lighting technology. Yet despite the small size, the SMD PCB terminal blocks from the 2065 Series offer space for connection cross sections of up to 0.75 square millimeter or 18 AWG for solid and fine-stranded conductors. The 2065 Series is therefore well suited for LED modules. Solid conductors can be terminated by simply pushing them in, thanks to the CAGE CLAMP® connection. Fine-stranded conductors can be terminated by the electrician using an operating tool. In addition, all conductor types can be easily removed as needed using the operating tool, which significantly facilitates any needed rewiring.

Figure 1: By the flexible substrate, the LED-Modul LLE Flex CC can be used in variety of ways. Photo: Getty Images.

High Contact Reliability with WAGO

The WAGO SMD PCB terminal block is securely and stably mounted on the LLE Flex CC LED module. A major benefit of the WAGO SMD PCB terminal block is the contact reliability that it provides. The conductor is always optimally fixed in the module, while the quality of solder points can vary. In addition, wiring with WAGO SMD PCB terminal blocks is faster than manual wiring and thus saves time.

Conclusion: Due to the WAGO 2065 Series SMD PCB terminal blocks, the LLE Flex CC LED Modules from Tridonic can be easily and safely connected. The PCB terminal blocks are mounted stably on the flexible substrate and cast no shadows, due to the low installation height, which benefits the light quality provided by the LED module.

Overview of WAGO's Technology

- Flat design: shadows are minimized by the compact installation height.
- Stable and safe: the conductor is firmly connected in the module, and the module is securely mounted on the flexible LED module.
- Largest conductor cross section in the smallest space: conductor cross sections up to 0.75 mm or 18 AWG are possible.

Reference

https://www.wago.com/global/lighting-technology

"When developing our LLE Flex CC LED module with a flexible substrate, the WAGO 2065 series was the logical solution for bringing our new product to the market at a reliable level of quality."

HRISTO GANEV, PRODUCT MANAGER OFFICE AND EDUCATION AT TRIDONIC

Figure 2: On the LED-Modul LLE Flex CC by Tridonic, WAGO's 2065 Series SMD PCB terminal block ensures simple wiring. Photo: Tridonic.

LED Solar Simulation Technologies

The Sun holds an unparalleled influence over the world around us. That influence has driven the development of solar simulation systems. From the production of solar cells and sunscreen, to the durability testing of space-bound craft, the ability to efficiently replicate solar radiation has become an essential tool in the manufacture of millions of products.

Ushio [1] has been reproducing the sunlight spectra for a long time. As scientific breakthroughs came and went, attention shifted from the standard halogen and xenon lamps. Now, we have entered a new era with the next generation of LED solar simulation technology. Solid state lighting (SSL) takes center stage, offering a flexible pulse drive and spectrum, as well as a lifetime that far exceeds its predecessors. In this article, Mr. Sam ROGERS and Dr. Fumihiko ODA explore the strict requirements of solar simulation and why the technological focus has shifted to LED.

References

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[9] SMBB family LEDs, https://www.ushio.eu/smbb-family
[10] EDC packages, https://www.ushio.eu/edc-family
[11] Epitex D Series https://www.ushio.eu/epitex-d-series-swir-leds-launch/

Solar Simulators

A solar, or sun simulator, is an artificial system designed to accurately replicate the spectral distribution and illuminance of natural sunlight. There are several different types of solar simulator, each with numerous technical specifications attuned to particular applications. The differentiation between the various types are often noted by the type of exposure in use—flashed, continuous, and pulsed.

The International Electrotechnical Commission (IEC) [2] described the properties of the natural sunlight that penetrates our atmosphere in IEC 60904-9; therefore, any industry-standard solar simulator must be able to operate in accordance with those guidelines.

The sunlight spectrum equal to that of the Sun is defined while taking into account the inevitable absorption and diffusion that takes place as the light passes through our atmosphere. More specifically, it is defined as the sum of the direct and diffused components of sunlight present under a pressure of one atmosphere[4], at a solar zenith angle[5] of 48.2°. This standardized definition is known as the Air Mass 1.5 Global (AM 1.5G) Spectrum (**Figure 1**). Under AM 1.5G, one Sun equals an irradiance of 100 mW/cm2.

Under IEC 60904-9, the overall performance of a solar simulator is measured and rated by three metrics:

- Spectral match to natural sunlight
- Uniformity of irradiance over the illumination area
- Temporal variability of irradiance

[4] One atmosphere equates to a pressure of 1,013.25 hectopascals (hPa).

[5] Solar Zenith Angle is the angle between the vertical from a single point on the Earth's surface and the corresponding line of sight to the Sun.

The IEC standard scores each of the three metrics on an "ABC" scale, with "A" representing the closest possible match to the respective properties of natural sunlight. This results in each solar simulation system being awarded an overall rating consisting of three letters, e.g. CBA, ABB, or in best case scenarios, AAA. That perfect triple-A score is certainly attainable with LED-based solar simulators, but to do so, some strict targets must be met.

The radiation of the sun simulator must match the AM 1.5G spectrum across several wavelength ranges between 300 nm and 1200 nm. For the highest class of sun simulators, the spectrum variance should not exceed ±12.5% in each wavelength range. The irradiation of any substrate, such as a typical 200 mm^2 solar cell, must remain even across the surface, too. The criterion on which this uniformity is judged gives a tight margin of just ±2%. Meanwhile, the stability of the irradiance over time is also a crucial factor. The power of the irradiance must fluctuate as little as possible throughout the simulation. Therefore, a measurement is taken to detect the maximum and minimum irradiance during the simulation. This gives a fairly accurate idea of how temporally stable the irradiance is.

Backgrounds

In 1969, already a significant year for space travel, Ushio developed the first 30 kW water-cooled solar simulation array. Based on the technology still used in giant screen cinema projectors today, the role of solar simulators in the testing and preparation of spacecraft soon became crucial to the safety and success of every mission.

Agencies such as ESA [3], NASA [4], and the Japan Aerospace Exploration Agency (JAXA) [5] need perfect solar simulation

services that go far beyond the AM 1.5G requirements. To prepare the Mercury-bound BepiColombo satellites [6] and next year's launch of JUICE [7] (arriving at Jupiter in 2029), discharge lamp solutions were used to test equipment durability while accounting for the punishing radiation that exists beyond the Earth's protective atmosphere. Beyond the Sun's line of sight, the vacuous void of space drops to a steady 2.7 K (–270.45 °C / –454.81 °F). Yet, in direct sunlight, objects in Earth's orbit are heated to approximately 393.15 K (120 °C / 248 °F). To maintain functionality, a spacecraft must have the ability to cope with these wild temperature changes. Temperature is only one affliction to worry about, as extreme radiation levels take their toll during a craft's operational lifetime. Certain radiation wavelengths also disrupt communications and damage vital components.

To mimic the barrage of energy sustained by spacecraft, nineteen 25 kW water-cooled xenon short arc lamps—capable of achieving flux of over 2.7 kW per m^2–were installed in in the largest vacuum chamber in Europe, ESA's Large Space Simulator (LSS) [8]. At 2,300 cubic meters, the LSS is specifically designed to accommodate thermal and mechanical testing of spacecraft and their payloads. For some power perspective, just twelve of the lamps operating at a reduced power of 20 kW are enough to achieve one solar constant[6].

Lamp-based vs LED Solar Simulation Technologies

Still in widespread use, pulsed xenon (Xe) short arc and metal halide (MH) discharge lamps have since been deployed to generate light equating to single or multiple suns. These lamp types are known for their stable light emission and a spectral output closely approximating that of our Sun. Unfortunately, discharge lamps present some drawbacks that LED technology can avoid entirely:

- Filter requirement: Xe lamps emit a wavelength range, from ultraviolet (UV) to infrared (IR), which does not exactly match that of the Sun. This requires the implementation of expensive optical band-pass filters to bring the spectrum in line with IEC 60904-9 requirements
- Excessive heat: xenon and metal halide gas lamps generate a large amount of heat. Not only does this require an extremely robust thermal management system, but the heat comes from wavelengths that are not representative of real sunlight
- Pulse width limitations and luminance degradation: In the case of pulse xenon lamps, it is not easy to control the lighting pulse time width (PW), and lighting with pulses longer than 100 milliseconds (ms) is technically difficult. Gas-based discharge lamps suffer from a decline in luminance over time. This means the brightness and intensity of the light output diminishes, leading to increasingly unreliable results and the frequent replacement of lamps
- Shorter lifespan: Depending on the type and model, discharge lamps can only last up to a few thousand hours. Alongside the reduced lifetime, using such lamps beyond their warrantied lifetime can result in potentially hazardous events, such as lamp bursts

Conversely, an array of LED packages can adequately cater for the AM 1.5G standards without running into those aforementioned problems. The main advantages of LEDs when deployed as the light source in a solar simulator are:

- Spectral flexibility: By controlling the wavelength of each individual LED, the synthesized spectrum can be flexibly changed, with benefits such as:
  - Increased spectral match precision
  - Reproduction of a variety of irradiation conditions, e.g. mimicry of sunlight at any point on the Earth, during any season, or time of day
  - For testing compound solar cells, systems can be configured to include wavelengths in the longer SWIR range
- Pulse drive flexibility: LEDs can offer a freely adjustable pulse width. Longer exposure times are required to test certain types of solar cells
- Built-in heat management: Epitex LEDs have various methods of dealing with excess heat. SMBB packages feature a copper heatsink with a high level of thermal conductively, while the smaller EDC packages possess the insulating and thermally conductive properties of a ceramic base.
- Longer lifespan: LEDs have an extremely long lifetime, saving maintenance, downtime for replacement, and time for recalibration

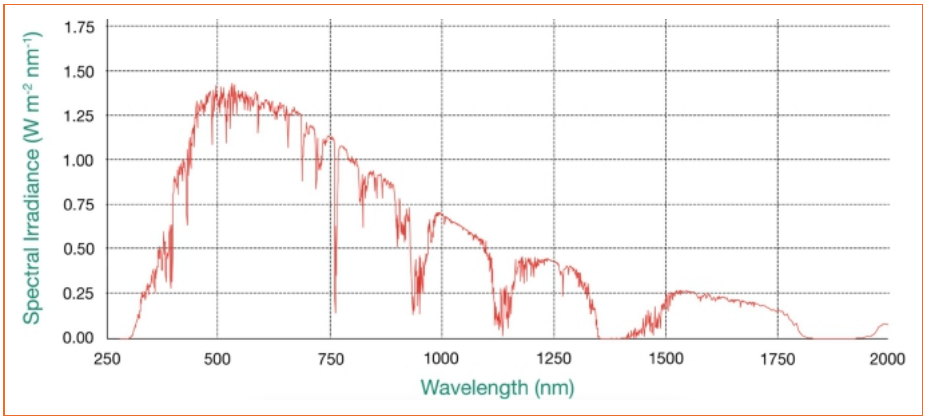


Figure 1: Air Mass 1.5 Global Reference Spectrum.

