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**Lps DIGITAL
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7 December 2022
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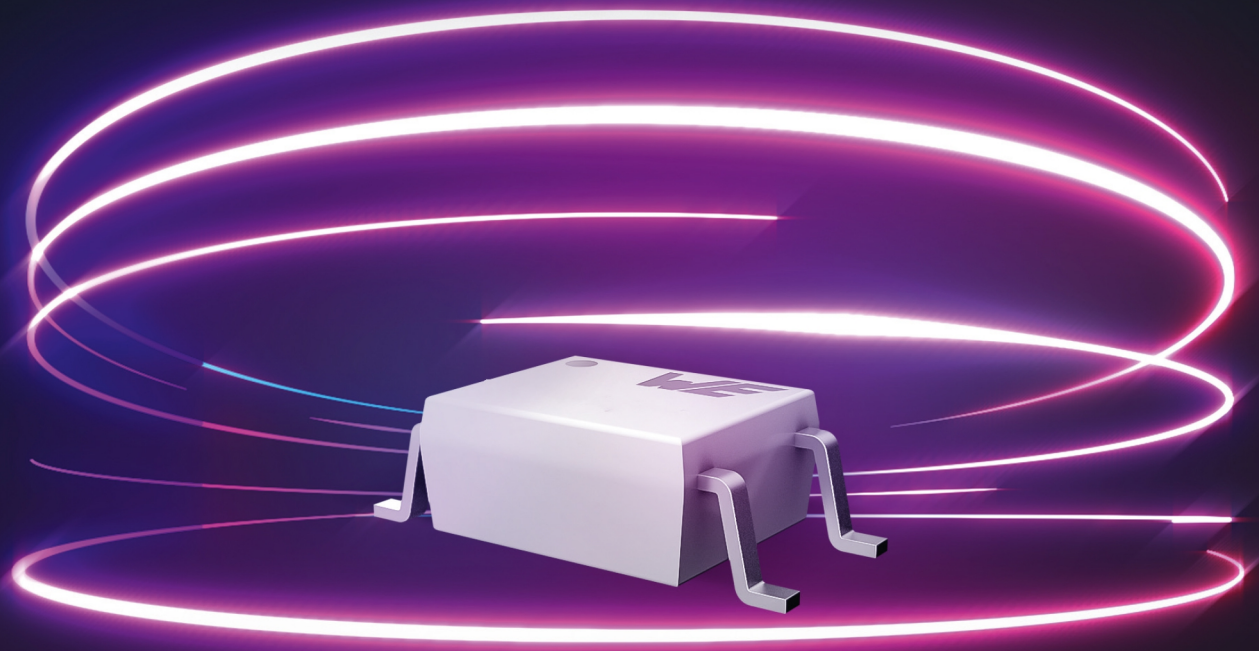
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Highlights

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



DIP-4



SOP-4



LSOP-4

From Inspiration to Innovation



This issue incorporates a great combination of what is needed to be inspired and how to generate innovations based on that inspiration. On the one hand, we dive into technological developments and look at MicroLEDs, energy efficiency and intelligent buildings. On the other hand, we incorporate how to learn from applications combining the latest technologies with promising innovative lighting solutions. In her piece, Laura Cizauskaite gives us examples of lighting in the hospitality sector. It was also very gratifying to have the chance to interview three masterminds of the lighting world, Hiroyoshi Ogawa, Stelios Zerefos and Rogier van der Heide. Their views on inspiration and innovation were thought provoking. Matthias Kassner, rounded everything up by suggesting that we be "Ready for the Unexpected".

We were very much inspired by our visit to the Light + Building in Frankfurt. Our many contacts, and the myriad of innovations and technology breakthroughs, gave us reason to believe in a positive development of the lighting sector in the coming year. Being inspired, being open minded, and using the latest technologies remains the key to success.

On Dec 7, we will hold the LpS Digital Summit 2022. This is where lighting trends and innovation topics will be discussed and the LpS Digital Awards 2022 for breakthrough innovations will be showcased. Make sure you take advantage of this opportunity and save the date.

Now, sit back and be inspired by the compelling articles in the LpR #94.

Yours Sincerely,

Siegfried Luger

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

A large graphic of white lines radiating from a single point on the left, forming a semi-circle that spans across the upper half of the page. The lines are thin and closely spaced, creating a sense of motion and light. The background is a gradient from light blue at the top to yellow at the bottom.

Dynasolis™ Light so Dynamic

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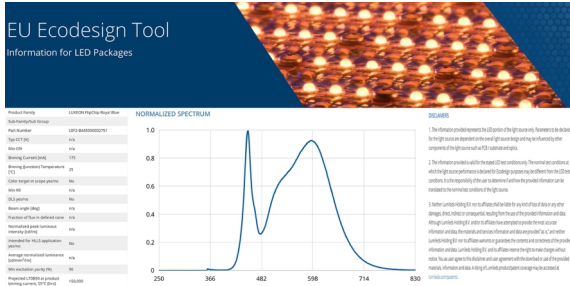
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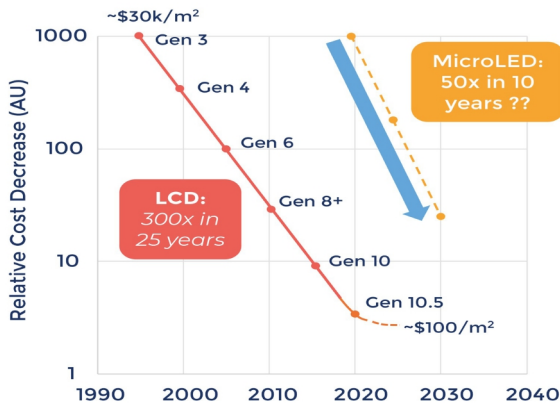
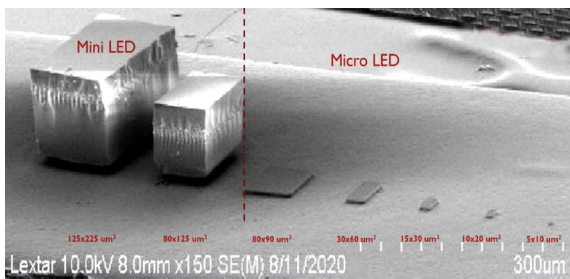
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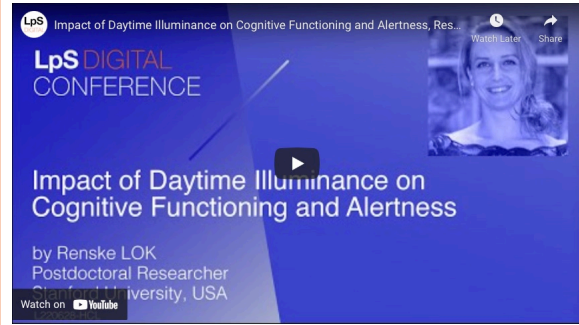
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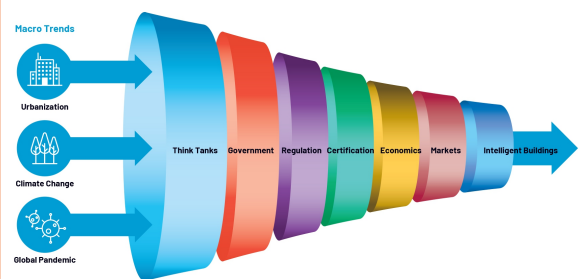
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Matthias KASSNER

Matthias leads the product marketing team of EnOcean where he is responsible for defining energy-harvesting solutions that deliver IoT sensor data. EnOcean sensors operate wireless and self-powered from the environment which makes them quick to setup and maintenance-free during operation. Data from these sensors is used to make our everyday environment - in the office and at home - smarter, more comfortable and more sustainable.

Before joining EnOcean in 2013, Matthias worked for 12 years at Texas Instruments (TI) in different positions from SW developer and Wireless Field Application Engineer to EMEA Product Marketing Manager for TI's Application Processor portfolio.

Being Ready for the Unexpected

Unexpected events provide challenges to our daily life and the environment we live in. The vast majority of our time – more than 90% for European residents according to the WHO - is spent indoors; making buildings smarter and more resilient is therefore a key requirement when preparing ourselves and our environment for unexpected events. Two major disruptions since the beginning of 2020 have highlighted both the opportunities and the challenges faced by adapting current technology such as smart lighting systems to address unexpected requirements. Let's look at those in more detail. First, the Covid pandemic radically changed work and life patterns in a way that had been unimaginable before. Occupancy and utilization restrictions, social distancing and other safety measures very quickly went from unimaginable to daily experience. Intelligent building automation systems – such as smart lighting controls – had the unique opportunity to demonstrate their added value. Simple control information – such as occupancy – could suddenly be used not only to control lighting or HVAC systems, but also to determine the utilization of office areas, enforce distancing and schedule cleaning and disinfection. Augmenting existing occupancy information with additional sensor data to track individual desk utilization or to monitor (and ultimately control) air quality would have enabled safer and healthier work environments.

Second, the recent energy crisis has re-emphasized the focus on sustainability and energy efficiency. Dramatically rising energy costs make demand-based lighting, cooling and heating a commercial necessity. Government legislation such as the requirement to reduce heating to 19°C during winter additionally underscores the need to effectively measure, control and document environmental parameters.

The ability to respond to these challenges has highlighted key differences between hard-wired, proprietary solutions and wireless, standardized, extensible solutions.

Adapting existing hard-wired solutions to extract and augment the available sensor data was largely not possible within the very limited timeframe, given the constraints on building access and available, skilled personnel. Even today, finding the required personnel to wire up new sensors to an existing building automation system or to extract certain data points from it would be a challenge. Achieving this within the time window between the start of Covid to full lock-down was outright impossible. Open, wireless systems that provide an open data interface or even the option to extend the existing system with new sensor types (such as CO₂, desk utilization or temperature sensors) could address these challenges much easier. Using wireless communication removes the need for installing new cabling and for physical access to the existing building automation system. Self-powered sensors that do not require wiring to provide their power supply, further optimize the installation. Having an open system configuration – with support for additional sensor types - and standardized access to the sensor data also proved to be a critical differentiator.

“We need to think of data as money.”

MATTHIAS KASSNER

This holds important lessons for the future – the value of data is rising, in normal and especially in unexpected circumstances. Having simple access to already available data - such as occupancy data in lighting control systems - can make a lot of difference to finance and operations. When implementing new technology – such as smart lighting systems – we need to think of data as money. We should focus on standardized, open systems that make existing data accessible and enable augmentation with additional sensors so that we are ready for future challenges – both expected and unexpected. ■

M.K.



The Light You Need.

Industry lighting: Five success factors you really need to know about

Almost every branch of industry needs powerful lighting to manufacture high-quality products. OSRAM DS identifies the five most important factors that you should know in order to be successful with modern, LED-based industry lighting today.

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Nicolai Heber
OSRAM Expert for Linear Lighting Systems

Convince your industry customers with these five factors:

- **Robust components:** Extremely low-maintenance lighting products are ideal for use in industrial applications.
- **Long service life** ensures long replacement intervals and enables extended system guarantees of up to 10 years.
- **High energy efficiency** helps industrial companies save electricity costs while protecting the environment.
- **Digital data exchange** offers industrial customers many advantages, because enormous saving potentials can be realized.
- **Future-proofing** lighting products enables customers to react quickly and flexibly to changes in lighting technology.

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Signify's Third Quarter 2022 Results

www.signify.com

Signify reports third quarter sales of EUR 1.9 billion, comparable sales growth of 4.3% and an operational profitability of 10.4%.

"In the third quarter, we delivered solid topline growth in an increasingly volatile environment. The strong performance of our professional business compensated lower consumer demand and the continued slowdown in China. We managed to improve profitability compared to the second quarter despite the impact of energy costs and currency movements. As expected, our free cash flow generation strengthened, driven by improved profitability and the stabilization of our working capital. Given the uncertain near-term outlook, the continued softness of the consumer segment and of the Chinese market, we now expect to achieve comparable sales growth between 2% and 3% for the full year 2022. Regarding the adjusted EBITA margin and free cash flow, we are targeting the lower end of both guidance ranges," said CEO Eric Rondolat.

"As we enter the final quarter of 2022, we have shifted gears to adapt the company to a structurally weaker external environment in the coming quarters, when current headwinds and volatility are likely to persist. We will therefore focus on measures to control costs and cash flow, in line with our track record of delivering margin expansion and strong free cash flow generation in difficult environments. While some areas will be more affected, connected energy efficient lighting solutions will continue to benefit from strong demand given the energy prices surge."

In the third quarter of the year, Signify continued to deliver on its Brighter Lives, Better World 2025 sustainability program commitments that contribute to doubling its positive impact on the environment and society.

- Double the pace of the Paris Agreement: Cumulative carbon reduction over the value chain is on track, mainly driven by energy-efficient and connected LED lighting
- Double Circular revenues to 32%: Circular revenues were at 30% and on track. This positive trend is driven by serviceable and circular luminaires
- Double Brighter lives revenues to 32%: Brighter lives revenues increased to 28%, mainly driven by the Safety & security and consumer wellbeing portfolios
- Double the percentage of women in leadership positions to 34%: The percentage of women in leadership positions was 27%, stable with Q2. Signify continued to create action plans to address gaps and accelerate its progress. In

addition, Signify published its first-ever Diversity, Equity, and Inclusion report.

Third Quarter 2022 Results

- Signify's installed base of connected light points increased from 103 million in Q2 22 to 109 million in Q3 22
- Sales of EUR 1,912 million; nominal sales increase of 16.3% and CSG of 4.3%
- LED-based sales represented 83% of total sales (Q3 21: 83%)
- Adj. EBITA margin of 10.4% (Q3 21: 11.1%)
- Net income of EUR 112 million (Q3 21: EUR 94 million)
- Free cash flow of EUR 135 million (Q3 21: EUR 85 million)
- Net debt/EBITDA ratio of 1.5x (Q3 21: 1.8x)

Outlook

Given the uncertain near-term outlook and the continued softness both of the consumer segment and of the Chinese market, we now expect to achieve comparable sales growth between 2% and 3% for the full year 2022. We are targeting the lower end of the range for both the 11.0-11.4% Adjusted EBITA margin guidance and the 5-7% free cash flow guidance. ■

ams OSRAM Solid Third Quarter Revenues and Operating Profitability

ams-osram.com

ams OSRAM (SIX: AMS), a global leader in optical solutions, reports third quarter group financial results. "We recorded solid results including sequential revenue growth for the third quarter as our business performed fully in line with our previous guidance. We continue to see a demanding market situation in several end markets in an environment of slowing macro-economic momentum globally. Despite these unfavorable trends our automotive, industrial, and medical businesses offered a solid performance in the quarter while our consumer business provided good contributions to group results. Looking forward, we are excited that, supported by excellent customer engagement, our strategic development and industrialization program for a leading smallest structure size microLED technology and the construction of our industry-first 8" LED front-end fab are advancing as planned," commented Alexander Everke, CEO of ams OSRAM.

"Beyond this highly prioritized strategic program and investment we see ongoing positive customer traction and engagement in target markets and applications. Irrespective of the current demanding industry situation, design activities and successes across our customer base continue to support our

pipeline for the mid to longer term. Customers are highly interested in harnessing the advantages and richness of our portfolio as they implement their roadmaps for future products in automotive, consumer, industrial and medical. In this context, I am glad to confirm a substantial pre-payment agreement for future deliveries which underpins an existing engagement. This is a testament to our highly attractive offering in innovative technologies," Everke added.

"We have reached the mid-point of the planned synergy creation period and I am glad to confirm that we have created 70% - or EUR 245 million - of the total expected synergies and savings so far which are fully in line with our plans. We are equally successful in advancing our integration programs as planned and they remain a key priority as we move towards completing the integration. We are also in the final phase of the planned disposals and expect total proceeds from the disposals of more than EUR 550 million. We now look forward to closing the last two already signed transactions, one of which is expected to close this quarter, as well as completing the last smaller-scale disposal. All in all, we continue to realize our targets related to the acquisition and integration of OSRAM Licht AG (OSRAM)."

"We are seeing previously mentioned inventory adjustments in end market supply chains, particularly in the automotive sector. Imbalances continue to impact several end markets including effects from lower automotive production and smartphone shipments globally. These trends create a demanding market and supply chain situation in an environment of increasingly unfavorable macro-economic momentum. Against this backdrop our revenues showed a solid development and sequential growth in the quarter. At the same time, the current market situation drove the previously mentioned decreased production volumes which impacted gross margin in line with expectations."

"As announced we are implementing additional cost mitigation measures to manage through the current and expected short-term market situation. These group-wide measures aim at diverse areas of our business and offer an expected cost mitigation volume of around EUR 100 million. In addition, we have revisited investment plans for 2022 in light of the market situation and now expect total capital expenditures for 2022 at a lower level of EUR 600 million."

"In view of financial markets developments, particularly with respect to increased interest rates and the related increased applicable cost of capital, as well as on-going macro-economic developments, we have recently conducted an impairment testing of assets in line with IFRS requirements and have recorded a one-off non-cash impairment



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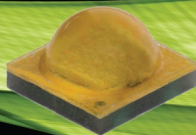
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charge, including the restructuring of certain production capacities, of EUR 335 million in the IFRS based (unadjusted) results for the quarter.”

“Significant changes in the macro-economic and industry environment over the course of this year include heightened uncertainty regarding the economic outlook as well as widespread and meaningful inflationary pressures driven by geopolitical developments. We are taking a cautious view given this demanding outlook for our markets and ongoing and expected cost inflation for our business and our customers, which is likely to impact mid-term volumes and technology adoption in certain markets such as horticulture, outdoor lighting or certain Android and non-smartphone consumer applications, resulting in less favorable product mix assumptions. We therefore update our mid-term financial targets and expect revenues of EUR 4.7 billion +/-300 million (previously EUR 4.9 billion +/-300 million) and an adjusted EBIT margin of 13% +/-100 basis points (previously 15% or better) for full year 2024. The expected timeline for the industrialization and the volume production availability of our leading microLED technology is not changed by these updated assumptions. Moreover, the long-term financial target model for the group, which is fully supported by our long-term strategy for leadership in optical solutions, remains unchanged.”