Potential Applications for LED Solar Simulators

- Aerospace
- Biomass
- Cosmetics
- Environmental Science
- Material degradation
- Photochemical catalysis
- Photovoltaics (PV) production and testing
- Plastics, paints, lacquers, varnishes, and other coatings
- Quality assurance
- Sunscreen research & development
- Textiles industry

LEDs for Solar Simulation: SMBB and EDC LED Packages

Among the most popular are the SMBB family LEDs [9], which feature excellent heat dissipation, and EDC packages [10], which boast a tiny footprint to cram even more LEDs into tight spaces. The package types include single- and multi-chip LEDs covering wavelengths from 365 nm to 1750 nm; crossing through the ultraviolet (UV) and visible light ranges, up to the short-wavelength infrared (SWIR) region (1050–1750 nm).

[6]One solar constant is equal to the amount of radiation energy that reaches Earth from the Sun.

SMBB Package

As a flagship 'family' of LEDs, the SMBB family is perhaps the most versatile set of LEDs on the market. Equipped with a copper heat sink, these record-breaking 5 mm^2 LED packages are available in single or multi-chip form (**Figure 2**).

This means solar simulators can have a series of single-wavelength, 1 mm^2 high-powered chips at their disposal; or mount up to three chips to emit three distinct wavelengths from each package. If the solar simulator requires more power in a certain spectral range, a multi-chip SMBB can be mounted with up to three chips of the same wavelength and triple its output. One example of this multi-tasking package type is the ability to emit and detect light within a single 5 mm^2 footprint.

Incidentally, the most powerful and efficient SWIR LEDs ever produced, the Epitex D Series [11], covers the long wavelength side of the solar spectral match specification (**Figure 4**). Combining all package and series types into a single array builds the perfect solar simulation solution with excellent customization options, including your choice of variations on wavelength, chip size, lens type, and more.

The D Series utilizes different semiconductor materials in order to find the perfect chip material for each wavelength. A wide range of semiconductor materials are selected depending on the wavelength required, including aluminum gallium arsenide (AlGaAs), aluminum gallium indium phosphide (AlGaInP), aluminum gallium indium nitride (AlGaInN), and indium gallium arsenide phosphide (InGaAsP). InGaAsP is used to emit the SWIR wavelengths beyond 1000 nm, up to the 1650 nm region. This longer wavelength range is particularly useful for the solar simulation testing of compound solar cells and even detecting defects in the production process.

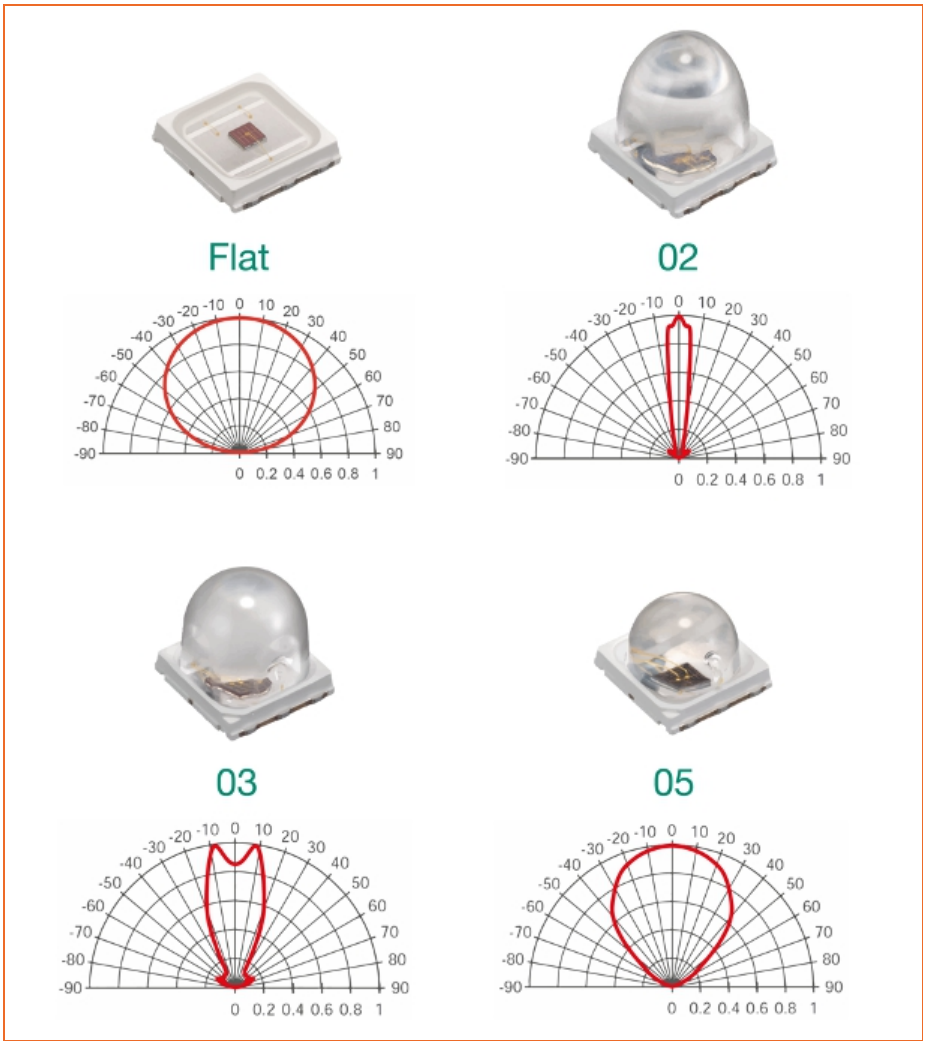


Figure 2: SMBB LED lens types and radiation characteristics.

EDC Package

The smaller EDC packages (**Figure 3**) feature a ceramic base, which serves as an excellent heatsink and provides exceptional isolation from the circuit. The 3.5 mm^2 EDC packages are mounted with a single 1 mm^2 chip to remain capable within the same applications as single-chip SMBBs. The key difference, however, comes with the smaller footprint, freeing up space for more LEDs or the addition of other space-hungry components.

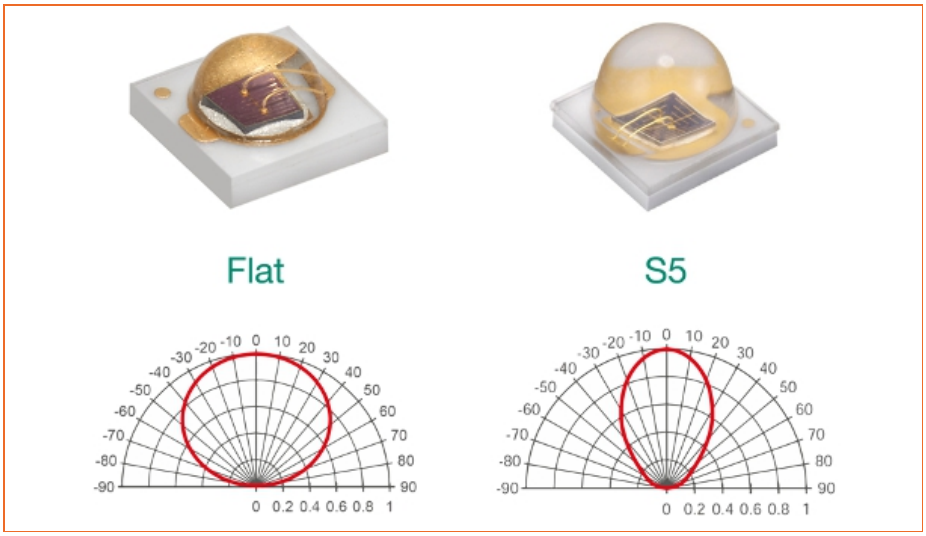


Figure 3: EDC LED lens types and radiation characteristics.

Silicon Solar Cell Production

One of the most important areas of application for solar simulators is the testing of individual solar cells or entire arrays that convert solar radiation into electrical energy. This principle of energy conversion - also known as photovoltaics - is used to generate electricity on the one hand and serves as the basis of photo-sensor technology on the other (**Figure 5**).

Constructed from semiconductor materials, the most common solar cells are silicon-based (Si). While there are other compound and organic materials that can be used for the same purpose, Si is one of the most accessible elements on Earth, which significantly boosts its popularity. Silicon has a "forbidden band gap" of 1.12 eV (electron Volts), which means the photons hitting the solar cell must possess energy in excess of 1.12 eV in order to generate an electronic charge.

Since the circumstances for a solar cell to operate are so specific, LEDs are perfect for imitating different environmental conditions. For example, solar cells will generate far less electricity on a cloudy day, than compared to midday in the height of summer. By using a solar simulation system driven by LEDs, manufacturers know exactly how efficient their cells are in every possible scenario.