“Our strategy is built around innovative applications across end markets that offer significant mid- and long-term growth opportunities. Accordingly, we will move forward by continuing to streamline our portfolio in full alignment with this strategy. Taking the demanding macro-economic and industry environment into account, we will continue meaningful R&D investments with a clearly defined focus on driving technology and product innovation in optical technologies,” Everke concluded.

Third quarter group revenues were EUR 1,213 million, up 3% sequentially compared to the second quarter 2022 and down 6% compared to same quarter 2021, influenced by deconsolidation effects. Adjusted^[1] group gross margin for the third quarter 2022 was 29%, down from 32% for the second quarter

and down from 34% for the same quarter 2021. The third quarter adjusted¹ group result from operations (EBIT) was EUR 91 million or 8% of revenues compared to EUR 104 million or 9% for the second quarter and EUR 133 million or 10% of revenues for the same period 2021 (unadjusted: UR -327 million or -27% of revenues for the third quarter). Third quarter adjusted¹ group net result was EUR 47 million compared to EUR -54 million for the second quarter and compared to EUR 10 million for the same quarter 2021 (unadjusted: EUR -370 million for the third quarter). Third quarter adjusted¹ diluted earnings per share^[2] were EUR 0.18 or CHF 0.17 (EUR -1.40 or CHF -1.36 unadjusted).

Third quarter group operating cash flow was EUR 151 million while group free cash flow was solid with EUR 56 million. Group net debt was EUR 1,595 million on 30 September 2022, translating into a group leverage of 1.75x net debt/adjusted¹ EBITDA. Through the expected repayment of the maturing USD convertible bond and a promissory note (Schuldscheinanleihe) in the third quarter the gross debt position has been reduced by over EUR 300 million sequentially. Cash and cash equivalents reflected the mentioned repayments and stood at EUR 1,243 million on 30 September 2022.

The group's Semiconductors segment provided the most relevant contribution to group results in the third quarter at 67% of group revenues. The semiconductor automotive business recorded a solid performance in the quarter in line with previous expectations. This reflected the group's previously mentioned reduced production volumes in several product areas to accommodate the demanding market environment. The overall market situation remained characterized by reduced automotive production volumes globally, existing imbalances and ongoing inventory adjustments in automotive supply chains. Demand trends reflected this situation as well as increasing uncertainty about macro-economic developments. At the same time, ams OSRAM is successfully advancing the market adoption of innovative next generation lighting for future car platforms together with design success in diverse automotive sensing applications.

The semiconductor consumer business offered solid results that tracked expectations for the quarter. Global smartphone shipments continued at lower overall levels year-on-year while new device launches were able to support market volumes worldwide. As this less favorable demand environment increasingly reflects macro-economic trends, ams OSRAM notes the benefit of its large portfolio and customer base in major consumer segments and device types. A broadening presence in mobile device optical sensing such as body temperature monitoring in latest wearables underlines the group's market position in the consumer market. The semiconductor industrial and medical business offered another solid contribution to segment results in the quarter. Shipments for differentiated LED and imaging solutions in important markets remained at attractive levels during the quarter while demand trends in certain industrial markets started to reflect the unfavorable macro-economic momentum exiting the quarter.

The Lamps & Systems (L&S) segment saw third quarter results in line with expectations contributing 33% of group revenues. Pro-forma third quarter segment revenues for retained L&S business after completion of all previously announced disposals, i.e. deconsolidation of all closed and to-be-closed disposals, were 26% of same basis group revenues or EUR 281 million. The L&S automotive business including legacy traditional lighting achieved a solid in-line performance in the quarter. Results reflected imbalances and inventory adjustments in the automotive sector while global aftermarket activities provided a positive contribution in a less favorable environment. The other L&S businesses for traditional industrial, building-related and medical applications performed in line with expectations given still supportive end market demand.

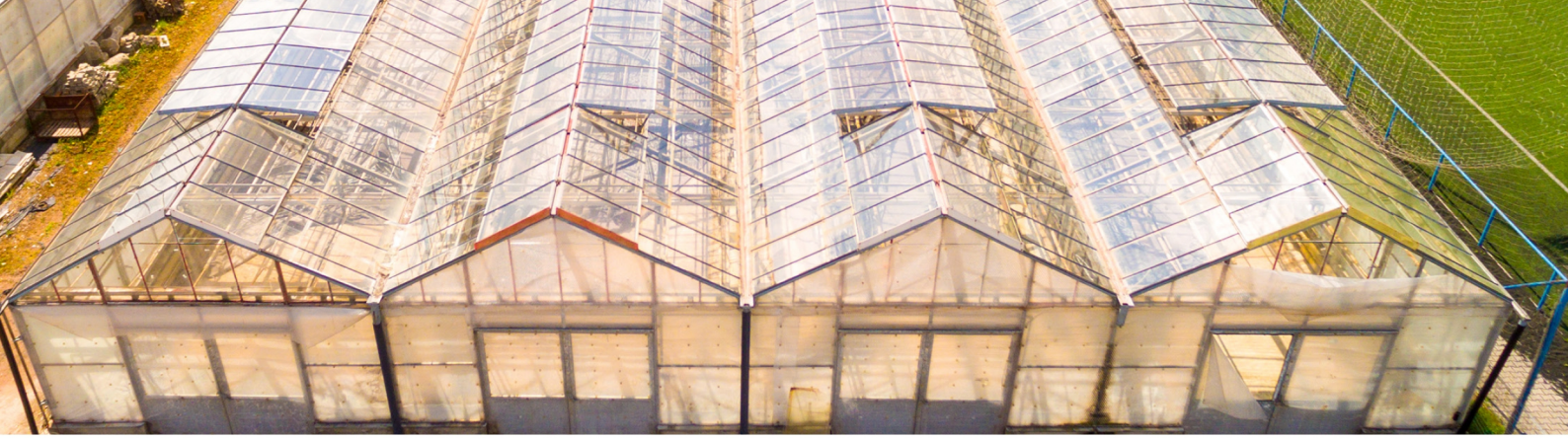
For the fourth quarter 2022, ams OSRAM expects group revenues of EUR 1,150-1,250 million, based on currently available information and exchange rates. ams OSRAM expects a flat revenue development quarter-on-quarter (approx., at the midpoint) in a market situation where slowing macro-economic momentum, less favorable demand trends and inventory adjustments result in a demanding environment. The expected revenue development is supported

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by the group's broad application and customer exposure across its end markets. In the prevailing industry environment decreased production levels are expected to continue in the fourth quarter. Incorporating these factors, ams OSRAM expects an adjusted operating (EBIT) margin of 6-9% for the fourth quarter.

The above expectations for the fourth quarter also include disposal-related deconsolidation effects compared to the previous year (fourth quarter revenue effect year-on-year of around EUR 70 million). ams OSRAM has started to implement the announced footprint consolidation measures in Asia as planned for the latter half of the integration and synergy creation period. Associated with these steps ams OSRAM expects to record a restructuring charge of up to EUR 60 million in the fourth quarter IFRS results. These one-time costs are part of the planned and previously announced total integration costs for the integration of OSRAM.

As previously announced, ams OSRAM has defined additional cost mitigation measures to manage through the more uncertain and evolving macro-economic environment, complementing the existing synergy creation programs. Together, these measures have a total cost mitigation volume of around EUR 100 million. Initiatives include reductions in global operating expenses including streamlining and efficiency improvements for certain R&D programs as well as various

efficiency improvements in production activities. Implementation of the initiatives is expected to be completed in the first half of next year. ams OSRAM has also revisited investment plans outside of the investment for its new 8" LED front-end fab in light of the current industry environment and has lowered total expected capital expenditures for full year 2022 to EUR 600 million.

Significant changes in the macro-economic and industry environment over the course of this year include heightened uncertainty regarding the economic outlook as well as widespread and meaningful inflationary pressures driven by geopolitical developments. ams OSRAM is taking a cautious view given this demanding outlook for its markets and ongoing and expected cost inflation for its business and its customers, which is likely to impact mid-term volumes and technology adoption in certain markets such as horticulture, outdoor lighting or certain Android and non-smartphone consumer applications, resulting in less favorable product mix assumptions. ams OSRAM therefore updates its mid-term financial targets and expects revenues of EUR 4.7 billion +/-300 million (previously EUR 4.9 billion +/-300 million) and an adjusted EBIT margin of 13% +/-100 basis points (previously 15% or better) for full year 2024. The expected timeline for the industrialization and the volume production availability of the group's leading microLED technology is not changed by these updated assumptions.

Moreover, the long-term financial target model for the group, which is fully supported by ams OSRAM's long-term strategy for leadership in optical solutions, remains unchanged. ■

Lumileds Successfully Completes Comprehensive Financial Restructuring and Announces Leadership Transition

lumileds.com

Lumileds Holding B.V. ("Lumileds" or the "Company"), a global leader in innovative lighting solutions, has successfully completed its financial restructuring and emerged from Chapter 11, having reduced its funded debt by approximately \$1.4 billion. With the restructuring transaction completed, Lumileds will be owned by a new group of long-term institutional investors, including Anchorage Capital Group, L.L.C., Nut Tree Capital Management, L.P., and Cerberus Capital Management, L.P.

Lumileds also announced that Steve Barlow, President of Lumileds' Automotive Business Unit, will be appointed Chief Executive Officer and to its Board of Directors, succeeding Matt

Roney. The appointment is effective on November 11, 2022.

Mr. Barlow brings over 30 years of experience in the semiconductor and LED lighting industries and several decades at Lumileds, having most recently served as the President of Lumileds' Automotive Business Unit and prior to that as President of the Lighting Solutions Business Unit. He first joined the Company in 2003 to help build its LED automotive, camera flash, display, and lighting businesses as head of sales and marketing. He previously held management and sales roles at Hewlett Packard, Cree, and Intematix Corporation. Mr. Barlow holds an MBA from Santa Clara University and a B.S. in Electrical Engineering from San Jose State University.

"We are pleased to have completed this process effectively and within the timeframe we originally projected thanks to the support and dedication of our employees, customers, vendors, suppliers, and our new owners," said Matt Roney. "It has been a privilege to lead this extraordinary company and team, and I look forward to following Lumileds' continued success under Steve's leadership."

"Lumileds holds a strong position as industry leader and innovator, with incredibly talented and committed people. I am energized and honored to lead Lumileds in this pivotal and exciting time in our business and in our industry," said Steve Barlow. "We enter this next stage poised for further growth, positioned to capture opportunities, and in an improved position to address changing global market environments."

For Lumileds, Evercore served as investment banker, Latham & Watkins as restructuring counsel and AlixPartners, LLP as financial advisor. PJT Partners was financial advisor for an ad hoc group of Lumileds' lenders, and Gibson, Dunn & Crutcher LLP was the group's legal counsel. ■

DALI Lighting Awards 2022 Open for Entries

www.dali-alliance.org

The DALI Alliance, the global industry organization for DALI lighting control, announces the call for entries for the DALI Lighting Awards 2022. With a closing date of December 2, 2022, the DALI Lighting Awards 2022 will highlight and recognize the best use of DALI control applications and solutions in lighting projects across the world.

Categories

The DALI Lighting Awards 2022 will accept entries for all projects linked with DALI technology in the following categories:

- Architectural & Entertainment
- Healthcare & Education
- Industrial
- Infrastructure
- Outdoor
- Residential
- Retail & Hospitality
- Workspaces

"The DALI Lighting Awards 2021 attracted a wealth of excellent DALI-based projects from around the world, with a diverse range of applications," said Paul Drosihn, DALI Alliance General Manager. "As DALI continues to evolve and add new features, we anticipate an even broader range of projects for this year's Awards." Winners of the DALI Lighting Awards 2021 can be viewed here.

The awards aim to promote the benefits and features of DALI, the internationally standardized protocol for digital communication between lighting-control devices.

Entry requirements

There is no entry fee for the Awards, and submissions are welcomed from all geographical regions. Entrants can nominate multiple projects, one per category, on an individual basis or as part of a team. Entries can be submitted from any section of the supply chain (including lighting designers, electrical consultants, architects, installers and commissioning engineers among others). Please see our website (www.dali-alliance.org/awards2022) for detailed entry criteria and a list of the information required.

Judges

Our international judging panel includes lighting designers, editors from lighting trade magazines, and representatives from lighting organizations in the USA, Europe and China.

Entries for the Awards are open until December 2, 2022. The winners will be announced in February next year and will receive publicity on the DALI Alliance website and other channels. ■

Fraunhofer IBP Study Confirms the Performance of Human Centric Lighting Solutions

www.nichia.co.jp/en

Nichia, the world's largest LED manufacturer and inventor of high-brightness blue and white LEDs, has commissioned the Fraunhofer Institute for Building Physics IBP, to analyze its Dynasolis solution. The solution consists of a combination of Nichia's cyan-colored Azure LED and the multiple award-winning H6 LED

family, which can adjust both color temperature and melanopic illuminance. Dynasolis can be adjusted within a color temperature range of between 2700 K (with little to no cyan) and 10 000 K (with a larger share of cyan).

The Fraunhofer IBP carried out comparative tests between standard LEDs (2700 K, 4000 K, and 6000 K, each with a CRI 83+) and the Dynasolis solution at color temperatures of 2700 K, 6000 K, and 10 000 K. The tests were designed to analyze the cognitive and psychological effects of different light color temperatures and spectrum on approximately 35 test subjects per test series, which included evaluating how the light can impact alertness, attention, and relaxation.

Inclusion of cyan increases attention

The Stroop-Task, a commonly used attention task, was carried out to evaluate the different effects of the standard LEDs and the Dynasolis solution on attention. Here, the subjects were asked to read e. g. the word "green" but written in red. These tests revealed significantly shorter reaction times of the subjects when conducted under the Dynasolis 6000 K solution when compared to the standard LED with no cyan at the same color temperature. There were also clear differences between the Dynasolis variations with an increase of cyan, with subjects responding faster under Dynasolis 10 000 K than Dynasolis 6000 K.

Color temperatures impact human reception

In the alertness test based on the AuReTim method where subjects were requested to press a button when they heard a beep from the headphones they wore, the study established that alertness is directly impacted by the color temperature, regardless of whether it is the standard LED or Dynasolis solution. The test subjects were less alert when exposed to a color temperature of 4000 K when compared with exposure to a color temperature of 6000 K.

To test relaxation potentials, subjects were first placed in a room with standard LED 4000 K, where they were allowed to acclimate to the light for five minutes. They were then placed under stress for 7 minutes with a cognitive task. This stress level was determined with a PANAS (Positive and Negative Affect Schedule) Test. This was followed by a five-minute relaxation phase under new lighting conditions (standard LED 2700 K, versus the Dynasolis 2700 K) with stress levels then being determined again. The results showed that the subjects were more relaxed under 2700 K than under 4000 K, regardless of the standard LED or Dynasolis.

Dynasolis – Human Centric Lighting Solution of new era

The results of the Fraunhofer Institute for Building Physics clearly show the advantages of the Dynasolis solution. The tunable

Dynasolis can provide equal or better results in the different phases of human lighting needs than a variety of standard LEDs. This is due to the color temperature tunability and melanopic illuminance tunability which is unique to Dynasolis.

In particular, the attention tests revealed significant improvements in reaction times of the subjects under Dynasolis. The good performance with regards to relaxation enables Dynasolis for the full spectrum of applications. For example in hospitality applications guests can find anything from a good place to work to a place to recover after a long day.

"The results of the Fraunhofer Institute IBP's tests confirm the goals we had when we developed the Dynasolis solution," said Ulf Meiners, Managing Director of Nichia Europe. "We set out to develop a solution for working environments that follows the principle of Human Centric Lighting. Conventional Human Centric Lighting systems mainly work by changing color temperature, the visual element. However, Dynasolis solution has been developed based on a totally new concept of changing both color temperature and melanopic illuminance simultaneously to support human circadian rhythms. It is a Human Centric Lighting solution of a new era." ■

Groundbreaking Motion Detection Turns Your Lights On and Off Without the Need for Sensors

www.signify.com

Signify (Euronext: LIGHT), the world leader in lighting, introduces a new app, features and products for its WiZ smart lighting system to enhance users' daily convenience. The new offerings include SpaceSense™, a motion detection technology for your lighting system that doesn't require any sensor to be installed. The new WiZ app V2 and the SpaceSense™ feature are available from the end of September, 2022.

Lights that work like magic

The SpaceSense™ feature is a never-seen-before innovation in the consumer lighting industry developed by WiZ. It uses Wi-Fi signals that are already present in the room to detect motion – without the need of dedicated sensors and batteries. Wi-Fi signals are slightly disturbed when people move around in a room, like a ripple in a swimming pool. By measuring the small deviations in signal strength caused by those disturbances, the WiZ lights can determine if there is an object moving in the room.

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More info



The detection is omnidirectional and doesn't require line of sight during installation, like in the case for a traditional motion sensor. The sensitivity of the system can be adjusted, for example, to prevent your pets from turning the lights on and off while running in and out of the room. You simply install at least two lights per room and connect them with the WiZ app V2. The new feature is completely opt-in so all WiZ users can decide themselves whether they would like to make use of it or not.

Danny Lousberg, Head of Software Product Management of WiZ: "For many users the need for extra hardware to enable motion detection in their system felt complex, expensive and cumbersome. Now, for the first time ever, SpaceSense™ takes those hurdles away, opening up automations and other smart lighting advanced benefits to everyone."