Benefits of LED-based Solar Simulation

- Can also be fitted with photodiodes for additional sensing and measurement capabilities
- Chips are almost completely monochromatic for increased accuracy in the simulation of solar radiation
- Continuous wave or pulsed optical output can be selected
- Extremely long operating lifetime
- Flexible light pattern
- High power output
- Independently-run chips
- Mercury-free
- Multiple chips of different wavelengths can be mounted in one LED package
- Relatively cheap to buy and to run
- Small footprint
- State-of-the-art technology

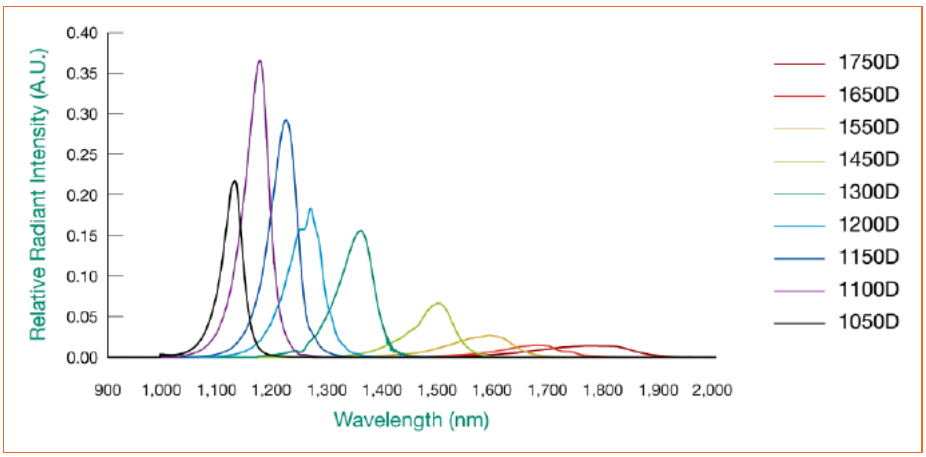


Figure 4: Epitex D Series SWIR LEDs.

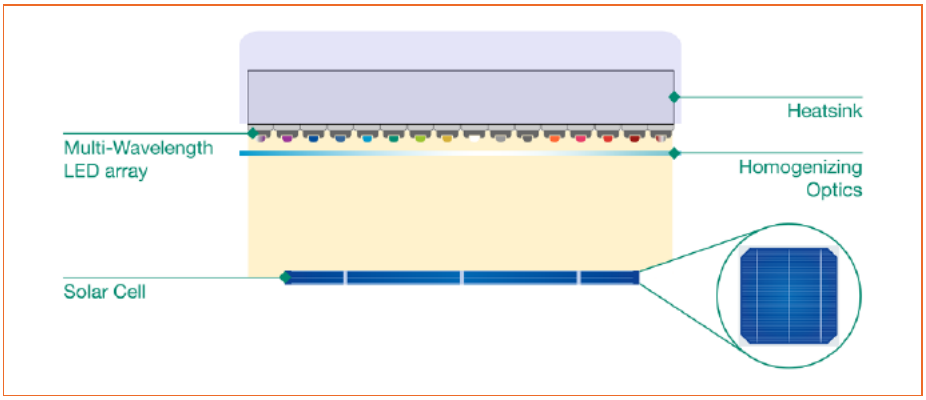


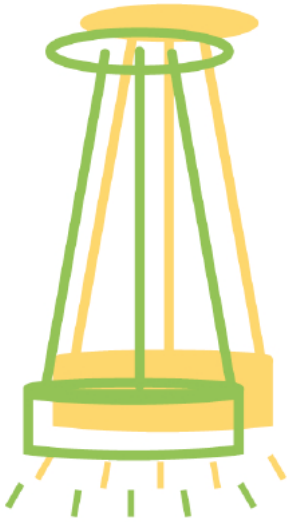
Figure 5: Concept schematic of an LED Solar Simulator for solar cell testing.

AUTHOR: Sam ROGERS
After working in the UK film & video industry and the Equity Capital Markets division of a Big Four corporate accounting firm, Sam ROGERS left Britain to become a freelance copywriter. He specialized in the research and analysis of ethics in arenas such as banking, the restitution of wartime-looted art, and global coffee production. Since 2019, ROGERS has worked alongside Agata MICHALAK to share the in-depth knowledge of Ushio's technical expertise, with particular attention to cinema projection, ultraviolet pathogen inactivation, and semiconductor technology.

AUTHOR: Fumihiko ODA, Dr.
Dr. ODA studied Material Sciences at Osaka University, in his native Japan, before completing his Ph.D. in laser generation based on synchrotron radiation, at the same institution. ODA-san joined Ushio Inc., in 2010. Alongside establishing himself as a key strategist within the Solid State Lighting division, he also spent three years sharing his technical expertise as the Group Leader of Ushio's SSL Module Development division.

Personal Good Light – The Second LED Revolution

by Jan DENNEMAN, Good Light Group, The Netherlands



Around the year 2010, LEDs became the lighting industry's main light source. The trigger for this transition was energy saving. Their introduction was one of many enormous contributions from the lighting industry to fight global warming.

LEDs are small electronic devices that can easily be integrated with other electronic components like switches, dimmers, chips, sensors, etc. Lighting systems became an integral part of smart buildings and sometimes even the backbone. This enabled several additional features like providing connectivity, LiFi, presence detection, indoor positioning, asset tracking and management, information about the use of buildings or streets, etc. This is the first LED revolution and it's in full swing.

The second LED revolution is the introduction of 'good light'. This will be even more impactful because it affects the billions of people that have to live and work inside. We spend more than 90% of our lives indoors where we are, to a large extent, deprived of natural daylight. Science is very clear about this: we need daylight to synchronize our biological clock. Lack of exposure to daylight causes poor quality sleep which can make us unfit and subject to mood swings. We need to be outdoors, in daylight, every day for at least two hours. As this is not possible for everyone, the light indoors needs to compensate for the lack of daylight. The indoor lighting needs to be transformed into 'good light': light that mimics daylight and positively influences our biological clock. Lighting systems in buildings cater to the visual functions, safety and ambience in indoor spaces. But these light levels are too low and too static to compensate for the lack of daylight. Light intensities need to be approximately five times higher with a more dynamic spectrum. For the detailed background and requirements of Good Light see: https://www.goodlightgroup.org/good-light-guide [1].

How can you have Good Light indoors if daylight does not penetrate far enough into a building? There are two options: The first one is to upgrade the current ambient lighting to match the requirements of Good Light. In professional environments most of the lighting is installed in ceilings far away from human eyes. This means that light levels need to be increased significantly. The alternative solution is to add Personal Good Light to the existing ambient lighting. Light closer to the users. This works for professional as well as for home situations. Think of a desk lamp that provides the compensation for daylight for people doing desk related work in offices and factories. Place a desk lamp next to the computer screen or workstation. Or think of standing lamps in living room areas or care centers, of hanging lamps closer to the eyes of children in schools and universities, or bed lamps for people in hospitals. There are many options to bring Personal Good Light into indoor environments. LED technology in smart connected systems make it possible to mimic the natural daylight cycle indoors. Personal Good Light can be tuned to the user's preferences and needs.

It is closer to the eye, which makes it easier to realize the light levels and dynamic spectra needed to enjoy the healthy effects of daylight.

The second LED revolution is focused on health and wellbeing. People need daylight. The lack of natural daylight in buildings can be compensated with Personal Good Light. This will help make billions of people healthier by helping them sleep better, giving them more energy during the day, and improving their mood. Upgrading the current ambient lighting systems and adding Personal Good Light is an obvious way to go to improve the life quality of billions! Join the movement of Good Light. Look for more information at https://www.goodlightgroup.org [2]. ■

AUTHOR: Jan DENNEMAN
Jan Denneman is the Founder and Chairman of the Board of the Good Light Group as well as Honorary Ambassador of the Global Lighting Association. The Good Light Group is a non-profit organization that promotes the use of Good Light indoors. Good light is daylight or electric light with comparable beneficial effects.

Jan has more than 40 years of experience in executive roles in sustainability, innovation and business development and has held senior innovation and marketing roles at Philips Lighting (now Signify) during the industry's transition to LED and Intelligent Lighting Systems. He founded several international consortia, such as the Global Lighting Association, Zhaga Alliance, the Connected Lighting Alliance and LightingEurope. Jan was President of the Global Lighting Association from 2007-2017 and President of LightingEurope from 2013-2017.