Take lighting into your own hands

Next to SpaceSense™, the WiZ app V2 is full of other surprises and offers exciting new features plus smoother interactions. The brand-new user interface makes for an even more intuitive experience to make people's everyday life easier. The Quick Action feature allows you to control your personalized lighting choices faster, independently from other users in your home, while the Light Scene feature lets your creativity come to life by creating a specific scene for any room. You can tweak light settings as desired, create a new scene, and initiate it within the app or with Siri voice control for an instant change in atmosphere.

A more comfortable, caring and joyful home

In addition to the various new features, WiZ introduces a range of new types of lamps and luminaires.

The battery powered Mobile Portable lamp can be used to light up any place inside or outside your home for the ultimate cozy feeling. It has a dual-zone design that creates a beautiful gradient color effect with dynamic light modes, allowing you to create a personal ambiance. In addition to smart control with app or voice, the lamp features a touch panel for quick control: set the mood with on/off button, pre-set modes and dimming features.

When you feel like painting every corner with

colors, the Pole floor light creates the desired feel with wide-angle wall-wash effects. Remove its foot and place it horizontally under your couch or behind your TV for the perfect movie night. It also comes with dual light zone design for you to mix a unique lighting experiences and take your creativity to next level.

Another addition to the WiZ table and floor lamp family is the Bar Linear Light. This slim bar radiates plenty of colors and is easy to fit in small spaces. This light adds playfulness to any space in the house – be it highlighting home décor or a display cabinet or bookshelf.

The new Panel Ceiling fits any interior style. Depending on your needs, the WiZ Panels are available in three different sizes and shapes. Set the right ambiance to transition from work to rest with tunable cool to warm white light and adjustable brightness. On top of being easy to install, this new LED panel ensures uniform light distribution for the comfort of your eye. WiZ is also moving outside of the home, with its first outdoor luminaire, the multicolor String Light. It is completely waterproof and weatherproof, so you can light up your garden or balcony in just a month from now with 16 million color options. Simply apply the Dynamic Light mode in the WiZ app for personalizing your festive lighting. The String Light's 12 LED bulbs will randomly light up multiple colors based on the chosen light mode, creating the perfect atmosphere for you to gather with your family and friends, whether it's a party, Halloween or Christmas.

The latest new accessory, the Smart Button, lets you control lights with just one click of a button. Like other WiZ control accessories, the Portable Button sends wireless commands directly to your lights without going through your Wi-Fi router, so it works even when your Wi-Fi is down. Just stick it on the wall with the included wall plate, or any metal surface such as your fridge, as it comes with a magnet embedded in the back. It controls all WiZ and Connected by WiZ lights.

Maikel Klomp, Business Leader of WiZ "At WiZ, we are on a mission to make smart lighting more accessible and meaningful in daily life. A ground-breaking feature like SpaceSense is yet another major step in bringing this mission to life." ■

Porotech Announces World's First "All-In-One" Full-color MicroLED Display

www.porotech.com

Porotech, a global leader in microLED and Gallium Nitride (GaN) semiconductor technology, announced the world's first public demonstration of an "all-in-one" full-color display of microLED pixels.

Porotech is pioneering the next generation of displays by using a single microLED diode for all colors, moving away from the constraints of the RGB (red-green-blue) sub-pixel model that underpins all current commercial display technologies. Porotech's innovation lies in its game-changing DynamicPixelTuning™ (DPT™) technology.

By using a new class of Gallium Nitride materials, DPT enables a single microLED chip to produce any visible color. The material that underpins DPT, PoroGaN®, allows a modulated current to be leveraged to emit visible light covering the entire color spectrum on a single microLED chip. Among the colors it can emit a DPT microLED is able to achieve a world first by emitting pure white color from a single pixel.

DPT's potential is game-changing for the display industry at large. Through removing the need for RGB sub-pixels, DPT allows a microLED-driven display to increase overall pixel density fourfold. As a result, DPT can produce substantial gains in resolution, brightness and efficiency for every type of display. This breakthrough is of particular interest for small form factor displays that demand high resolutions, such as AR and VR displays, as well as wearable tech.

According to a market report from Grand View Research, the global AR market size in 2021 sat at \$25.33 billion and is expected to grow by 40.9% a year from 2022 to 2030. Porotech is already making waves in the AR industry, including in Silicon Valley, with the DPT technology winning 'Best Prototype' at the 2022 Display Week industry gathering.

MicroLEDs represent the only viable solution



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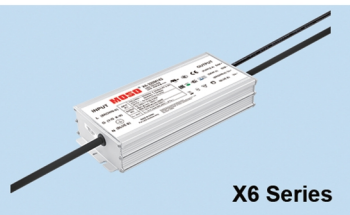
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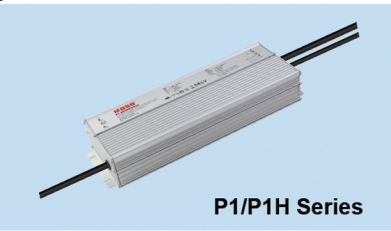
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for the future of display technology, offering myriad benefits such as improved brightness, energy efficiency, contrast ratio, longer device lifetimes, along with greater pixel densities and resolutions. Porotech's all-in-one pixel technology allows microLEDs to achieve unparalleled commercial viability, removing the reliance on RGB altogether – a cumbersome approach dating back to the days of cathode-ray tube (CRT) displays.

Porotech will be making the first public debut of DPT at CES 2023 in Las Vegas, where it will be showcasing a 0.26 inch DPT microdisplay with a <5 micrometer full color pixel, followed by various other industry events in Q1 2023.

Porotech's CEO and Co-Founder Dr Tongtong Zhu says: "The world's first full color and all-in-one microLED display is a monumental achievement by Porotech. Mass-produced microLEDs will be pivotal for the future of displays, particularly the emerging AR and VR spaces. Our technology has solved a fundamental technical and engineering problem facing microLED display quality, manufacturability, and – most importantly – system integration."

"This doesn't just herald widespread adoption of consumer-grade MR, VR, and AR. In fact, DPT also offers radical improvements in TV, signage, and smart wearables in both consumer and professional contexts. By allowing pixels to move beyond RGB and

quadrupling the resolution of any given display, DPT is set to unlock new uses for displays in every segment of society." ■

Fluence Selected as Supplemental Lighting Solution for Wageningen University & Research Facility

fluence.science/

Fluence, a leading global provider of energy-efficient LED lighting solutions for commercial cannabis and food production, has been selected by Wageningen University & Research (WUR) as the LED technology partner for its new Netherlands Plant Eco-phenotyping Centre (NPEC). In NPEC's state-of-the-art phenotyping greenhouse, VYPR DUO 3x2 fixtures are used to support research on genotype-phenotype associations.

The official opening of NPEC took place preceding the weeklong International Plant Phenotyping Symposium 2022 (IPPS 2022), held from Sept. 26 to Sept. 30 in Wageningen, Netherlands. Fluence, a Gold Sponsor of IPPS 2022, attended the conference and opening of NPEC in Wageningen.

NPEC consists of six modules across two university campuses, each offering dedicated phenotyping platforms with its own measurement systems. A specialized greenhouse at the WUR campus houses five climate-controlled compartments outfitted with Fluence's VYPR DUO 3x2 fixtures. The compartments' 3D and hyperspectral imaging, conveyor systems and various sensors produce high-precision measurements—including plant size, color and leaf positioning—that can be examined to understand the genetic response of plants to varied conditions and treatments, such as heat, drought or increased soil salinification.

"Using highly customizable technologies that generate high-quality plant performance data on how environmental parameters affect the plant phenotype was a key requirement when selecting our equipment partners," said Rick van de Zedde, senior scientist and project manager for NPEC. "Having worked with Fluence for the lighting in our Serre Red high-tech quarantine greenhouse, we knew PhysioSpec™ BROAD R4 white spectrum fixtures could help establish a near-ideal research environment in the NPEC greenhouse."

In addition to Fluence's VYPR top lights, which feature PhysioSpec™ BROAD R4 white spectrum, NPEC researchers will use the Maxi-MARVIN imaging cabinet to assist in research, a high-throughput 3D modeling

system developed by WUR that can reconstruct a plant's architecture within milliseconds. Other high-tech research tools at WUR include a dark and light adaptation chamber and imaging systems capability to analyze the photosynthetic efficiency of plants.

"Establishing research on genotype-phenotype associations, specifically how ecological and environmental variables impact the plant phenotype, is essential for the development of novel, climate-proof crops," explained van de Zedde. "Automated phenotyping will also allow for a dramatic increase in the speed of plant breeding and time to market for novel crop varieties."

"We are honored to partner with WUR to advance the future of high-quality food production and sustainability in cultivation," said Theo Tekstra, Fluence's technical director for Europe, the Middle East and Africa and team lead for the WUR project. "Our PhysioSpec™ BROAD R4 white spectrum came closest to what the WUR scientific team defined as an ideal spectrum to do year-round research on a wide range of plant species."

Fluence's continuing partnership with WUR also includes LED fixtures in a specialized greenhouse for insect research and phenotyping climate rooms at Wageningen. ■

TactoTek and ams OSRAM Cooperate to Optimize RGB LED to Drive Innovations in Car Illumination

www.tactotek.com ams-osram.com

Finnish IMSE pioneer TactoTek and ams OSRAM (SIX: AMS), a global leader in optical solutions, has announced that they are co-operating to help revolutionize the car interior market by delivering thin, seamlessly integrated, three-dimensional illuminated structures. The companies have developed a demonstrator with the new RGB side-looker LED OSIRE E5515 from ams OSRAM, which thanks to TactoTek's in-mold structural electronics (IMSE) technology can be integrated into automotive interior in a space-saving design.

Decoration, illumination, and functionality within one structure
Molded into a thin plastic trim part with TactoTek's IMSE technology, the ams OSRAM RGB side-looker LED OSIRE E5515 allows lightweight and thin applications designed for car interiors. This combination enables designers to build rich, seamless designs by merging surface decoration, illumination, and functionality into one smart surface, thus eliminating the boundaries that have held designers back when designing with

conventional and current technologies. Driven with modern controllers, illuminating the surface from within, the LED from ams OSRAM sets the mood, informs, guides, and adapts to the designer or user's needs. The broadest color gamut on the market means design freedom without compromising color quality and performance.

Features of OSIRE E5515

The OSIRE E5515 is a three-color, RGB side emitter enabling light coupling into thin materials, such as lightguides. "The package design of ams OSRAM's OSIRE E5515 enables ultra-compact designs and is optimized for the low height required for in-mold applications", says Gerald Broneske, VP Global Product Marketing Automotive at ams OSRAM. "This offers customers flexible design options for automotive ambient lighting applications while benefiting from the outstanding brightness performance of the automotive RGB sidelooker." The LED impresses with a performance of 1100 mcd for red, 2600 mcd for green and 500 mcd for the blue color at 20 mA. Also, deep blue colors are available. The RGB LED from ams OSRAM offers the maximum flexibility in terms of driver selection and interconnection. The package provides 6 pins, so each color's chip can be contacted to both its individual anode and cathode. This allows customers to be flexible with the electronics architecture for the driver and choose between high-side and low-side drivers for the board design.

Paavo Niskala, SVP IMSE Technology at TactoTek, comments: "Light is a key factor in creating compelling, brand-differentiating user experiences, especially in automotive interiors and exteriors. We trust that user interface functions and light will become an integral part of natural and plastic automotive surfaces without sacrificing sustainability. Incorporating OSIRE E5515 from ams OSRAM into our IMSE technology enables designing very low height applications with reduced weight, specifically of interest to the automotive industry. Our strong collaboration with ams OSRAM enables us to drive innovation into making light a critical element in the automotive living space."

Verified for use in automotive
The new product KRTB AELPS2.32 of the OSIRE E5515 family from ams OSRAM is specifically designed for in-mold processes. The LED has been validated by TactoTek for its IMSE technology and qualified for use in automotive applications (AEC-Q102) by ams OSRAM opening new illumination opportunities. ■

Far UV-C and Deep UV-C LEDs with New Tech

silanna.com

Silanna UV has announced new far UV-C and deep UV-C LEDs that take advantage of the company's patented short period superlattice (SPSL) technology for industry-leading performance in the difficult-to-obtain 230–265 nm UV range – including the highest output power in any mass-produced UV LED at 235 nm.

The far UV-C 235 nm SF1 series and deep UV-C 255 nm SN3 series are both available in either 120-degree or 30-degree viewing angle SMD packages, making them ideal for a wide range of tasks. The 30-degree package's parabolic lens provides greater irradiance than even traditional UV lamps. Both the SF1 and SN3 series boast low power consumption and have exceptional operating lifetimes.

These new LEDs offer the perfect solution for various deep UV and far UV use cases such as sterilization, water and gas sensing, and instrumentation applications. The SF1 and SN3 series are powerful, small footprint deep UV-C emitting devices that deliver long lifetimes and high conversion efficiency.

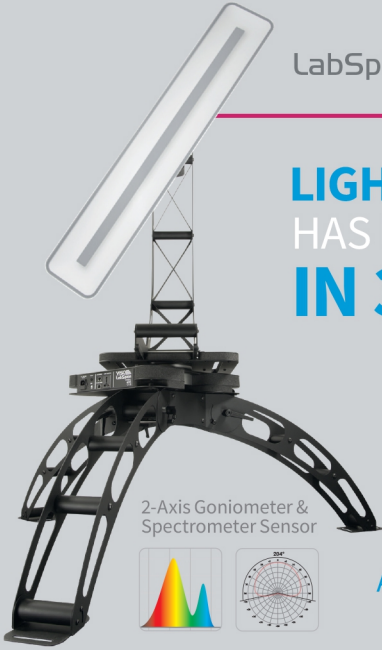
SF1: UV-C LEDs for nitrate sensing, gas detection, liquid chromatography
The 235 nm peak wavelength SF1 series comprises the 120-degree view angle (SF1-3C3FWL1), and the 30-degree (SF1-3U8P3L1). These far UV LEDs are effective for water quality detection of nitrate (NO₃) and nitrite (NO₂), gas detection and high performance liquid chromatography (HPLC). Sensing applications will be enhanced by the higher irradiance of the SF1-3U8P3L1's 30-degree collimated source design.

SN3: UV-C LEDs for COD, suspended solids, ozone detection, medical analyzers
Silanna's 255 nm deep UV-C SN3 series is ideal for water quality applications, including UV254 organic compound sensors, chemical oxygen demand monitoring, and measurement of suspended solids. Other application of the SN3 series are ozone gas (O₃) detectors and medical analyzers. Both 120-degree (SN3-5C3FWL1) and 30-degree (SN3-5U8P3L1) package versions are available. The 30-degree collimated source design of the SN3-5U8P3L1 package offers higher irradiance for enhanced resolution in sensing applications.

Revolutionary SPSL technology
Silanna UV's groundbreaking patented SPSL approach overcomes many of the difficulties that plague competing AlGaIn UV-C LED technologies. By engineering a nanostructure from alternating layers of AlN and GaN, Silanna UV have developed a new material that is easier to control, and which has far

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superior properties to traditional AIGaN. Silanna's SPSL mitigates several issues that AIGaN has for short wavelength LEDs – in particular, the older method's poor light extraction and electrical performance. This means revolutionary benefits for UV-C LED quality. ■

**Lightfair to Move to Biennial
Event Schedule**

www.lightfair.com

LightFair, North America's largest architectural and commercial lighting trade show and conference, announced that it is transitioning to a biennial event schedule beginning with the 2023 event, scheduled for May 21-25 at the Jacob K. Javits Convention Center in New York. As the major player in this vibrant space, LightFair's updated schedule will better serve the industry's manufacturing cycle, product marketplace and the overall needs of lighting professionals.

"The lighting industry has been shifting and we took an opportunity to reflect on what we offer and optimize our event in a way that better aligns with industry needs," said Dan Darby, show director. "We've heard and felt the path of the industry moving and it's important that we evolve with it. LightFair always has the best interest of our robust community of

lighting professionals in mind, and we are excited for its brighter biennial future."

The schedule change is part of an overarching strategic plan that LightFair's management committee developed in response to the changing needs of lighting manufacturing and specification. This plan continues to position LightFair at the forefront of the industry, with exciting new features in 2023 including partnerships with NYCxDESIGN and the International Contemporary Furniture Fair (ICFF), immersive lighting installations, learning tours, audience expansion to include residential lighting professionals and more.

LightFair's new biennial Conference and Trade Show schedule will allow attendees to continue to see the newest products during odd-numbered years, on a frequency that aligns with every-other-year manufacturing cycles. With this exciting shift, LightFair welcomes an increase in attendance from all segments of the industry, providing additional business opportunities for lighting designers, distributors, engineers and architects to come together to celebrate lighting innovation on its grandest scale.

"As one of the owners of LightFair, the International Association of Lighting Designers (IALD) is excited to embrace this new biennial cadence that we know will best serve our community in the years to come," said IALD CEO Christopher Knowlton. "LightFair is

evolving and we encourage our members to join us on this sensational journey."

"The Illuminating Engineering Society remains committed to its mission to improve the lighted environment by bringing together those with lighting knowledge and by translating that knowledge into actions that benefit the public," said IES Executive Director, Colleen Harper. "With this transformation LightFair will continue to be a mainstay of the lighting industry, allowing us to work together as a community to connect, engage and inspire."

Increasing attendance by 110% over the previous year, LightFair 2022 drew more than 10,000 people from 63 countries to source brand-new products, advance their knowledge and connect with other industry professionals. The 2023 edition is expected to continue this trend with a new strategic plan to dynamically expand the event.

The 2023 LightFair Trade Show and Conference will focus on future-shaping innovations and an incredible attendee experience driven by new product discovery, networking and on-floor education, Sunday, May 21 through Thursday, May 25, at the Javits Center in New York City. Registration for LightFair 2023 opens February 1, with complimentary expo hall access for IALD and IES members, and is at <https://www.lightfair.com/new-york-2023>. ■

Most Inspiring Lighting Designer — Rogier van der HEIDE, rogier@rogiervanderheide.com



Rogier van der HEIDE:

“Great lighting design gives your building and your brand an emotional dimension. I combine technology with art & craft, and make your brand stand out. Let the light tell your story”.

Mission and Vision Statements: Rogier van der Heide's Lighting Design atelier empowers their clients to turn their buildings into memorable experiences that are profound, and full of joy and imagination. They are curious, and they foster discovery and imagination. They create very desirable lighting and they are committed to pragmatic solutions that are feasible and financially viable.

LED professional: Thank you for taking the time to do this interview. Could we start by asking you about your professional background and how you came to the subjects of Design and Light?

Rogier van der HEIDE: I have always been a lighting designer, and I always wanted to innovate. What is behind the horizon? When I started, lighting designers picked lamps from a catalogue. I had a keen eye for technology, but no formal education. I studied at the Academy of Fine Arts. So you can imagine, I wanted to look at light differently: understanding its expressions, how it connects with people, and how it interacts with materials and with space. That became a "Leitmotif" of my practice: even now, more than 30 years later, we specialize in the interaction of architectural light with materials.

I founded my practice, Hollands Licht in 1994. "The Light of Holland" is an eyewink to the Old Masters of Dutch painting: Rembrandt and Vermeer. They could "paint light" as if it was a material. Twenty years after that, I spent days and nights in front of their paintings, creating the lighting design for the National Museum in Amsterdam. That was a life changing experience.

The big design and engineering firm, Arup, in London, was present in most of the larger projects that Hollands Licht committed to. It was only natural that the practice was acquired by Arup in 2003, and continued under the name

Arup Lighting. For me, that was the second time I changed the industry: until then engineers did lighting plans the way they did it: with a focus on technology. But Arup proved that strong artistic leadership and outstanding technical competence makes a fantastic marriage. It was a privilege to lead Arup Lighting for almost ten years, and we made it the best lighting design firm in the world.

LED professional: You've worked both as an independent lighting designer and on the industry side as a designer. What insights have you gained from this for your work and projects?

Rogier van der HEIDE: That's right. Towards the end of my tenure at Arup, the industry had changed. Digitization was about to become mainstream in lighting, and many manufacturers struggled to understand - and capture - the opportunities. I met with Rudy Provoost, who was CEO of Philips Lighting, and he asked me "how do I crack the code?". He meant: what is needed to change an entire industry towards purposeful, valuable propositions that are based on the new and fascinating possibilities of digital lighting? I had many questions too: as a designer, I did not understand why manufacturers focused so much on energy savings, and so little on new possibilities. LED was endlessly smaller, colder, more precise, more efficient and simply more fun than conventional lighting. I imagined thousands of new possibilities. Rudy appointed me as the first Chief Design Officer of Philips Lighting. Together with CTO Klaas Vegter, the CEO of Philips

Design Stefano Marzano and of course with Rudy, we outimagined our competitors. We introduced Hue, for wireless lighting at home, new concepts for stadiums, urban lighting, museum lighting, and much, much more. I did hundreds of talks and presentations all over the world, to understand the customers and their projects, and to introduce Philips as partner that brings a complete lighting solution. I think it was the third time that I could make a substantial difference to the industry.

My transfer to the Zumtobel Group was unexpected to many, because why would you ever want to leave the Leadership Team of Signify? It was a hard decision to make, but I was interested in Zumtobel. It is a company that more than Signify has the application of light in its DNA, and that always strives to be innovative in the sense that the brands offer designers new instruments and new ideas. I also had a long-lasting emotional connection with Zumtobel: when I started in the early nineties, the company's local salesman would visit me and show me some very cool things. Coming from theatre, I had little interest in the design of the luminaires. Zumtobel changed that for me at the beginning of my career in architecture.

Even though I got appointed at the highest level (I was Zumtobel's Chief Design Officer and Chief Marketing Officer at some point) I do not consider my time at Zumtobel Group entirely successful. What I learned is that to perform well, good leadership is essential. Zumtobel



A botanical garden on an abandoned motorway that flies over the city of Seoul. Architects MVRDV gave new purpose to a desolate place. "Seoullo 7017" is not the city's favorite nighttime hangout. Rogier created the lighting design: a deep blue galaxy of diffuse LED light, that immerses the trees, plants and the visitors in a mysterious ambiance.

went through difficult years in that sense, and it is only more recently that fortunately the company got things back on track.

I currently run an independent lighting design atelier. As we say: you can't escape your destiny! But the freedom is a source of great innovation, and my atelier is characterized by an intense process of research, exploration and design with a focus on the interaction between light, materials, and space. Daylight is extremely important, too. We model architectural spaces and assess them in our artificial sky, we use an artificial sun to study shadows and shading, and I am proud that my practice delivers detailed technical specifications of everything. We often challenge architects; the adage "enhancing the architecture" as is so often said about lighting design, is perhaps not exactly what I do. I merely develop a partnership with the architect to see how we can elevate the building design together. I am confident discussing glazing, finishings, materials and everything that occurs at a large scale as well as tiny things such as optics, filters, grids and electronics that can make or break the project at a very small scale. Light is everything!

My clients often work with me for multiple days. I always involve them: it is not sufficient to work with architects and engineers alone. A client can tell you much more about their intentions, use of the building, expectations et cetera. I also prefer to work directly for the client; it puts me on a level playing field with the architect.

LED professional: First, let's look at the side of the light designer. What changes have occurred in work and requirements of projects in recent years? For example, does daylight play a more significant role due to the energy issue?

Rogier van der HEIDE: Knowledge and understanding of daylight, as well as a strong opinion on it, have become essential to lighting designers to continue their success. Designing daylight is not easy, and good lighting designers can add a great deal here. Mastering daylight means you can contribute to the energy balance of buildings: primarily because good daylighting warms up the building much less than bad daylighting, and warmth takes a lot of energy to

be cooled. Understanding natural light transfers a lighting designer into a truly holistic project contributor.

LED professional: Where should the lighting industry be heading? The industry is, after all, heavily impacted by disrupted supply chains. On the other hand, the level of customization is very high.

Rogier van der HEIDE: There is a demand for solutions that are simple, robust, and intuitive by means of their controls. The key is to remove all the unrewarded complexity from lighting. There is also a keen opportunity for well-designed luminaires. Clients are used to everything being designed so neatly and nicely. Why are so many luminaires still ugly?

The lighting industry will also further consolidate, with small players only being fit for the future when they deliver outstanding product design, a strong contribution to zero-carbon real estate, and superb integration both digitally (in the building's management systems) and physically (by integrating light into materials).

In general, lighting catalogues are very large and this is only intimidating and scaring away clients. It keeps the engineers in a strong position and perhaps that is what manufacturers like, but do not forget: the client pays for the lighting. If you talk with a marketing director of a retail chain, instead of with the electrician, you're talking about more interesting topics and, moreover, a different price tag. I think the lighting industry will rethink its sales channels and the way manufacturers go to market.

LED professional: You've been involved with drone technology for quite some time. Where are concrete starting points for using drones for lighting design or lighting in general?

Rogier van der HEIDE: In 2010 we experimented with drones that carry lights. The idea was: Bring light to the streets only where you need it. It was a conceptual thought and though interesting, there was no practical application. We currently use drones to create point clouds of buildings and their facades, that we use to make lighting renderings that help clients to understand our proposals. It is amazing how detailed the output is. Our atelier operates two enter-

prise drones, one of which can lift 15 kgs so even a heavy camera and measuring equipment can easily fly.

We also use drones to assess current lighting conditions of cities. We have a good track record in master planning lighting for entire cities, and a thorough understanding of the current situation is part of making a great project. The drone tells us many things: light distribution across the city, type of lighting used for each street, business of the streets and pedestrian areas, but also health of trees for instance. Using hi-res thermal sensors combined with 4K digital cameras, the drone sees everything you and I cannot see.

"Rogier is the most inspiring lighting designer I have met in 32 years."

FRANK VAN DER VLOED, PRESIDENT EUROPE, SIGNIFY

LED professional: Do you offer services with your high-end drones?

Rogier van der HEIDE: The drones that my atelier currently has in use are the same as the ones used to shoot Hollywood movies. One of our drones actually can also take off in bad weather. It's very different from the small drones that you see more and more. The smaller drones are a lot of fun, but their professional application is limited, mostly because there are limits to their payload. Our drones are available to everyone who wants to do something innovative with them. We perform, for instance, inspections of solar power farms on a regular basis. It has not much to do with lighting, but flying the large drone is a lot of fun and the output is very professional.

LED professional: You are also working with 3-D printing technology. Is sustainability the issue here, or where does this technology make sense in the lighting sector?

Rogier van der HEIDE: Just like drone technology, 3D printing is important so we can explore the meaning of it to the lighting industry and see how we can innovate or perhaps even revolutionize the industry. We currently print from





The headquarters of the BBC is an outstanding example of the synthesis of light and architecture. Both daylight and the LED lighting solution are tightly integrated with the glass design of the monumental facade. During the day, the facade is solid, offering the BBC teams an introvert place to concentrate on their work. At night, the facade turns transparent and shows the BBC in clear blue light: the color of the sky that spans the entire globe, symbolizing the BBC's objective presentation of global news. The transformation from opaque to transparent was designed by Rogier using innovative acid-etched patterns on the glass that is combined with precise lighting.

liquid resin, in 4K resolution, to produce very fine results. By rinsing the products with pure alcohol and curing them with strong UV light, we create transparent objects that perform reasonably well as optics. This opens the door to specialty applications that solve very specific lighting problems with ordinary LED chips. We did, for instance, the world's largest edge-lighting project that contains hundreds of edge-lit glass facade panels.

The prototypes were all made with 3D printed optics that injected the light into the glass at very high efficiency.

LED professional: You are currently working on a notable project in the Arab region; even in the desert. What are the challenges there, and what innovations are being used there?

Rogier van der HEIDE: The project has a lot of daylight, so I would say the answer to your question is obvious: how can one create beautiful, interesting, comfortable daylighting that is safe to the art and a pleasure to visitors, while outside there is 120,000 Lux of illumination? It is a true challenge among the biggest I have experienced throughout my career. I think we are the right team to tackle it though.



The drone uses a high-resolution camera to capture a large set of data points in space that describe a building's geometry, shape, and textures. This information, a "point cloud", is imported in Autodesk Revit: Architectural software that converts the point cloud into a 3D model of the building. Rogier then uses the model to develop the lighting design.



Always at the forefront of technology and pushing the boundaries of the lighting design profession, Rogier's atelier now uses drones to create models of buildings or to analyze lighting conditions across cities. The atelier operates two enterprise drones that are sometimes used for other purposes as well, such as cinematography or even to support the rescue of people in the mountains!



Rogier sees a future of outdoor lighting where control technology and high end optics enable sustainability, a dark sky, and conservation of biodiversity. Responsible outdoor lighting, Rogier says, means humans shape their "light environment" with respect for Earth and for all other life on our planet.

LED professional: More generally, where do you see the future of the lighting world going, and what particular tips would you give designers and the industry along the way?

Rogier van der HEIDE: Designers are the ones that can change the industry for the better. I founded the first independent practice in the Netherlands that applied a multidisciplinary approach to lighting. I founded the first lighting design group within a global engineering firm, and today every big firm has a lighting team. I was the first Chief Design Officer in the lighting industry, and I currently run a unique design atelier. I did not plan any of this, but I would like to change the industry one more time, in partnership with the manufacturers of course, because they have the ability to make the change. To designers I would therefore say: keep believing it is possible, it is your responsibility to "think different", and play with light a lot so you can confidently handle it. Do not trust computers

until you have had the light in your own hands. In other words: make sure you always understand in detail what you are doing.

LED professional: What are the next steps you are planning for your professional life?

Rogier van der HEIDE: I have many ideas. A design competence center for the lighting industry would be fantastic: The lighting industry needs to foster new entrants with refreshing ideas, and supporting them is critical. I also want to profile my atelier more in the periphery of the lighting design profession: Light and health, climate change, biodiversity, dark sky and the business transformation of the lighting industry are all topics that we have recently added to our menu, and it really makes a change for our clients: This is the added value they expect for the fees they pay us.

Finally, better education is high on my list: As much as I can see how lighting design education has come a long way, it currently falls short. So much has changed in the industry, and in the understanding of light, and as a result, things are challenging for those with a master's degree in lighting design. I'd like to collaborate with a university, and start a lighting design curriculum that really makes sense!

A summer course perhaps to begin with, so we can see the appetite among architecture graduates, young engineers, and designers, to evolve gradually in a complete 1-year curriculum. That would be awesome! ■

www.rogiervanderheide.com

From Architecture to Lighting Design and Education – Professor Stelios ZEREFOS, Hellenic Open University, Greece



Professor Stelios ZEREFOS

"Design for Life" is my moto.
Creating spaces that respect all
aspects of life is my goal.

STELIOS ZEREFOS & ASSOCIATES [1] is an award winning architectural practice based in Athens, Greece. Established in 2000, they have vast experience in architectural design projects of different scales and uses, ranging from residential projects to museums and educational institutions. Architectural design is always complemented by rigorous research, so as to promote human health and wellbeing in every environment, while at the same time respecting the environment in any possible way. Their work has attained international and national awards and is published in architectural magazines and scientific journals.

LED professional: Thank you for the opportunity to do this interview. Can we perhaps start by asking you about your professional background and how you came to the subjects of Architecture, Design and Light?

Professor Stelios ZEREFOS: I have a formal education as an Architect from the University of Plymouth, U.K. and the University of California in Los Angeles, U.S.A. Getting my ideas realized was always an incentive for me. During my studies and at the beginning of my professional career as an architect, core areas of interest were always the physical aspects of building performance, such as energy consumption, human centric design and wellbeing, as well as the visual representation of architecture. This combination led to my pursuit of the design of spaces, in which light plays a major role in all aspects, from the visual aesthetics of a space to the energy consumption and wellbeing of its residents.

LED professional: As Professor at the Hellenic Open University, what are your specific areas of research and education, and what direction are you going to develop the future of your work?

Professor Stelios ZEREFOS: My work at the Hellenic Open University has two main pillars. The first one is formal academic education. As the only Distance Learning Higher Education Institution in Greece, at the Hellenic Open University we develop and research methodologies that make distance education at

any level possible. To this end I have led and contributed to the development and the evolution of 10 graduate and post-graduate distance learning courses, one of which is dedicated to lighting design. The second pillar is light and lighting, from the lighting design of spaces and buildings, to research on the life-cycle of LED light sources, even to projects such as the design of new metric methodologies for identifying optical characteristics and the performance of old lanterns and ancient lamps. As the director of the Lighting Design Laboratory (lightinglab.eap.gr), I secured funding to obtain state-of-the-art equipment for measuring light and light transmission in the past two years, thus making the laboratory a space for experimentation and education. In the future we would like to expand our educational resources and offer specializations in lighting not only for buildings, but for any discipline, including technology and design of lighting for cinema, theatre and live performances.

LED professional: You are also the initiator of the project ECOSLIGHT, which the European Commission funds. Can you fill us in on the background and targets of the project?

Professor Stelios ZEREFOS: ECOSLIGHT [2]: Environmentally Conscious Smart Lighting is a project funded by the Erasmus+ Programme of the European Union. It started in December 2019 and will finish in May 2023. The objective of ECOSLIGHT is to support the development of human cap-

ital in the lighting sector. In this regard, ECOSLIGHT has identified a set of emerging job role profiles that represent the current and future market (skills) needs. These include (a) the Lighting Designer, (b) the Lighting Systems Engineer, (c) the Lighting Systems Assistant Engineer, (d) the Lighting Consultant, (e) the Landscape and Street Lighting Technician, (f) the Street Lighting Business Manager, and (g) the Smart Lighting Systems Technician. According to the market needs, ECOSLIGHT selected four of them in the EQF level 5 and developed modular VET curricula. These four include the Smart Lighting System Technician, the Lighting Consultant, the Lighting Systems Assistant Engineer and the Landscape and Street Lighting Technician.

The methodology defined for the design of the VET curricula is based on the learning outcomes and the principles of professional education, exploiting the potential of online, face-to-face and work based learning. Each VET curriculum is composed of competences identified during the analysis of needs and training offers, including lighting-related competences, digital competences, life and green competences. A repository of digital Open Educational Resources (OERs) is developed to support the acquisition of the aforementioned types of competences. Using these, a MOOC for acquiring the basic and common competences of the different job role profiles, and a Specialization Training Course including motivational e-learning, face-to-face lectures and a work-based learning

phase will be offered in France, Italy, Germany and Greece. The project will adopt European instruments in order to improve the recognition of the identified qualifications. Communities of practice that ensure sustainability of results beyond project end will be formed as well.

LED professional: What is the project's status right now, and who is working in the ECOSLIGHT team to reach the aforementioned goals? Specifically, which organizations are part of the project and what expertise do they contribute?

Professor Stelios ZEREFOS: The project is at a phase where preliminary results are completed and published, such as the results of the market needs analysis, the emerging job role profiles, and various dissemination activities have already taken place. Now, the project is at the phase of delivering the first of its human capital development activities, a Massive Online Open Course (MOOC) entitled "Essential Skills for Environmentally Conscious Smart Lighting Professionals", starting on October 17, 2022. The registration to this MOOC is free to anyone and the aim is to support lighting and the wider construction industry professionals (or aspiring ones)

to improve their lighting, digital, green, entrepreneurial, and life competences.

The project will offer specific learning modules aimed at enhancing know-how and skills in the fields related to (a) innovative, sustainable, and human-centric lighting systems and products, (b) digital technologies for co-creation processes, and (c) entrepreneurial mindset and critical thinking. The course is 100% free and 100% online, with a flexible, self-paced learning path available in English. Upon successful completion, learners will earn online badges and a certificate, in accordance with the European and national qualification frameworks and the European credit system for vocational education.

Moreover, learners that successfully complete the MOOC will have the possibility to enroll in specialization courses for the selected job profiles, as mentioned above. The specialization courses will be available for people living in the program partner countries (France, Italy, Germany, Austria and Greece). Combined with the specialization courses, the trainees will take part in a Work-Based Learning Experience in companies of the lighting sector for the implementation of real projects.