References

[1] https://www.goodlightgroup.org/good-light-guide
[2] https://www.goodlightgroup.org

ENLIGHTEN YOUR CLOCK

How your body tells time

written and illustrated by Coline Weinzaepflen
Edited by Manuel Spitschan, PhD

SCRAMS

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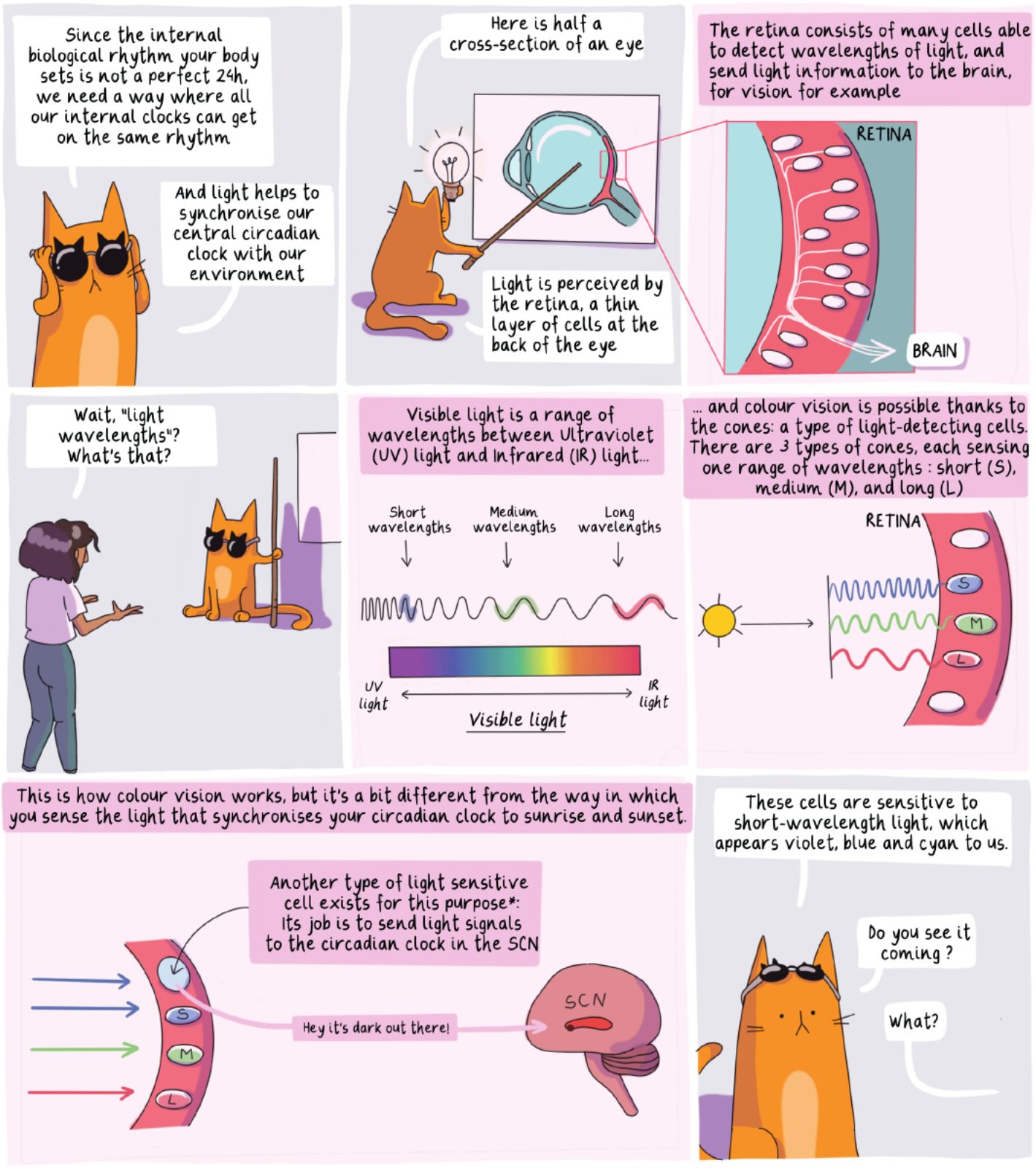
Topics

Appendix

Good Morning

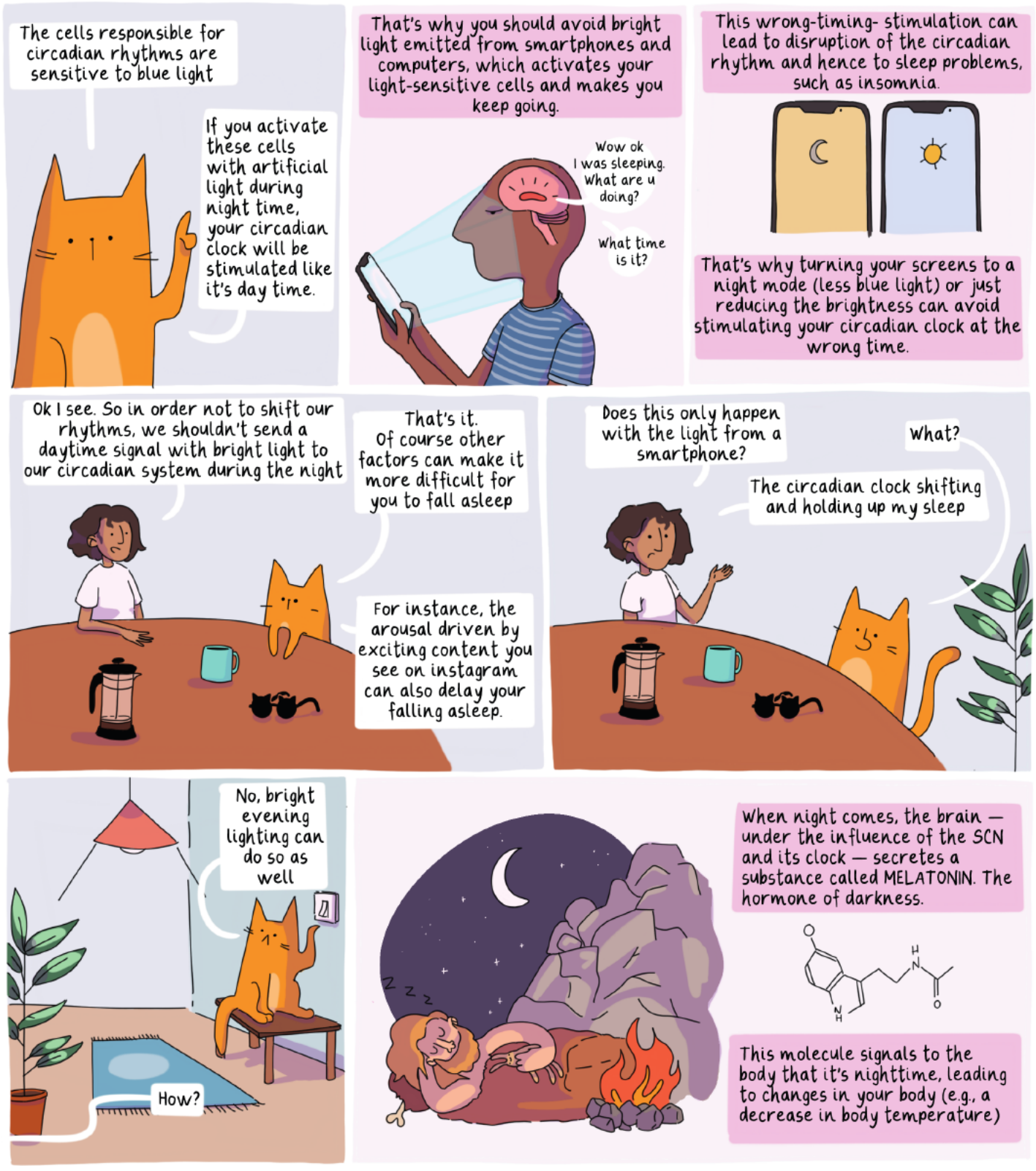
Your Circadian Clock

Sensing and Perceiving Light



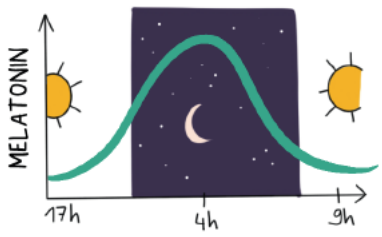
* Neuroscientists call them the ipRGCs : intrinsically photosensitive retinal ganglion cells

Rhythms in the Evening



Melatonin Secretion and Its Suppression by Light

In normal conditions, melatonin is synthesised during the night...



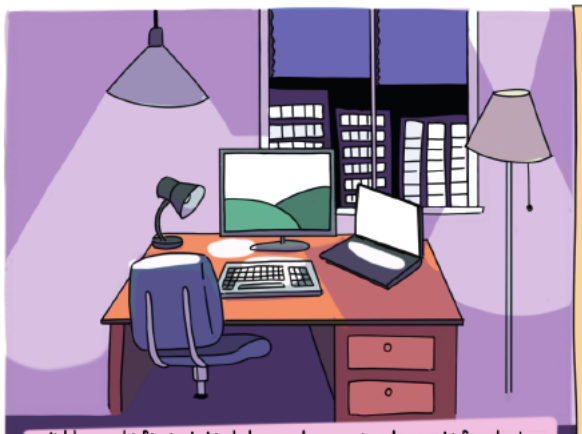
...but it is not produced throughout the day

In diurnal animals, melatonin is a signal for sleep.

In nocturnal animals, melatonin is still secreted during the night but it is a signal for activity

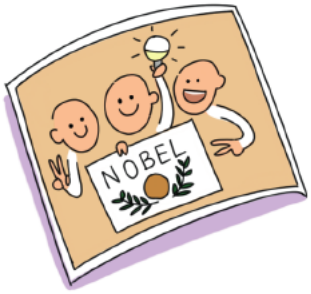
→ melatonin has different effects depending on the species

But the light environment has been subject to many changes for humans since the arrival of artificial light during the 19th century



With artificial light and our indoor lifestyle, light doesn't stop with the sunset

Bright light can reduce night time secretion of melatonin depending on the light environment and the kind of light bulb used (LED, incandescent, fluorescent)



In 2014, the Physics Nobel Prize was awarded for the invention of blue LEDs, which paved the way to making white-light with energy-saving LED light sources

So light in the environment contains blue light

Blue light stimulates circadian cells in the retina

Circadian cells acts on the SCN and suppress melatonin secretion (just like in daylight)

This can lead to circadian disruption and sleep disturbances

All my light comes from LED lights ...