The ECOSLIGHT consortium includes 12 partners from 5 EU countries (France, Italy, Germany, Greece and Austria). It includes Higher Education Institutions, VET providers, Research Institutes, Sector Representatives, Association of VET providers and a Certification Organization.

The ECOSLIGHT partners are the following:

- Hellenic Open University (HOU) (GR) – Coordinator
- National Technical University of Athens (NTUA) (GR)
- Technical Chamber of Greece (TCG) (GR)
- European Grants International Academy (EGInA) (IT)
- Link Campus University (LCU) (IT)
- Institute for Freshwater Ecology and Inland Fisheries (IGB) (DE)
- European Lighting Cluster Alliance (ELCA) (IT)
- Europäischer Verband Beruflicher Bildungsträger (EVBB) (DE)
- Université Paul Sabatier Toulouse III (UPS) (FR)
- Association Française de l'éclairage (AFE) (FR)
- ECQA GmbH (AT)
- Brainymotion (DE)



Lighting design proposal for the new Amphitheatre of the Hellenic Open University in Patras, Greece.

LED professional: As an architect, you work with light in all your projects. What do you think of the new technologies in lighting and how have they changed architectural concepts?

Professor Stelios ZEREFOS: New technologies, like LEDs and advanced lighting systems have changed the way designers are designing with light during the past decade. The fact that LED technology became cheaper during this period has, however, created several misconceptions, in many cases increasing energy consumption due to either over lighting, or due to a lack of design knowledge. Architects are still not educated enough when it comes to artificial lighting, and LED technologies have provided the means to create almost any light in any shape. While this ability could actually be thought of as freeing creativity from technological bounds, it can also pose problems, especially when users' needs and wellbeing are not at the core of the design process. In my opinion LEDs have all the necessary means to create interesting spaces and dynamic scenes that can change over time and fulfill several human-centric needs. The real power in designing with LEDs is this plethora of characteristics and the endless possibility to change its visual characteristics over time.

“Sustainability, daylighting, energy conservation and a human-centric approach to design, are the factors we work with in every project.”

PROFESSOR STELIOS ZEREFOS

LED professional: Lighting could go in many different directions, in the future, such as energy-efficient, smart, intelligent, and possibly, many more. How do you see lighting evolving in the future?

Professor Stelios ZEREFOS: How I see lighting in the future and how I would like to see lighting in the future are two different things. It is my belief that lighting technology and especially LEDs will inevitably become more expensive in the coming decades, due to the increase in embedded electronics in light sources and control and the coming lack of the

necessary resources and raw materials to produce LEDs. Proper recycling of LED light sources is paramount to reacquire needed materials and unfortunately in the domestic sector, recycling and upcycling of LED light sources is not properly regulated.

What I would like to see in the future is an increase in the qualitative characteristics of light sources. Taking into account the quality of human vision vs production cost. Color rendering is one such quality, really misunderstood in favor of mass production. In my opinion the CIE and IES should establish color rendering as a paramount quality for light in much wider usage scenarios, while the industry could limit the production of less than acceptable light sources (i.e. < 90CRI) and increase the production of high quality LED lighting. This should also be the case for exterior lighting, where unfortunately, we still notice the use of unsuitable luminaires that do not take into account light pollution or the effects of high CCT on the biodiversity.

Therefore, International Standards should be updated with these directions in mind. This, of course, has to be supported by the market and the consumers, who should be continuously educated on the benefits of good quality light sources and good quality lighting.

LED professional: What are the next steps you are planning for your professional life?

Professor Stelios ZEREFOS: In terms of education in the lighting sector, my aspiration for the School of Applied Arts and Sustainable Design is to become a hub for all lighting related disciplines. The Laboratory of Lighting Design, has a plethora of state-of-the-art equipment for measuring light and its effects, and doctoral candidates can use it for cutting edge research.

As far as the design practice, I will continue to support my beliefs on designing lighting for human activities and wellbeing even if this means not lighting something, which is always a viable and interesting option. ■

About Professor Stelios ZEREFOS

Stelios ZEREFOS is an architect (B.A. (hons), M.Arch.II, Ph.D.) and Professor at the School of Applied Arts and Sustainable Design of the Hellenic Open University since 2009. He is the Director of the Master's Program "Lighting Design", Director of the M.Sc. "Protection of cultural heritage and monuments of nature from the effects of climate change" and Director of the Lighting Design Laboratory. Apart from the Hellenic Open University, he has taught graduate and post-graduate courses at the National Technical University of Athens, the University of West Attica, the Technical University of Crete, the University of Athens, the ESAD Matosinhos in Portugal, the Technical University of Wismar and the Technical University of Berlin in Germany.

He has led or taken part in designing and delivering six University Graduate Program Curricula with a distance learning methodology. He is an educator member of the IALD, of national and international scientific organizations, as well as editor and reviewer in international scientific journals such as Sustainability, Energies, Energy and Buildings and Solar Energy. He has scientific papers in peer-reviewed journals and conference proceedings and is also the author of four books. He was a Country Representative member for Greece in two EU COST actions (ES1204 and C13) themed after light pollution and interactive building envelopes, respectively.

He is currently the scientific coordinator of the Erasmus+ SSA project ECOSLIGHT, as well as of a research project on identifying lighting characteristics of ancient lighting devices. He has also coordinated two finished research projects and participated in another 10 European Research Projects as a research member. His professional architectural work numbers more than 60 buildings, 7 of which have achieved awards in Greek and international architectural competitions.

References

- [1] <http://www.zerefos.gr>
- [2] <https://www.ecoslight.eu>

Interview with Nichia Corporation's President & CEO Hiroyoshi OGAWA

LED professional published by Luger Research e.U.

At this year's Light + Building in Frankfurt (Oct. 2-6), Nichia Corporation's¹ President & CEO Hiroyoshi OGAWA and Luger Research's² Founder & CEO, Siegfried Luger, met for an interview. The primary focus was on the core issues of the future strategic directions of Nichia and the lighting sector in general.

"While focusing on the fundamental essence of materials and technology, we pursue honmono – the best quality in the world. Honmono is a Japanese word that originally means something true, real or genuine."

NICHIA CORPORATION'S PRESIDENT & CEO
HIROYOSHI OGAWA

LED professional: What are Nichia's highlights at this year's Light + Building that you would particularly like to share with our readers?

President & CEO Hiroyoshi OGAWA: Taking center stage is Dynasolis™, a new LED tuning solution that regulates circadian rhythms by simultaneously adjusting melanopic illuminance and color temperature while maintaining high CRI and high efficacy. The building industry is increasingly encouraging designs that bring more natural light indoors, with human centric lighting (HCL) and circadian lighting gaining attention. Most existing HCL systems work by changing CCT (correlated color temperature), the visual element. However, Nichia also focuses on the non-visual element that truly addresses human circadian rhythms, from waking up to going to sleep. Dynasolis™ achieves this effect by offering both color and spectrum tuning, ranging from energizing azure to a peaceful, calming warm-white hue. By combining two separate LED spectra, building markets such as healthcare, education and office at last have a solution that provides independent control of this critical functionality, allowing biologically effective light to enhance mood and wellbeing on a sustainable level.

Furthermore, Nichia's H6 LED Series, which heralds a new era of LED adoption by delivering the industry's highest joint-boost in color quality and efficacy. By combining the company's accumulated phosphor technology with KSF narrow-band red phosphor and TriGain® technology, Nichia has optimized the light spectrum and overcome the trade-off between efficacy and CRI. The portfolio extends from mid-power to chip-on-board (COB) products, presenting ideal solutions for applications that include retail, hospitality, and offices.

Show visitors interested in solutions for street lighting, as well as area and landscape lighting, will find a product of great interest in the form of Nichia's HPS color LED series. This product faithfully re-

produces the emission color of a high-pressure sodium lamp (HPS), which finds common use in road and outdoor lighting. Unlike existing market solutions, the key feature of Nichia's HPS color LED is that it maintains the nostalgic atmosphere of the landscape with the same emission color as HPS while improving color visibility through its higher CRI (Ra≥70). Lighting fixtures equipped with this LED not only offer a lifespan 2.5 times longer than that of HPS, but also provide higher luminous efficiency, lower energy consumption, and less impact on the ecosystem.

LED professional: What strategic course has Nichia set to secure and expand its leadership role for the next 5 to 10 years?

President & CEO Hiroyoshi OGAWA: Nichia is committed to further technological advancements and will provide new innovative technological developments for our customers in the future. In addition to further developing LED technologies for the general lighting market, we will also offer MircoLED solutions for the automotive sector, e.g. for headlights. We are also looking at laser light technology as a future light source.

LED professional: What internal orientations within Nichia are most vital to you for the future of the company and your employees?

President & CEO Hiroyoshi OGAWA: For me, it is crucial that we focus on the sustainability of solutions and that our employees consistently keep the focus of environmental compatibility in mind for our customers.

LED professional: Thank you very much for your time and we wish you and Nichia a bright future.

President & CEO Hiroyoshi OGAWA: Thank you for the opportunity and greetings to the LED professional team. ■

¹<https://www.nichia.co.jp/en/>

²Luger Research e.U. is publisher of LED professional, Trends in Lighting, Global Lighting Directory and organizer of LpS Digital.



Nichia Corporation's President & CEO Hiroyoshi OGAWA (left) and Luger Research's Founder & CEO Siegfried Luger (right) at Nichia's booth in Frankfurt.



Dr. Ulf MEINERS (Managing Director, Nichia Europe), Hiroyoshi OGAWA (President & CEO, Nichia Corporation), Anna MUELLER (Business Development Manager, Nichia Europe), Siegfried LUGER (Founder & CEO of Luger Research), Armin WEZEL (LED professional's Representative in Germany); (left to right).

Hospitality Focus

Laura CIZAUSKAITE, Lichtvision Design



Laura CIZAUSKAITE is an expert of high-end hospitality lighting at Lichtvision Design with over 10 years of experience in the field. Here is her take on creating mood lighting for Autumn and Winter season.

After a few years break from travelling, I hope most of you have finally managed to escape for a long awaited and deserved holiday before we step into Autumn, with memories to carry us through the winter. What did you enjoy the most during your holidays? The beach, the margarita, or maybe a bit of both? It's no secret that a great experience cannot be described by just one factor – you need a whole, picture-perfect scenario – the place, the cocktail, and the sunset, to make it a memorable experience. Have you ever wondered how to recreate that feeling in your own home or in a project you're working on so you can enjoy that holiday feeling for longer? A sea view might be a hard box to tick for most of us, but surely a nice, cozy spot can be found, cocktails can be made with a little effort, and finally, the lighting scene – that I can help you to recreate.

For generations people have admired the sunsets, the warm glow it provides, and have used candles to replicate this effect in their own homes. Nowadays, we also use artificial decorative lighting to give this effect. So let's take a look at what makes artificial decorative lighting so good and cozy or rather, how some spaces are so immaculately lit, that you fully immerse yourself in the moment and never want that experience to end. As Ludwig Mies Van Der Rohe once said – the devil is in the details, and so is the secret for decorative lighting – it lies in a selection of shade types and colors.

Lighting can be used to cover multiple needs: above eye level lighting can be used for general and task illumination, while below eye level solutions can be used for more localized tasks such as reading a book or relaxing. The type of lighting we use usually corresponds with the time of the day: when sun is high up we are the most active and productive, hence we need a good amount of above eye lighting; when the sun is setting we intuitively know - it's time to relax and usually turn on our low level lights. The most common practice

is to use low level lighting to provide an instant cozy setting and mixing different layers of lighting can create a complete atmosphere to enjoy – whether at home or at a bar. Decorative lighting comes in many categories such as chandeliers, pendants, wall lights, floor lamps and table lamps and all of these fixtures use some sort of shade. Shades are required to cover the lamp that we don't want to see and reduce the glare so only a soft glow effect is seen. Below, I will share my experience with the various shade types available and tell you which works best to achieve the 'sunset effect', highly used by many world renown hospitality brands such as Edition, Marriot, Standard, Nobu and others.

Fabric Shades

Fabric shades are the most commonly used type of decorative lighting – they are relatively cheap to produce, light and come in many different shapes, fabrics and colors. Some consider them dated / old-fashioned while the current market offers many intricate designs. However, such shades are still very commonly used by many top high-end hospitality brands. I segregate fabric shades into three categories: light / white, colored and dark. My recommendation is to use light colored shades with the most fabric transparency allowing to replicate that glowing 'sunset' effect. If you are considering using a colored shade to match your interiors or make a bold statement be aware that it will offer a reduced amount of glow, so it is important to check the fabrics' color transparency, avoid double lining and use a higher output lamp to maximize the glow. Very dark and black shades offer the least amount of light transmittance, hence it will be hard to create very glowing effect. It's best when such lights are used for task lighting or complimented by other sources of light. A drum shape is also important – if open at the top, it can provide unwanted spill to the ceiling but it can also offer facial skin glow, while closed top shades contain light circularly and downwards, so the light spill is more controlled.

Costa Smeralda

Architect: Tihany Design, Jeffrey Beers International, Rockwell Group, Dordoni Architeti, Partner Ship Design
Lighting Designer: Lichtvision Design
Image Copyrights: Costa

Alwadi Hotel & Sofra Bar, Doha

Architect: Gensler
Lighting Designer: Lichtvision Design
Image Copyrights: Accor



Alwadi Hotel, Doha: The use of soft cream shades at low level provides cozy ambiance and balances double height hotel lobby.



Alwadi Hotel, Doha: Dark shaded table lamp on the left does not emit much light and works more as a decorative object to compliment the room styling. On the contrary, bedside wall lamps use light shades and provide soft pools of light.







Costa Smeralda: Feature chandelier that contributes to the general lighting is created using opal glass globes making it comfortable for the eye. On the other hand, if clear glass globes were used such a chandelier could be quite glary.



Sofra Bar, Doha: This is a perfect example of when clear lamps are in use. They can be quite glary hence dimming and supplemented lighting is advised to balance the ambiance.

Opal Shades

Opal shades are another traditional option for decorative lighting and come in two shade categories – clear and opal. Shades are usually made using blown glass or a plastic diffuser. The advice for selecting the right shade to replicate a cozy ‘sunset effect’ is very similar to fabric shades. Opal glass contain the light inside the shade and provide a glowing effect, perfect for creating the interior atmosphere. Clear shades, on the contrary, do not hold light well and disperse it 360 degrees into the space, hence, it is much harder to create contrast for a moody atmosphere.

If you like using clear shades, I suggest choosing ribbed glass ones that contain the light better. Make sure lights can be dimmed and use supplement lighting to highlight other interior areas to form the atmosphere. Final touches, such as choosing correct lamp, are also important. Clear lamps work better with clear shades and frosted lamps are better to ensure a smooth opal effect to the opal shades.

Solid Shades

Historically, solid shades have been quite widely used as well, for example, metal shades - for its availability and durability in

exterior use. Nowadays, solid shades can be made of all sorts of materials – plastic, concrete, wood or fully recycled materials. Solid shades are those that have no transparency and light is omitted only in the direction where the shade is open – for example downwards. Due to its nature to direct the light, such lamps can be great for task lighting – such as a reading light or a table / desk lamp. Since these lights do not offer any internal glow, they can be seen more as decorative objects and will not provide a long-distance glow to guide you through the space. Such lights are best to be used for task lighting or supplemented with additional accent lighting to highlight the interiors and create pools of light.

There is a vast variety of lighting types to consider when creating the atmosphere of the room and it can be hard to navigate through all the options, thinking not only about the aesthetics of the light but also the function and the effect. On a positive side, decorative lighting is the easiest to add a wow effect to any space. It is easy to install and readily available on the market, compared to the other light sources. And remember, when you want to immerse yourself back into the holiday mood, you may just be just one light click away. ■

Laura is holding multiple light training and workshop events in London for the industry available throughout 2022-2023. Please follow the LinkedIn page for details.



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Alwadi Hotel, Doha: Solid shades example – table and floor lamps are used for specific tasks – work and read, while complimentary cove lighting is used to create a balanced atmosphere.

Ecodesign Directive: Success in Stimulating Demand for Sustainable Lighting

Dr. Wouter SOER, Director of Product Development, Lumileds

The European Union's new Ecodesign regulation for lighting, which took effect in September 2021, plays an important legislative role in the region's sustainability program. Also known as the Single Lighting Regulation (Commission Regulation (EU) 2019/2020), it sets minimum functional and power requirements for light sources. It is complemented by the Energy Labelling Regulation (Commission Delegated Regulation (EU) 2019/2015), which requires light source manufacturers to advertise the light source's energy efficiency classification on the product itself, and in supporting documentation (Figure 1).

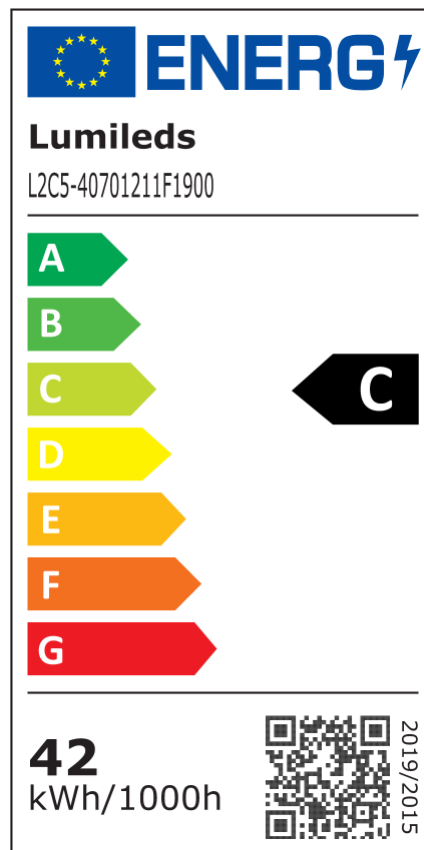


Figure 1: The EU's Energy Labelling regulation sets a standard format for displaying a light source's energy efficiency classification. (Image credit: European Commission's EPREL [1].)