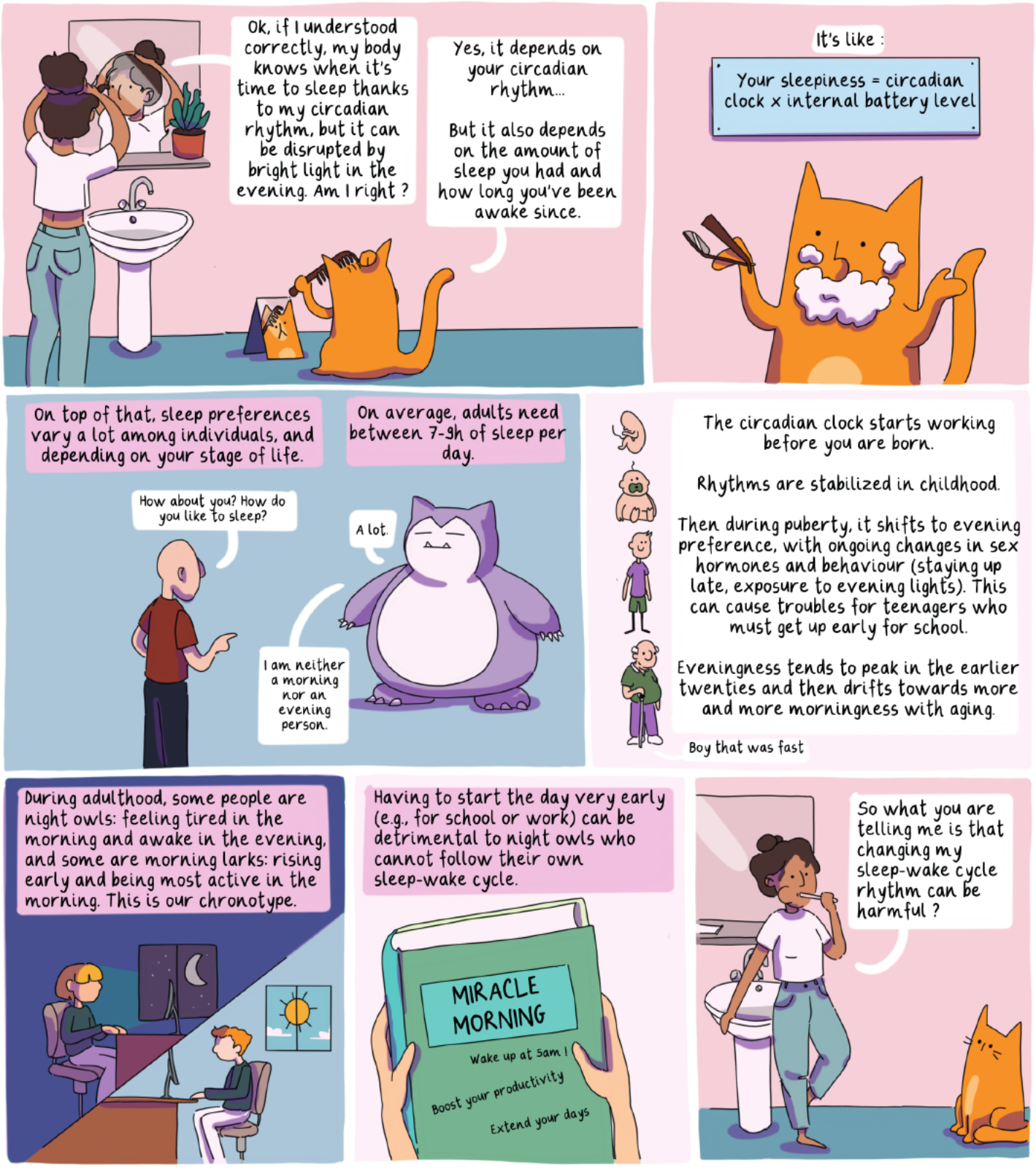
Don't panic, you can just dim your lights in the evening

Plus, all humans aren't equally sensitive to melatonin suppression by indoor lights

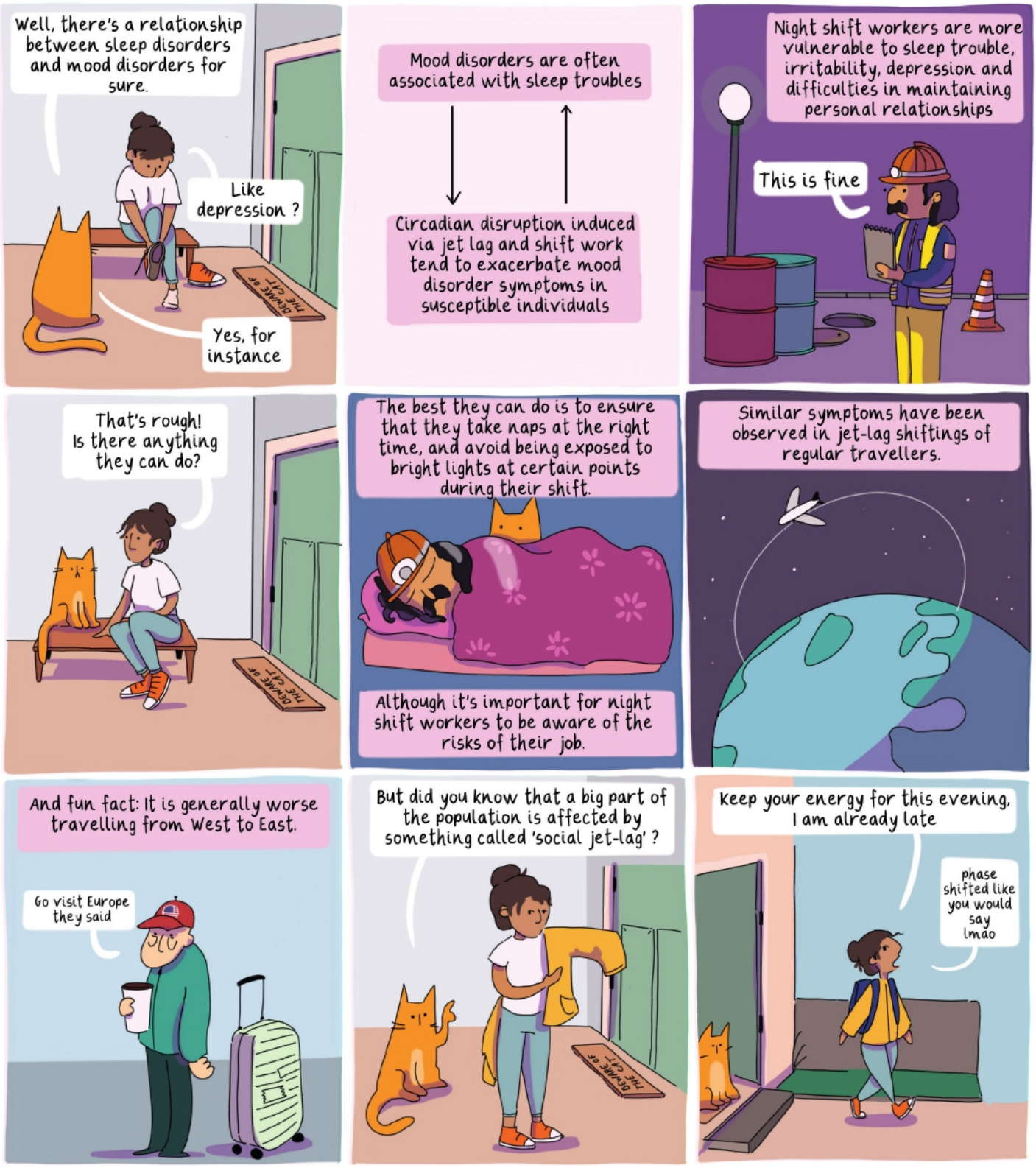
But for people having sleep problems, getting less bright light at night can be helpful for better sleep!