Compliance with the Ecodesign regulation imposes obligations both on light source manufacturers and fixture manufacturers, with the goal of increasing the use of more energy efficient lighting products instead of less sustainable alternatives. Now that the Ecodesign regulation has been in force for over a year, expert observers are ready to cast judgment on the regulation's effect, and the weight of the compliance burden that it imposes. In Lumileds' view, the reg-

ulation has had some clear successes, but it has not been without its problems. Many fixture and light source manufacturers are finding that the legislation's complexity makes implementation difficult. Drawing on the expertise and products of Lumileds can help them overcome the hurdles and achieve compliance without a substantial effect on product development schedules and processes.

Market Responds to Push for Sustainability

The most important outcome of the introduction of the Ecodesign regulation is the desired one: Lumileds' experience is that fixture manufacturers are more likely to specify light sources with a high energy efficiency rating than they were before the introduction of the regulation.

Over time, this means that the installed base of lighting equipment in Europe will on aggregate, consume less electrical power per lumen of light emitted, with a consequent reduction in greenhouse gas emissions. As the EC reviews the implementation of the regulation, however, it should take note of the effect of applying the efficiency specifications at the lowest possible level (the light source) rather than at the fixture level. This makes it possible for a fixture manufacturer to drive a light source at different conditions from those at which it was tested, or to use a fixture design with substantial optical or electrical inefficiencies. In either case, the actual efficiency of the fixture will not match the advertised efficiency of the light source. To avoid extreme discrepancies, the regulator relies on light source manufacturers to declare performance at representative conditions, and

on fixture manufacturers to design efficient systems around light sources.

It is also worth noting that energy efficiency is not the only aspect of sustainability governed by the Ecodesign regulation. It sets a requirement that the light source should normally be replaceable: this should mean that fixtures last longer before disposal, with a consequent reduction in the lighting industry's contribution to the volume of waste dumped in landfill sites.

The Ecodesign regulation also requires light source manufacturers to declare their products' performance on other parameters such as lumen maintenance and color rendering. It seems likely that the greater transparency about these aspects of an LED's performance will encourage the market to choose superior products, resulting in an improvement in the quality of European lighting installations.

Crossing the Compliance Hurdles

These gains in efficiency and performance, however, are not cost-free: the compliance effort on the part of lighting equipment manufacturers consumes considerable administrative and engineering resources. It's not only a question of testing every product variant and documenting the results: even just understanding the legislation and figuring out how to implement it is difficult and time-consuming.

To be fair to the EC, its intention was to eliminate loopholes and ensure that no type of white light source avoided the need to comply. This meant that it drafted a complex set of rules and eligibility criteria, and devised complicated formulae for measuring a light source's energy efficiency.

The implementation of complicated legislation is manageable for Lumileds, a large company which can draw internally on a deep well of engineering and legal expertise. And the products and expertise that Lumileds has to offer can ease the compliance burden for customers.

The most obvious way is to use light sources that are certified to be compliant with the Ecodesign regulations. Lumileds' Matrix and chip-on-board (COB) products are light sources as defined by the regulations. To date, Lumileds has registered close to a thousand such products with corresponding markings and energy labelling information in compliance with the new regulations. Lighting equipment manufacturers that use Matrix or COB products rather than an internally developed light source are freed from the burden of testing, certification and documentation.

Viewing Part #L1HX-3070200000000
CHANGE PART

PART DETAILS

Product Family	LUXEON HL2X
Sub-Family/Sub Group	
Part Number	L1HX-3070200000000
Typ CCT [K]	3000
Min CRI	70
Binning Current [mA]	700
Binning (Junction) Temperature [°C]	85
Color target in scope yes/no	Yes
Min R9	-40
DLS yes/no	Yes
Beam angle [deg]	123
Fraction of flux in defined cone	0.81
Normalized peak luminous intensity [cd/lm]	0.324
Intended for HLLS application yes/no	No
Average normalized luminance [cd/mm ² /lm]	n/a
Min excitation purity (%)	n/a
Projected L70B50 at product binning current, 55°C [hrs]	>50,000
X _{LMF} at product binning current, 55°C	0.98
Survival factor	1.00

NORMALIZED SPECTRUM

DOWNLOAD CSV

Figure 2: The Lumileds Ecodesign Tool helps fixture manufacturers to comply by providing detailed information about its LUXEON LED products. (Image credit: Lumileds) [2].

Unlike many light source manufacturers, Lumileds has access to the test data from the LED production units of which its light sources are comprised. Lumileds uses this data to report the performance of the light source. Moreover, the flexible Matrix process allows customers to request performance specifications that are optimized for their application. Lumileds' intelligent assembly technique, which selects LEDs based on test data for each LED unit, enables these optimizations to be realized in production light sources.

These benefits are available to buyers of products defined as light sources according to the Ecodesign regulation. To support customers that buy LED packages rather than light sources, Lumileds set up a dedicated online Ecodesign Tool: this tool streamlines light source manufacturers' compliance efforts by providing all the information that they require about a product on one webpage (**Figure 2**).

Without these types of support, compliance can be a heavy burden. Evidence for this is shown in the number of errors in the product listings shown in the European Product Registry for Energy Labelling (EPREL) – the EU's database of products which declare that they are compliant. When studying a random sample of entries, it is not hard to find examples of product data which are obviously wrong or are internally inconsistent.

It seems unlikely that this is the result of deliberate or fraudulent misstatement of a product's specifications. No doubt most examples are honest errors: either mistakes in applying the formulae for calculating parameters such as energy efficiency, or failures to understand how to apply the rules properly.

For instance, the regulation has a complex definition of a 'directional light source': the flux measurement of a directional light source should only apply to light emitted in the intended direction, rather than total flux, but the correct application of this section of the regulation calls for concentrated study of the wording of the law.

Requirement for Strong and Public Enforcement

Currently, then, fixture manufacturers and the general public cannot have total confidence in the product information published in the EPREL. Confidence would be increased if there was any evidence that erroneous entries will be dismissed from the list of compliant products.

What is needed is a public show of enforcement. This is in the hands of member states rather than the EC. Clearly it would be impossible for the member states to check the more than 200,000 individual products registered on the EPREL. But member states could perform a series of random spot checks of products, followed by public disclosure of those products that have been removed from the EPREL database because their manufacturer had published false or erroneous data about them.

Over time, there might also be steps which the EC could take to make the legislation simpler and compliance less onerous.

Lumileds, for its part, will continue to help lighting manufacturers by supplying compliant light sources and comprehensive information about packaged LED products, and by providing expert advice and support.

Industry on the Right Side of the Sustainability Argument

Lumileds believes the Ecodesign regulations are right for Europe and the industry in general. Its concerns are mainly centered on the need for more enforcement and support to help manufacturers to comply more easily. Lumileds itself has long advocated for sustainability to be at the heart of business practice, and holds itself accountable for this by publishing an annual Sustainability Report.

The switch from incumbent lighting technologies to LEDs has already had a huge positive impact in reducing the greenhouse gas emissions attributable to lighting. LEDs are also a long-life product and have reduced the volume of waste which the lighting industry sends to landfill.

Now Lumileds supports moves to improve the industry's record on sustainability, such as more detailed and effective supply-chain monitoring to track the provenance of the materials used in LEDs and other components. The EU's Ecodesign regulation can play its part in this improving sustainability story, and Lumileds stands ready to help the industry to ease the burden of compliance. ■



AUTHOR: Dr. Wouter SOER

Wouter Soer is a Director of Product Development at Lumileds. He leads early stage LED product and application development programs for a wide range of lighting applications, and participates in external working groups related to policy, standardization and funding programs to facilitate market introduction of innovative lighting products. Wouter has more than 15 years of experience in the lighting and semiconductor manufacturing industries and holds a Ph.D. in Materials Science.

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- [2] Lumileds Ecodesign Tool www.lumileds.com

About Lumileds

Lumileds is a global leader in OEM and aftermarket automotive lighting and accessories, camera flash for mobile devices, MicroLED, and light sources for general illumination, horticulture, and human-centric lighting. Our approximately 7,000 employees operate in over 30 countries and partner with our customers to deliver never before possible solutions for lighting, safety, and well-being. To learn more about our company and solution portfolios, please visit www.lumileds.com.

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2022

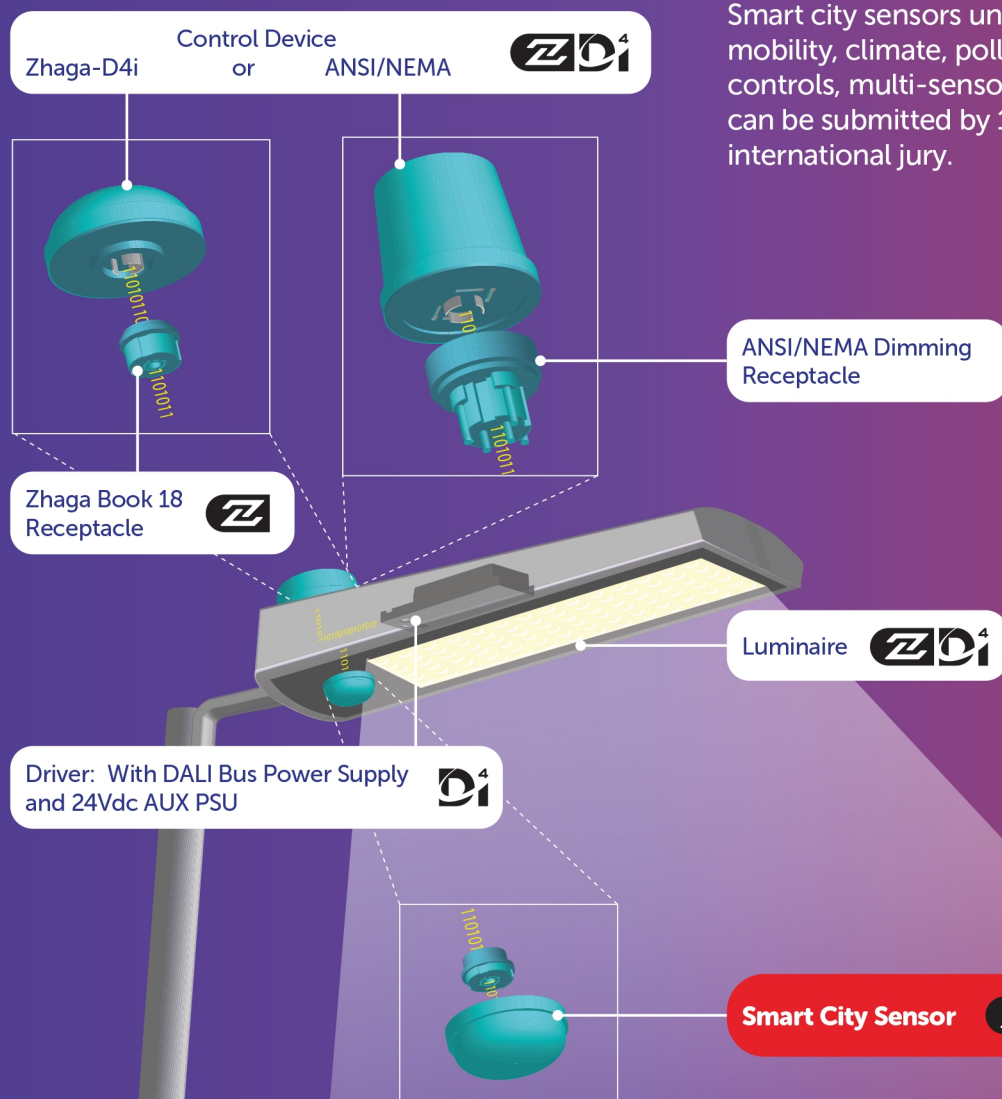
Zhaga Smart City Sensor Awards

The Zhaga Consortium is launching the global Zhaga Smart City Sensor Awards to encourage and recognize excellence in smart city sensors that can be installed on streetlights using the new Zhaga Book 18 standard and will be suitable for Zhaga-D4i certification.

Sensor manufacturers who win an award will receive international public recognition. Students and researchers are eligible for a 2000€ prize.

The underlying premise of the Zhaga Smart City Sensor Awards is that the streetlight is the ideal and perhaps lowest cost place from which to perform many smart city sensing tasks.

Smart city sensors under the following categories: mobility, climate, pollutants, sound, lighting controls, multi-sensors, innovation and research, can be submitted by 16 December 2022 to the international jury.



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Will MicroLEDs Revolutionize the Display Industry?

Eric VIREY, Ph.D., Senior Market and Technology Analyst at Yole Intelligence (Yole Group)

MicroLEDs promise new generations of displays with improved performance in terms of brightness, energy efficiency, contrast, color gamut, etc. Many companies have shown prototypes in various sizes and performances aimed at a wide variety of applications, ranging from augmented reality to automotive, wearables, televisions, public information displays, etc. The first commercial, consumer-oriented microLED displays are coming to market in 2022. Yet, despite all its promises, adoption remains anecdotal. What are the remaining roadblocks preventing more rapid adoption?

MicroLEDs are not to be confused with miniLEDs. There are no rigorous and commonly accepted definitions to distinguish both technologies. Chip size is only one factor. In practice, a combination of size, architecture, manufacturing and assembly technologies, as well as applications, is used to define mini and microLED (Figure 1).

In a nutshell, miniLEDs are much larger and easier to manufacture than microLEDs and don't require any fundamental technology breakthrough. In terms of applications, on the consumer side, miniLEDs are used to enhance existing Liquid Crystal Display (LCD) technologies by enabling better backlights which confer LCD contrast performance closer to that of OLED, allowing the 40+ year old technology to remain relevant and competitive in the high-end segments of the TV, monitor, notebook and tablet markets. In the industrial (non-consumer) markets, they are used in high definition, high performance, large Direct View LED Displays of the kind often seen in high-end retail shops and shopping malls, movie and TV broadcasting studios, corporate lobbies, or high-end conference rooms [1].

MicroLED Characteristics

Just like OLED, microLED is a self-emissive display technology in which each individual red, green, and blue sub-pixel is an independently controllable light source: a tiny LED chip less than 50 μm in size, ideally less than 10 μm for consumer applications. Like OLEDs, microLED displays offer high contrast, high switching speed, and wide viewing angles. They could also deliver a wider color gamut, much higher brightness, significantly reduced power consumption, improved lifetime, ruggedness, and environmental stability. MicroLEDs also allow for the integration of sensors and circuits within the pixels, enabling thin displays with various embedded sensing capabilities, such as local brightness measurement, fingerprint scanning, in-display camera, touch function, gesture control, and more. Finally, unlike OLED which requires encapsulation to protect the fragile organic materials from air and moisture, and LCD which requires a seal for the liquid crystal, microLED is the only display technology allowing the production of bezel-less displays. This not only allows for elegant, nearly 100% screen-to-body ratio devices but opens the door for seamless, modular displays of virtually any size that could be assembled from smaller modules.

A Strong Momentum

Since there is currently no high-volume microLED consumer market, a good proxy to gauge the level of interest from the industry is to look at patent filings. Yole Intelligence has been closely monitoring and analyzing trends since 2017. Research on microLED displays started in the early 2000s, pioneered by various research teams such as Professor Jingyu Lin and Hongxing Jiang, at the time at Kansas State University, or companies like Sony. But as illustrated by historical patent filing trends, it was the acquisition of microLED display startup Luxvue by Apple in 2014 that really put microLED on the map. For the most part, display makers were late in the game, either

because LEDs were too far from home in terms of technology expertise, or because display makers didn't immediately see the potential of microLEDs, and, therefore, the threat it posed to their OLED efforts. However, since 2016, display makers have significantly accelerated their microLED effort and are now dominating microLED patent activity, which is growing exponentially (Figure 2).

Another indicator of interest in microLED is the amount of money being invested. As of mid-2022, microLED startups have raised more than \$1.7 billion from venture capital and strategic investors, with a handful raising more than \$200M. Larger companies have already snatched up some of those startups, with acquisitions also totaling more than \$1.7B so far. At more than \$1B, Google's acquisition of Raxium and Jasper Display carries most of that amount, but Apple, Facebook/Meta, and others also spent significant amounts of money in acquiring microLED technology and talents. The acceleration of the development has propelled microLED into a virtuous cycle. Research and development have reached a critical mass, enabling microLED technologies to progress on all fronts and major bottlenecks to be progressively lifted. The improving prospect has convinced equipment makers to develop and commercialize dedicated microLED tools for mass transfer, yield management, testing, and inspection. The availability of these off-the-shelf tools is lowering the barrier to entry and accelerating development cycles. Even more significant are the first moves toward mass manufacturing. In April this year, Osram announced an €800M investment over two years to build 8" μLED lines in Kulim (Malaysia), with manufacturing to ramp up in 2024. Leading LED chip-maker San'an is spending \$1.9B on a new miniLED/MicroLED fab, and Hong Kong startup JBD (Jade Bird Display) is currently building a \$100M microLED microdisplay fab in Heifei. Many other players, such as Ennostar/Epistar, Aledia, Tianma, etc., are currently setting up microLED fabs or pilot lines. All in all, we estimate that by 2025,

more than \$10B will have been spent on microLED development and early manufacturing infrastructure. While this is a meaningful number, it, of course, pales compared to the more than \$130B spent to date on OLED fabs, but microLED is still young, and the momentum is here. So, now that microLEDs have entered a virtuous cycle, what is still preventing the technology from taking the display industry by storm [2]?