*Light-emitting diodes

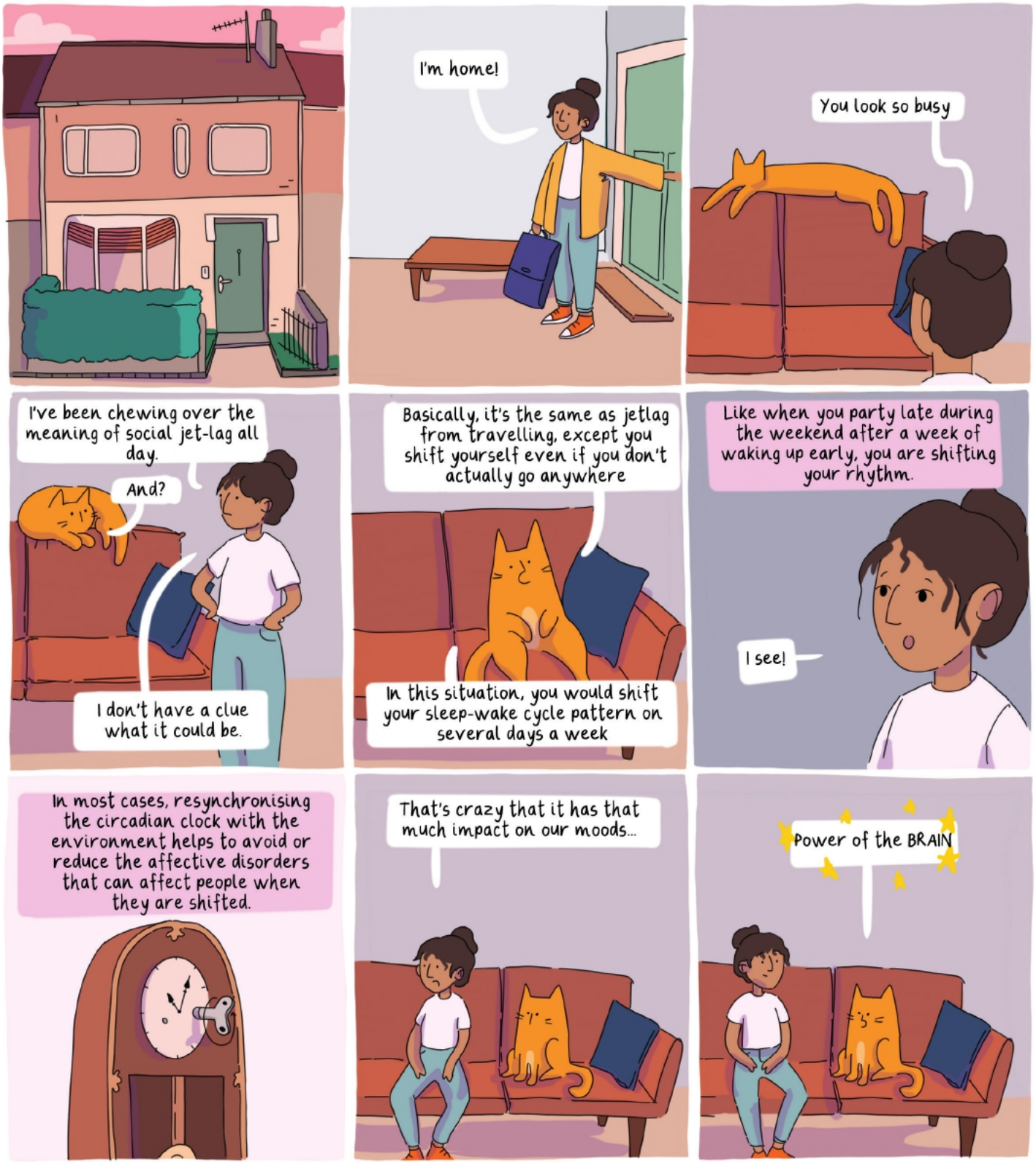
Chronotype and Sleep Timing Preferences



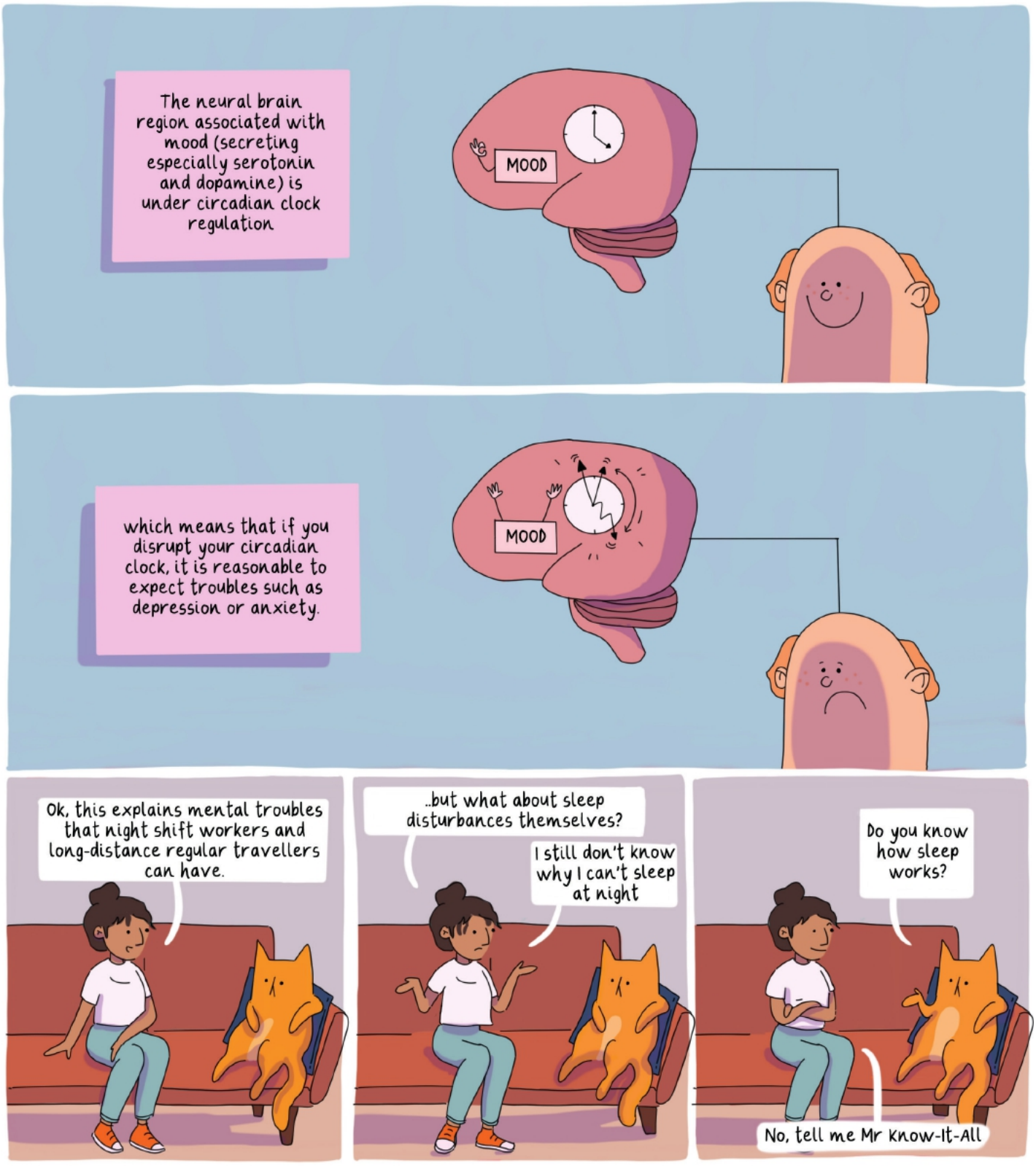
Circadian Rhythms Shifting and Consequences



Social Jetlag



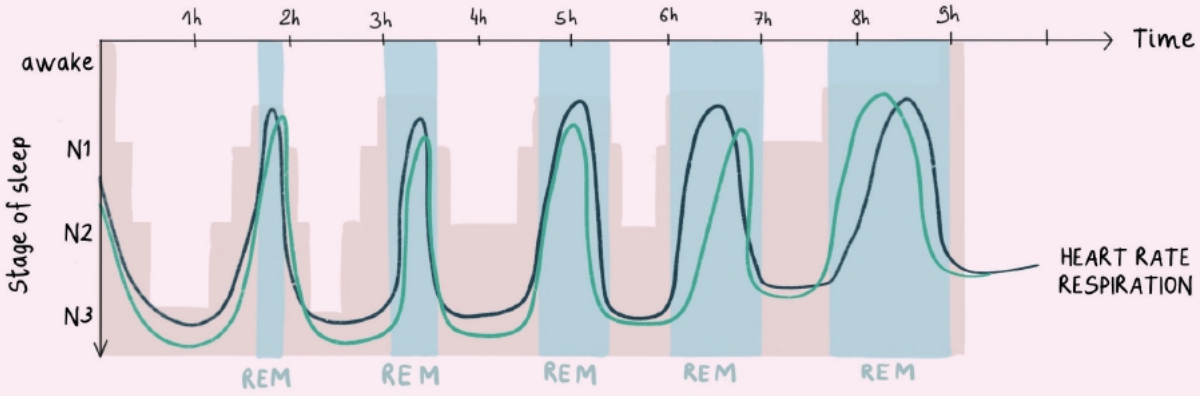
The Relationship Between Sleep and Mood



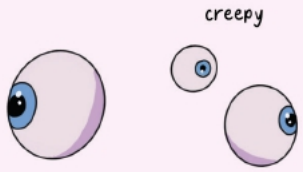
Sleep Phases and Dreams

For centuries people thought that sleep was a uniform passive state of rest. Nowadays, scientists are better at studying sleep. The approach used to record sleep activity, called polysomnography, is also used to diagnose some sleep disorders for instance. It consists of the patient spending nights in a sleep laboratory. Thanks to this technique, sleep can be understood better!

By studying sleep, scientists have discovered that sleep oscillates between different states: stages N1, N2, N3 and Rapid Eye Movement (REM). Our respiration and heart rate (and others) vary depending on the phase we are in.



REM (rapid eye movement) is a phase also called paradoxical sleep. Your eyes are making large movements behind your eyelid.

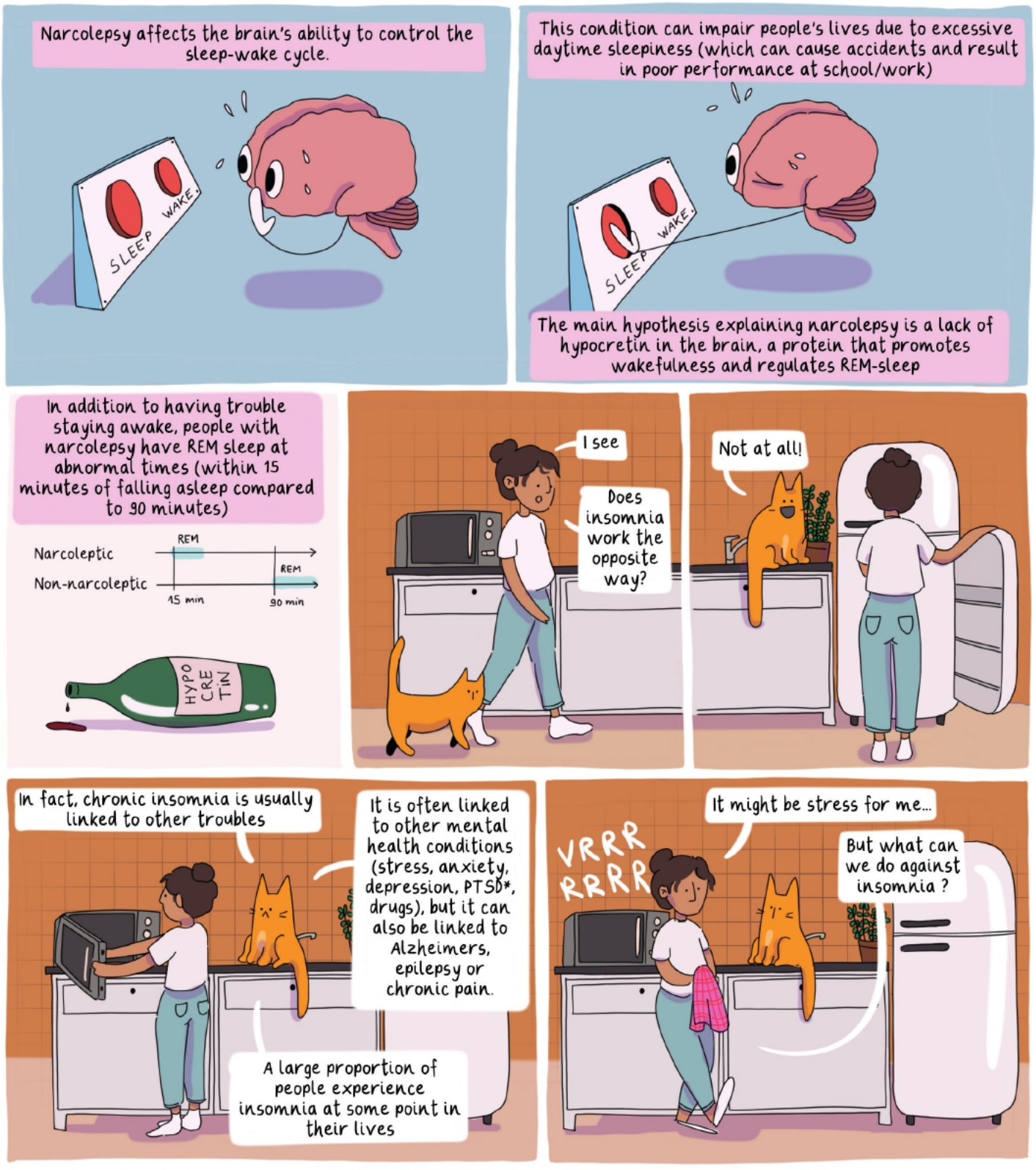


Humans have 5 or 6 REM phases per night. Scientists suggest that this stage of sleep would promote learning functions.

REM-phase is when the dreams occur, especially the most bizarre ones. When you remember your dreams when you wake up, it's very probable you were in REM-sleep.

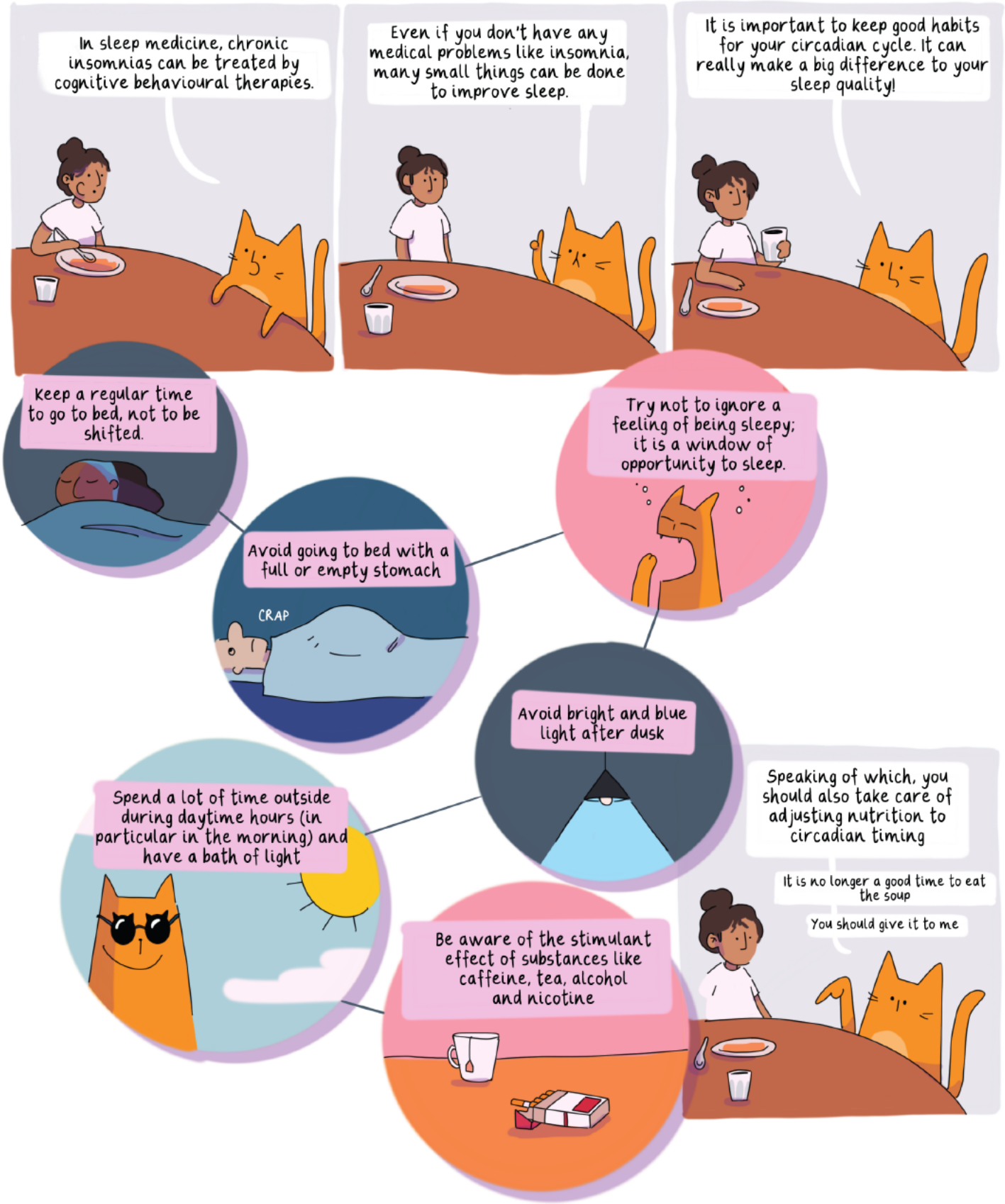
Now that you have understood what REM is, it is easier to understand pathologies like narcolepsy