Mass Transfer: The Elephant in the Room

The art of making μ LED displays consists of processing an LED epiwafer into an array of microLEDs that are poised for pick up and transfer to a receiving backplane substrate for integration into a heterogeneously integrated system incorporating the LEDs, pixel-driving transistors, optics, etc. [2]. Assembling an 8K resolution (7680 x 4320 pixels) microLED display implies transferring and assembling almost 100 million microLEDs that are the size of bacteria, with a typical placement accuracy of $\pm 1 \mu\text{m}$ and doing so in less than 10 minutes to be economically viable. Today's best die bonders can't manipulate the very small dies (3–15 μm) required to enable high-volume consumer applications. In addition, at the required level of precision, they typically have throughput in the range of 1,000 dies per hour. At this pace, it would take more than 11 years to manufacture a single 8K TV. There is, therefore, a need for a paradigm change: the development of mass transfer technologies that can manipulate and assemble much smaller dies than typical pick and place equipment and do so with a throughput of at least 5 orders of magnitude faster. It is no surprise then that developing mass transfer processes with sufficient yield and throughput has long been seen as the major challenge for μ LED displays and a major research and development thrust area for the industry (Figure 3).

Dozens of processes have been proposed. They can be classified as illustrated in Figure 4. The most popular transfer methods involve the use of polymer "stamps" able to exert a pickup force on a large array of LEDs (tens of thousands or more). After the stamp picks the die up, various die-release mechanisms can be used to drop them off on the display backplane. Among them, laser transfer has been gaining a lot of traction due to its ability to enable fully addressable processes where only good dies identified by upstream metrology and testing are transferred while defective ones can be eliminated from the workflow. Other

transfer methods involve different types of MEMS or self-assembly in a fluid or gas medium.

Progress in mass transfer over the last five years has been spectacular, to the point that, as of early 2022, many industry players no longer see it as a fundamental roadblock. Some companies claim transfer yields ranging from 3N (99.9%) to 4N or higher. There is, of course, still a long road to mature, cost-effective, and robust processes ready for high-volume manufactur-

ing of consumer μ LED displays, but there is now a clear path ahead. As a result, an increasing number of established semiconductor and equipment makers have developed and are now offering commercial microLED mass transfer, repair, and testing equipment and solutions. This is a paradigm change: until 2020, a company interested in developing microLED displays first had to invent its own transfer process and build the corresponding equipment. Fast forward to 2022, and more than

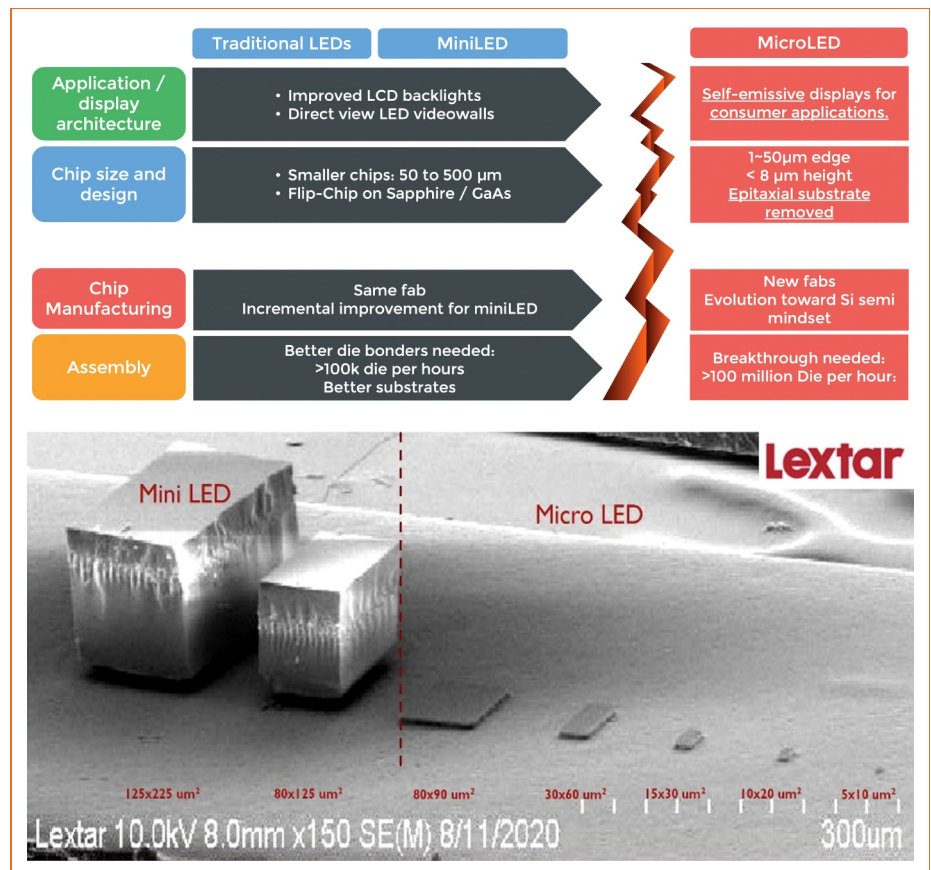


Figure 1: **Top:** Major differences between different types of LEDs. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021. **Bottom:** MiniLED vs. MicroLED. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021. Image: Courtesy of Lextar.

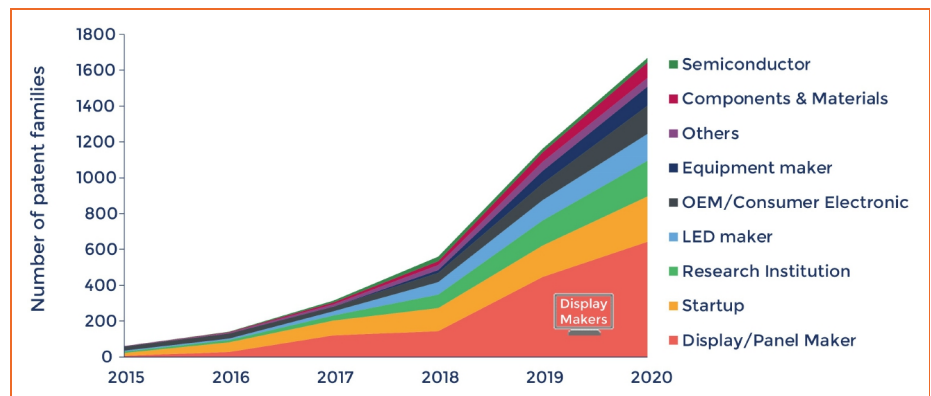


Figure 2: MicroLED Displays; Patent Publications by Company Type. Source: MicroLED Displays – Intellectual Property Landscape report, Yole Intelligence, 2021.

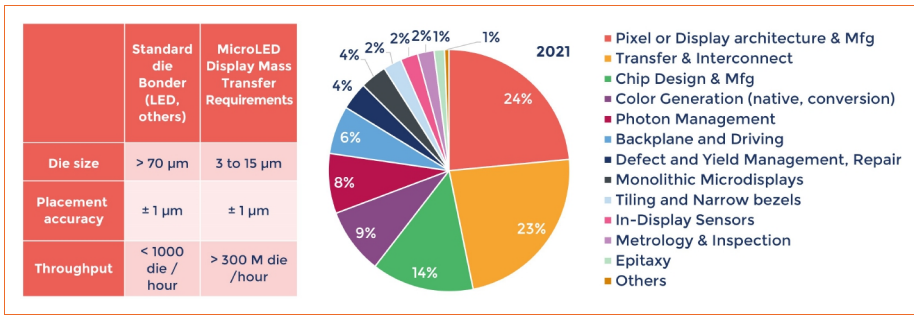


Figure 3: Requirement for MicroLED Consumer Displays and Breakdown of MicroLED Display Patents by Technology Nodes. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021 and MicroLED Displays – IP Landscape and Analysis report, Yole Intelligence, 2021.

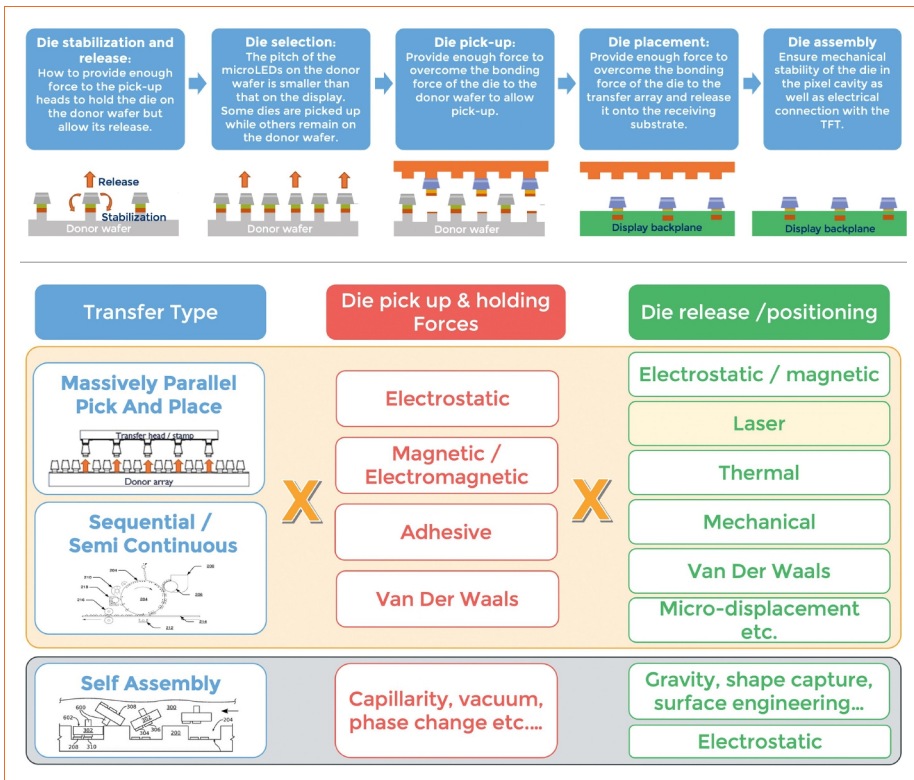


Figure 4: **Top:** Mass Transfer Major Steps and Classification of Major Processes. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021. **Bottom:** MicroLED Mass Transfer Major Steps and Classification of Major Processes. Source: MicroLED Displays – IP Landscape and Analysis report, Yole Intelligence, 2021.

Selected Area Growth & 3D LEDs	Chip Design	Chip Manufacturing
<ul style="list-style-type: none"> Grow the LED on patterned seeds or through a mask to produce the 3D chip structure without etching → no sidewall damages. 	<ul style="list-style-type: none"> Tunnel junctions (improved injection) Current confinement structures Improved doping profiles Angled MQW (away from sidewalls), etc. 	<ul style="list-style-type: none"> Improved etching Sidewall passivation Sidewall “repair” (ALD, MOCVD regrowth, etching, annealing...)

Table 1: MicroLED EQE Possible Remediation Technologies. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021.

a dozen tools are available off-the-shelf from reputable display and semiconductor equipment manufacturers. Any company can now purchase these tools and almost immediately start assembling microLED display prototypes. This is significantly lowering barriers to entry and shortening development cycles.

Efficiency: How to Beat OLED?

Another major thrust area is microLED chip structures and fabrication. Efforts revolve around improving efficiency, devising structures suitable for mass transfer, or creating RGB monolithic chips which could simplify the display assembly. At very small dimensions, μLED operation is impacted by nefarious sidewall effects related to surface and subsurface defects such as open bonds, contaminations, or structural damage in which non-radiative carrier recombination dominates. Sidewall effects also lead to leakage currents. They result from the harsh manufacturing conditions (plasma etching) and can spread over distances similar to the carrier diffusion length, typically 1–10 μm: not a big deal in LEDs that are 100s of microns across but a killer for microLEDs where they could affect the entire volume of the chip. As a result, the External Quantum Efficiency (EQE) of microLEDs tend to be significantly smaller than their larger counterpart (Table 1). The drop in LED efficiency at small sizes is now well documented, and its causes are better understood [3,4]. Researchers have devised various ways to alleviate those effects and improve efficiency.

While microLED efficiency still falls short of standard-sized LEDs, progress has been significant over the last few years, especially for red emitters that had initially been lagging significantly behind blue and green [5]. Researchers have improved performance with both AlGaInP and InGaIn-based systems [6], though for some applications, such as microdisplays for augmented reality, red efficiency is still insufficient, prompting many research teams to consider using blue chips with quantum dot color conversion, which deliver higher efficiency than native red microLEDs.

Chip efficiency is just one contributor to power consumption. Display driving is also critical. In an LCD, the Thin Film Transistor (TFT) is only used as a switch. In self-emitting displays (OLED, μLED), the emitters are current-driven, and performance depends a lot on the capabilities and stability of the driving transistors which inject the current into the LED. Due to their low

mobility and poor characteristics (compared to monocrystalline silicon), TFTs are not very efficient current sources. For OLED, 30-40% of the power is dissipated by the TFT. The situation is even worse with μ LED due to their lower driving voltage. Optimization of the TFT backplane by display companies will be critical if microLED wants to beat OLED in terms of power efficiency.

Finally, pixel structures and beam shaping are also essential to bring the optical energy to where it is needed: the eyes of the users. Requirements vary from one application to another. The more stringent requirements are for micro-displays used in Augmented Reality (AR) applications. In AR devices, the image is delivered to the eye via complex optics so that the display doesn't obstruct the users' field of view, and the image just looks as if it is floating in the air a few meters from the viewer superimposed over the real-world view. The acceptance angle of such optics is narrow, typically $\pm 20^\circ$ or less. Light emitted out-

side of this narrow cone is wasted. Worse, it can cause optical cross-talk, reducing the sharpness and contrast of the image. Once coupled into those optics, more optical losses are encountered. Ultimately, the overall wall plug efficiency of AR display and optics systems is often less than 1%, hence the requirement for very bright displays, ideally exceeding a million Nits per color (Figure 5).

Yield Management and Repair: The Crux of MicroLED Display Manufacturing

A major challenge for microLED display manufacturers is defect management. In modern consumer displays, dead or defective pixels are no longer acceptable. No matter how good one is at improving epitaxy and chip manufacturing and assembly yields, defective pixels will always occur. Manufacturers must, therefore, develop

effective defect management strategies combining pixel redundancies and/or individual pixel repair, along with chip and pixel testing and binning. Contributions to defects are spread across the process. A chain is only as strong as its weakest link. As of 2022, this weakest link is the LED chip itself. Defects can occur at the epitaxy level, with particles originating from the manufacturing or storing environment, the substrate, or the MOCVD reactor. Most of the defects, however, stem from chip manufacturing: the lithography, etching, and coating steps that lead to a fully formed μ LED chip.

The transfer and bonding (electrical and mechanical interconnects) steps add more defects. Ultimately, even a combined yield of 99.485% (Figure 6) means that, in an 8K resolution TV, more than half a million pixels will be defective.

The industry is striving to reduce this number and is deploying various yield management strategies such as die redundancy or upstream testing and selective removal of Known Bad Die (KBD) before they are transferred and connected to the display backplane. Nevertheless, some pixel repair steps will remain unavoidable. Some companies are developing "mass repair" processes where multiple defective microLEDs can be replaced in a single operation. The repair step can occur on the final display but also upstream, on an intermediate microLED carrier. Indeed, an increasing number of companies are considering 2-step mass transfer, where microLED dies are first transferred to an intermediate carrier. Defective or missing dies are repaired on this carrier before being transferred and permanently bonded to the display backplane. But defects will occur at that step as well, so additional repairs will be needed. Ultimately, efficient defect and yield management strategies have become the crux of microLED displays.

MicroLED Display Costs Need to Decrease by 95%, and a Paradigm Change is Required in LED Manufacturing

Depending on the application, a microLED display cost is still 20x to 50x too high to address actual consumer products. The challenge appears daunting. However, looking back at the history of LCD volume production, LCD costs decreased 300x, from 30,000/m² to 100/m² in 25 years. The situations of LCD and microLED are different, though: LCD started from a blank

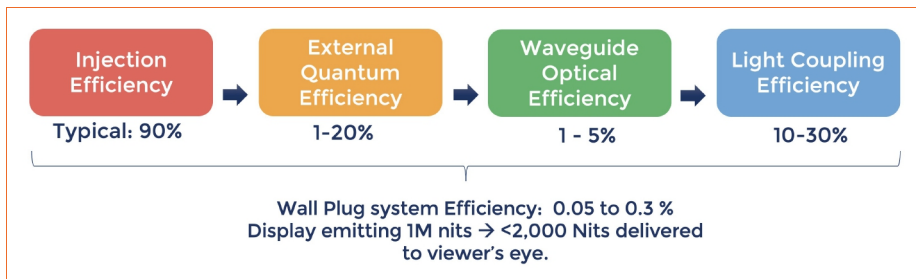


Figure 5: Augmented Reality Display and Optics System Efficiency. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021.