Narcolepsy and Insomnia

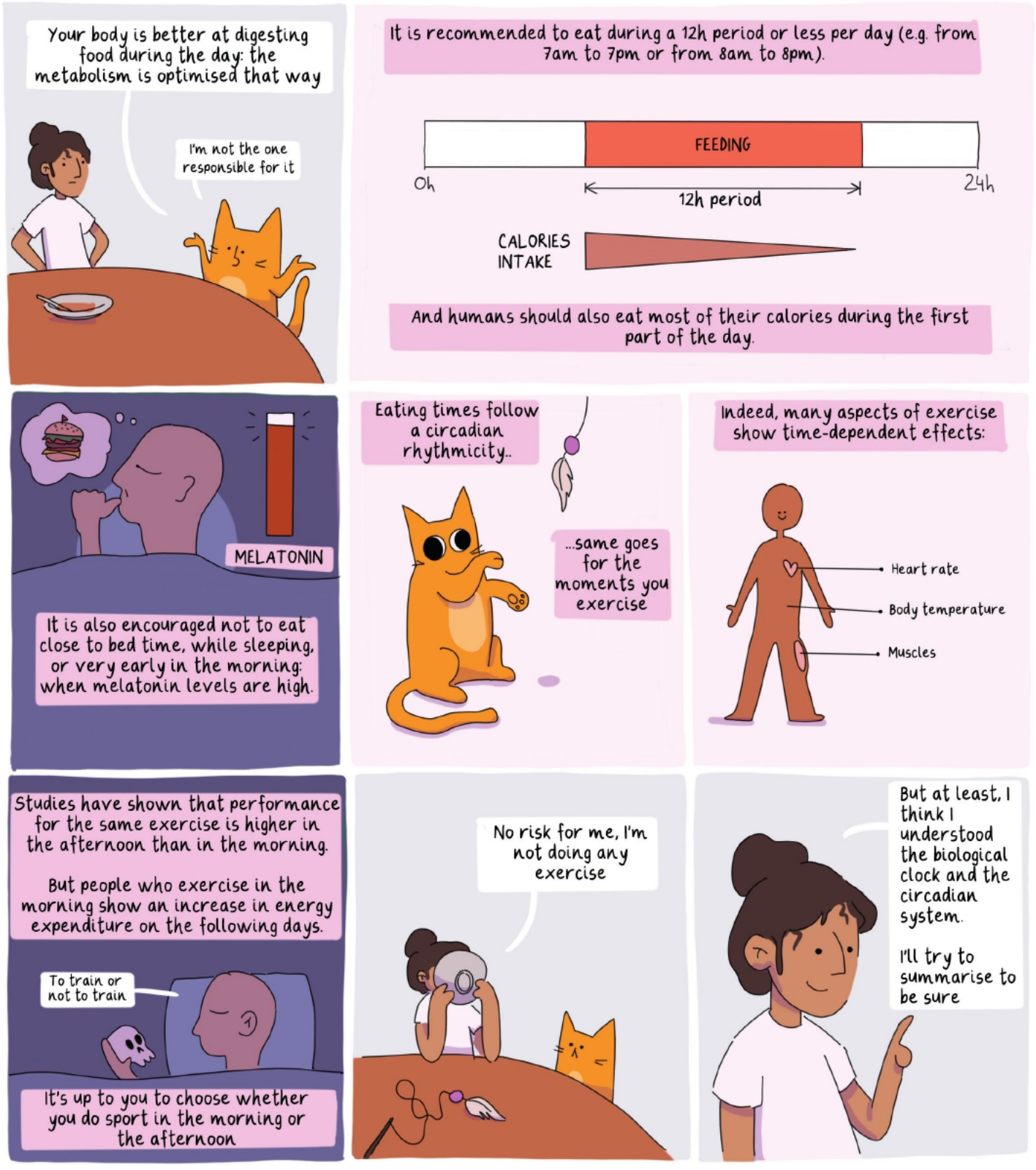


*PTSD: Post-traumatic stress disorder

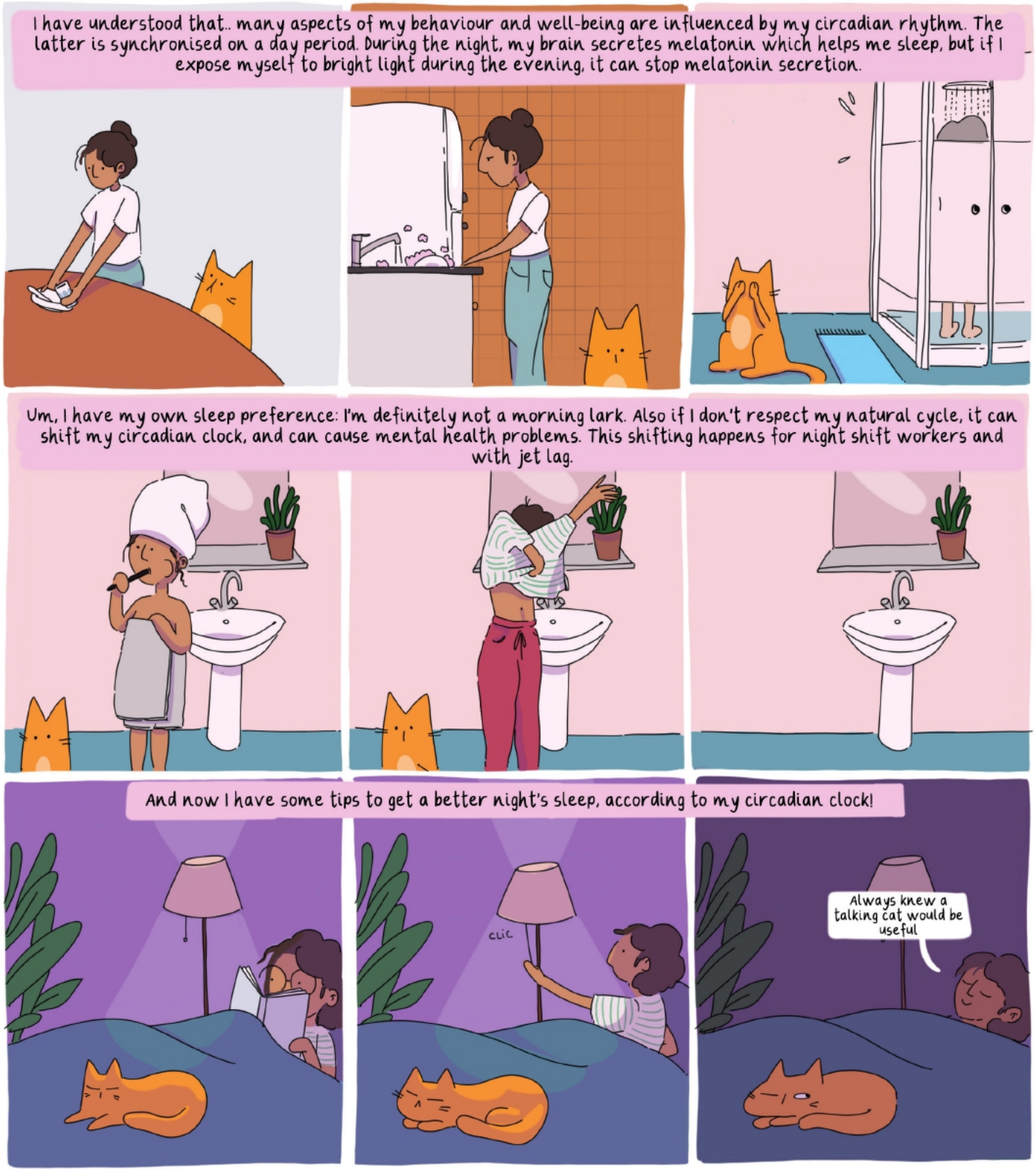
Good Habits to Support Your Circadian Clock and Sleep-wake Cycle



Nutrition and Exercise in Circadian Rhythms



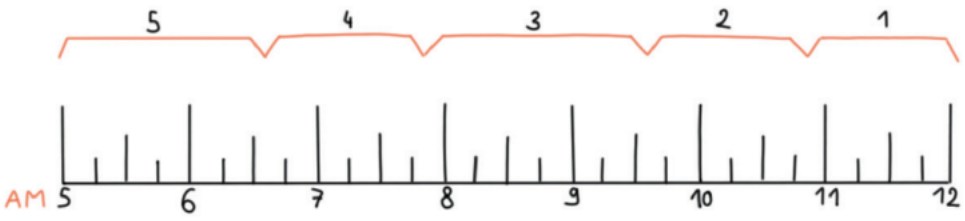
Conclusion


I have understood that.. many aspects of my behaviour and well-being are influenced by my circadian rhythm. The latter is synchronised on a day period. During the night, my brain secretes melatonin which helps me sleep, but if I expose myself to bright light during the evening, it can stop melatonin secretion.
Um, I have my own sleep preference: I'm definitely not a morning lark. Also if I don't respect my natural cycle, it can shift my circadian clock, and can cause mental health problems. This shifting happens for night shift workers and with jet lag.
And now I have some tips to get a better night's sleep, according to my circadian clock!
clic
Always knew a talking cat would be useful

Test Yourself: Are You a Morning Lark or a Night Owl?

Score your points from each question

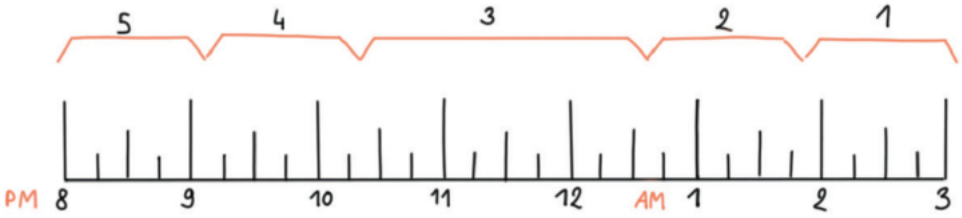
1 Considering only your own «feeling beat» rhythm, at what time would you get up if you were entirely free to plan your day?



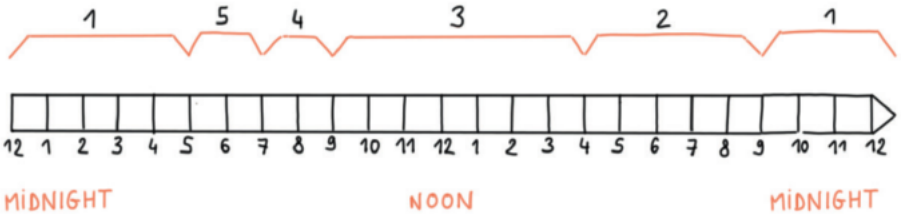
2 During the first half hour after having woken in the morning, how tired do you feel?

Very tired 1
Fairly tired 2
Fairly refreshed 3
Very refreshed 4

3 At what time in the evening do you feel tired and as a result in need of sleep?



4 At what time of the day do you think that you reach your «feeling best» peak?



5 One hears about «morning» and «evening» types of people. Which ONE of these types do you consider yourself to be?

Definitely a «morning» type 6
Rather more a «morning than an «evening» type 4
Rather more a «evening» than a «morning» type 2
Definitely a «evening» type 0

Results

On the basis of the range of the direct total score, we can divide people, approximately, into five groups based on their score.

If you want to do the full questionnaire and get specific advice depending on your chronotype, visit this website:
chronotype-self-test.info/index.php?

Score

22-25 ..... Definitely Morning Type
18-21 ..... Moderately Morning Type
12-17 ..... Neither Type
8-11 ..... Moderately Evening Type
4-7 ..... Definitely Evening Type

Adapted from the reduced Morningness-Eveningness Questionnaire (DOI: doi.org/10.1016/0191-8869(91)90110-W)

Further Information

If you have found this book interesting and would like to learn mode, here are some interesting

How to sleep better:

More details about clinical conditions and sleep in general
www.mentalhealth.org.uk/publications/how-sleep-better

Here you will find more details about many topics (Do I have insomnia?/Am I getting enough sleep?/The causes of snoring, etc.)
www.thensf.org/sleep-health-topics/

More information and support for children, adults and professional
thesleepcharity.org.uk/information-support/

Insomnia:

What causes insomnia? Dan Kwartler – TED-Ed
A well explained video about insomnia
youtu.be/j5Sl8Lyl7k8

7 healthy tips for a better night's sleep
blog.ed.ted.com/2016/08/23/7-healthy-tips-for-a-better-nights-sleep/?utm_source=youtube&utm_medium=social&utm_campaign=insomnia

Sleep in teenagers:

The Teen Sleep Hub
A series of videos about anxiety, social media, peer pressure, and their relation to sleep
teensleephub.org.uk

SCRAMS
Teenagers are not lazy!
scrams.sphsu.gla.ac.uk/?page_id=213

Sleep Scotland
A guide entitled "Sleep support for adolescents" is available here:
www.sleepscotland.org/education/teen-zone/

If you think your sleep troubles could be linked with anxiety or depression, here are some useful resources to find help:

A centralised website with a lot of information about mental health
youngminds.org.uk/find-help/conditions/depression/

Whatever you're going through, you can contact the Samaritans for support.
www.samaritans.org
Phone (from UK): 116 123
Email: jo@samaritans.org

Offers confidential advice and support for young people struggling with suicidal thoughts.
www.papyrus-uk.org
Phone (from UK): 0800 068 4141
Text: 07860039967
Email: pat@papyrus-uk.org

Childline If you're under 19 you can confidentially call, chat online or email about any problem big or small.
www.childline.org.uk
Phone (from UK): 0800 1111

Disclaimer: This book does not replace medical advice or diagnosis. Please contact your health provider if you are concerned.

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