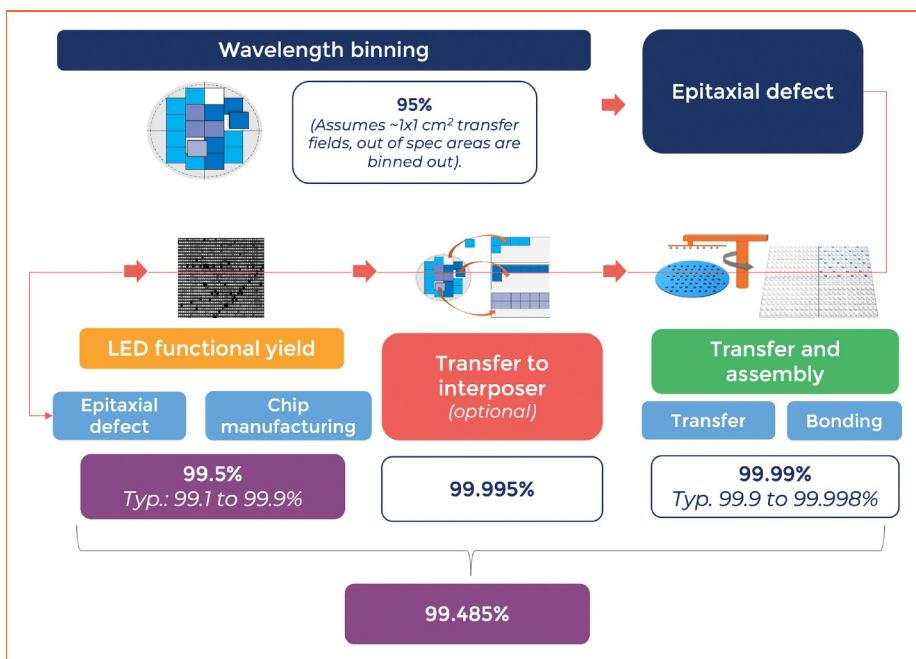


Figure 6: MicroLED Process Flow and Major Yield Contributions. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021.

canvas, and cost reduction opportunities lay across the board: materials, equipment, processes, etc. Once the low-hanging fruits were harvested, the bulk came from generation scaling, i.e., substrate sizes. For those coming from the semiconductor or LED industry, it is often baffling to learn that the micron-size, complex circuits used as the backplane of traditional displays are manufactured on glass substrate than exceed 10m² in size. MicroLEDs, on the other hand, are grown on traditional 4" to 12" wafers and exist at the intersection of the mature Semiconductor, LED, and Flat Panel Display industries. This means fewer cost contributors present 300x reduction opportunities, but in many cases, microLED hasn't yet leveraged on many existing technology bricks and wafer processing equipment that could help deliver a 20-50x reduction at a faster pace than it took LCD (Figure 7).

MicroLED display costs are driven mainly by:
 1) LED die prices, the single largest Bill of Material (BOM) contributor, and
 2) yield management and repair, the single largest manufacturing cost contributor.

Reducing die size is, therefore, the single largest opportunity to reduce microLED display costs. At Yole Intelligence, we have

conducted extensive cost simulations for multiple clients that all lead to the same conclusion: for most consumer displays, a die size below 10 μm will be required to reach a cost level that can be competitive with OLED and compatible with consumers' expectations for high-end devices. Smaller die sizes, however, imply lower LED efficiency and increase manufacturing challenges. Interestingly, with microLED displays, die size is driven by cost requirements, not performance: LEDs are extremely bright and can be driven very hard, so in most cases, there is no concern about getting sufficient light from the chips.

Besides LED size, the manufacturing process and infrastructure are also key for cost reduction. Different approaches can be taken for the front end, i.e., LED chip manufacturing.

- Push capabilities of existing LED fabs and avoid intense capital expenditure.
- Build greenfield, dedicated microLED fabs, ideally with large wafer platforms (200 or even 300 mm).

The first approach might work for pilot lines and initial products (TV, watch, auto) or small displays, but producing the very small die sizes with the high yield required for high-volume consumer displays will be ex-

tremely challenging. The technology gap and investment are larger with production on 200 mm or even 300 mm wafer in microLED-dedicated fabs. But, by opening the door to a vast array of battle-tested semiconductor processing tools with high consistency, capabilities, productivity, and yields, it could provide a unique cost/performance improvement opportunity.

In our opinion, which is increasingly shared by the microLED community, existing LED fabs are unsuitable for high-volume, consumer-grade microLEDs. High-yield production of small-size, high-performance microLEDs requires much better clean rooms, typically class 100 or better, than the ones commonly encountered in traditional LED fabs. Mask aligners must be replaced by high-resolution stepper lithography, while microLED-specific processes and equipment such as Atomic Layer Deposition passivation and laser lift-off are required, etc. But more than anything, successful microLED manufacturing will require a paradigm change toward a semiconductor-like mindset with high efficiency, a high level of automation, end-to-end yield management, and defect prevention strategies, etc. Few LED makers will be able to afford such investments without a firm commitment from customers.

Application Trends

For most applications, we struggle to deliver a cost model scenario where microLED is significantly cheaper than OLED, let alone LCD. Strong differentiation is therefore needed, and, in any case, microLED will mostly compete in high-end segments for each application, i.e., flagship TVs, smartphones, etc. MicroLED adoption, however, will be easier in segments with no good incumbent technology.

Despite early success in the enterprise market, such as warehouse workers, maintenance, medical procedures, etc., Augmented Reality (AR) is still in search of a strong use case for high-volume consumer adoption. It also faces many technological challenges besides displays, including power consumption, form factor, processing bandwidth, eye tracking, etc. However, when all pieces of the puzzle are in place, microLED will likely be the only display technology capable of providing the right combination of cost, brightness, efficiency, and size required for this application. Unlike other microLED displays, microdisplays do not rely on mass transfer. Instead, the full array of LEDs constituting the display is directly bonded (hybridized) to a Si-CMOS backplane featuring the pixel driving cir-

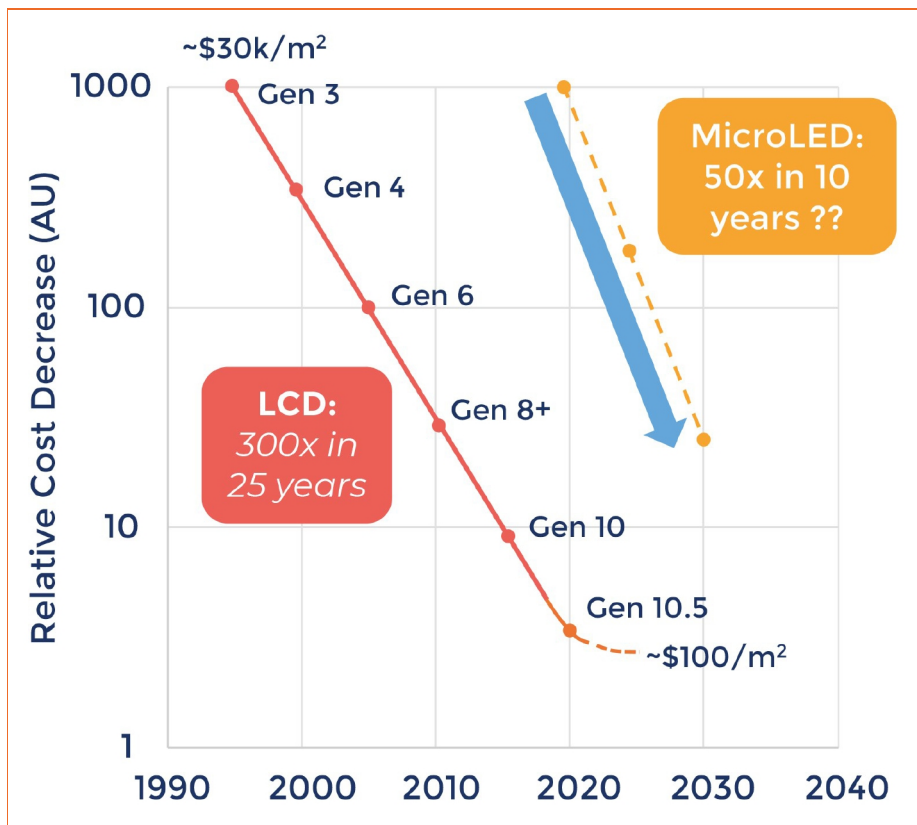


Figure 7: LCD vs. MicroLED Cost Reduction Trends. Source: MicroLED Displays – Market, Industry and Technology Trends report, Yole Intelligence, 2021.

cuity [7]. The challenge, however, is in realizing full color (RGB) microdisplays since there is not yet any good solution to producing the 3 colors on the same LED epiwafer and at the required LED die size (often close to or smaller than 1 μm) so assembling individual pixels from different wafers by mass transfer becomes impractical. Until full-color microLED microdisplays are available, LCOS (Liquid Crystal on Silicon) and MEMS-based displays are set to continue dominating the field (for this specific application, OLED will likely lack brightness).

High price elasticity and strong opportunities for differentiation, such as power consumption, image quality, and the ability to integrate sensors and new functions into the frontplane, make smartwatches a compelling case for microLED. Apple is leading the charge on this application, with smartphones as the endgame. Apple's current plans call for volume production of the microLED smartwatch to start in 2024, with Osram's 8" microLED foundry providing the chips. A Smartphone is a different beast, however. OLED displays are already doing a great job in terms of both price and performance. To get within the cost envelope for this application, microLED sizes will need to shrink below 5 μm, most probably 3 μm. This compounds all the challenges of low efficiency, manufacturability, and transfer yields. This also explains why Apple is making the challenging bet of manufacturing on an 8" wafer platform. While risky at first, we see this strategy as the only one capable of delivering such small dies with high yield and performance. If anybody can make microLED smartphones happen. Apple is the best-positioned candidate.

Samsung is more focused on the TV market. The company introduced the first microLED TV in 2021, a 110" version, for about \$150,000. By our definitions, however, this product would qualify more as a miniLED Direct View LED Display, based on 75x125 μm LED dies assembled by standard pick and place equipment on a PCB backplane with discrete passive matrix drivers. At CES 2022 in January, the company showed its second generation of microLED TVs expected for late 2022 in 89", 101", and 114" sizes. This second new design does qualify as microLED with smaller (34 x 58 μm) dies assembled by laser mass transfer on an active matrix TFT display backplane. As of the time of writing this article, the cheapest model, an 89" 4K, is anticipated to retail for around \$90,000. This is still about 14x times more expensive than an OLED TV in terms of \$/m². However, compared to the 2021 110" model, this represents a more than 40% price de-

crease in terms of \$/pixel and close to 20% in terms of \$/area.

Finally, automotive is a compelling application for microLED displays which can deliver the right combination of high brightness, contrast, ruggedness, longevity, and power consumption that automakers so much desire. Cost reductions will allow microLED to enter the market, but adoption will be slow due to long design and qualification cycles.

Conclusion

While intrinsically superior to OLED in terms of performance in almost all aspects, it remains to be seen if and when microLED costs can reach a level where it can effectively compete with OLED. In light of the recent progress, however, we no longer see microLED as a fundamental science project but more as a vast engineering and manufacturing challenge.

There is now a strong momentum for MicroLED. Apple put the technology on the map when it acquired Luxvue in 2014. Display makers were initially skeptical but now increasingly believe that, while still challenging, microLED displays might be credible contenders, at least for some applications. As a result, money and resources are flowing into microLED, initiating a virtuous circle, fueling faster development, newer and better solutions, improving prospects, and attracting more companies and investors.

Strong momentum doesn't guarantee success, though: many technical and supply chain challenges could still derail microLED. There are still many question marks regarding yield management and display-driving architecture. Cost is still 20x to 50x too high for consumer products. Many solutions look great on paper (and in a patent), but real-life process integration in a high-volume manufacturing environment is much more challenging. Nevertheless, many players now have clearer roadmaps to achieve those cost reductions and solve the remaining problems. Some are starting to set up their supply chains and are preparing for volume manufacturing.

Many companies have some pieces of the microLED puzzle, but none have them all. It is unlikely that any player will fully integrate all elements internally. Complex supply chain and partnership arrangements will also be required to enable high-volume manufacturing of consumer microLED products. ■



About Eric Virey, Ph.D.

As a senior market and technology analyst at Yole Intelligence, Eric Virey, Ph.D., is a daily contributor to the development of LED, OLED, and display activities at Yole Group. He has authored a large collection of market and technology reports as well as multiple custom consulting projects on subjects including business strategy, identification of investments or acquisition targets, due diligence in buying and selling, market and technology analyses, cost modeling and technology scouting. Thanks to his deep knowledge of the LED/OLED and display industries, Eric has spoken at more than 30 industry conferences worldwide over the last five years. He has been interviewed and quoted by leading media all over the world. Previously, Eric has held various R&D, engineering, manufacturing, and business development positions with the Fortune 500 Company Saint-Gobain, based in France and the United States. Dr. Eric Virey holds a Ph.D. in Optoelectronics from the National Polytechnic Institute of Grenoble.

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Smart Buildings vs. Intelligent Buildings: Why Intelligent Buildings Are the Better Choice

Barry MULLIGAN, Marketing Manager, Analog Devices

This article defines the term intelligent building, discusses the driving factors that are influencing intelligent buildings today, and explains how new Ethernet technologies enable transformation of existing buildings into intelligent buildings.

What Is an Intelligent Building?

The term “intelligent building” was first used in the U.S. in the early '80s and a definition given by the Intelligent Building Institution in Washington was:

An intelligent building is one which integrates various systems to effectively manage resources in a coordinated mode to maximize: technical performance; investment and operating cost savings; flexibility.

You've probably heard the phrase “Someone is too smart for their own good” but have you ever heard the phrase “They were too intelligent for their own good”? This is because there is a distinct difference between being smart and intelligent. One of my favorite quotes is “Smart people talk, intelligent people listen.” Similarly, the difference between a smart building and an intelligent building is that in a smart building, the user will program systems to act in a manner dictated suitable to the best intentions of the user. However, an intelligent building has the appropriate sensing and processing capabilities to listen for itself and then program itself to do what it sees as optimal. To achieve this, the building must have the relevant sensing capabilities to take as much of the external environment in as necessary, the appropriate communication pathways to transport these data back to the “brain” of the building (which could be located onsite or in the cloud), and machine learning algorithms in its brain to process the information it

is getting to dictate the optimal action to take. The action must then be communicated back out to the relevant systems for execution via the same communication pathways.

The Current State of Play with Intelligent Buildings

If you ever find yourself in the unfortunate situation of being lost in the wilderness or stranded on a desert island, it is the rule of three that will keep you alive. This rule states that to survive you have 3 hours to find shelter, 3 days to find water, and 3 weeks to find food before you will perish. Shelter is the top priority to your survival in this scenario, yet while we may not be currently lost in the wilderness, how we fulfill the human need for shelter by shifting to intelligent buildings is paramount for the future of our planet and humanity. Making a new or existing building intelligent is done via digitalization. This is the process of turning the factors that affect the running and maintenance of a building into digital signals that can be measured in real time and communicated back to the brain of the building to be analyzed and then managed. How we digitize new and existing buildings in order to make them more energy efficient and sustainable is the key to securing the future of our carbon footprint as a species. There are four key areas to consider when discussing the future of intelligent buildings:

- **Health and safety**—Is the space designed with the intent of increasing the state of well-being of its occupants? If the occupants feel safe and their environment is designed to enhance their mood and quality of life, they will be more productive [1]. This is even more paramount in the age of COVID-19 as people return to the office.
- **Sustainability**—Is the space as efficient

as it needs to be to reduce its carbon footprint? This theme not only enhances the lives of the building owners by saving money on energy bills and reducing maintenance costs but also has environmental, economic, and social benefits for the wider population.

- **Resilience**—Is the space designed with the future in mind to stand the test of time? The buildings of today are built to last 150 years or more. We do not know what innovations or technologies wait to be discovered in the future, but we can plan so that our buildings' information technology (IT) and operating technology (OT) infrastructure can handle the expected data traffic increase of the future as more systems start to come online and become IP addressable.
- **Economics**—Without the right financial incentives, it is very difficult to implement change. Money is value and there is value to be gained from buildings by making them intelligent. At first, however, capital investments are needed before the savings can be harvested. Innovative financing models will be needed to allow building owners to upgrade their buildings to intelligent buildings.

These four themes can be addressed through building automation. Today, building automation is largely based on closed and siloed systems working in isolation to perform their function without influence or actuation into other systems. In a building, these systems are the HVAC, lighting, access control, fire alarm, elevators, and occupancy detection to mention a few. Siloed systems are largely inefficient, contributing to a larger carbon footprint.

In the next sections, we will discuss the big macro trends driving the shift to intelligent buildings and the key benefits that can be derived from investing in intelligent building technology.

Why Do We Need Intelligent Buildings?

In **Figure 1**, we have what is called the funnel of influence. It is a rough outline of the ecosystem for how the need for intelligent buildings is driven in the modern world. First, we start with the macro trends of the world, which are urbanization and climate change.

Urbanization is the migration of the world's population from rural areas to urban areas such as cities. People move to cities for a better way of life. Cities offer employment prospects as well as better access to goods, services, healthcare, and education. Population growth also contributes to urbanization and it's estimated that >65% of the world's population will live in an urban environment by 2050. It is predicted that the global building floor space will double by 2060, equivalent to adding an extra New York to the world every month for 40 years [2].

Climate change is the change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onward that's been attributed largely to the increased levels of atmospheric carbon dioxide produced by using fossil fuels. The IEA estimates 40% of the world's carbon dioxide emissions can be attributed to buildings, with 28% of the emissions being contributed by the running and maintenance of the buildings alone [3]. The alarming estimate is that 50% of the energy currently used by buildings is

wasted [4]. The energy consumption and, in turn, CO₂ emissions in buildings have barely flattened off in recent years, showing that with more buildings due to come online, the impact of buildings on the environment will only get worse unless energy efficiency is improved.

Many influential think tanks such as the United Nations Environment Programme and the World Bank are now focusing on policies for improving energy efficiency in buildings, providing incentives to invest in sustainable and intelligent buildings, and retrofitting old buildings to meet current EU sustainability standards.

The world's governments bound by their obligations to tackle climate change are starting to implement these suggested policies. The EU, as part of their Green Deal policy, is now providing funding for a large retrofit program. There are approximately 220 million buildings in the EU, 85% of which were built before 2001 and 90% of existing buildings will still be standing in 2050, providing a large base for retrofitting. The EU aims to retrofit 30 million buildings by 2030. Equally, there's hope in the U.S. that the Infrastructure Bill and Smart Buildings Acceleration Act and the China 5-year plan will drive similar initiatives in these markets [5].

Government policies and building regulations drive energy improvements with the upcoming updates to the Energy Performance of Buildings Directive in the EU. Equally, the ASHRAE standards in the

U.S. are driving regulatory compliance, with other country specific regulations also coming online.

It is also becoming more and more common for buildings to have green and intelligent building certification. In some cases, this is a requirement for specific financial investments, but mostly it is understood that these certificates add a significant premium to the building's earning potential. LEED, BREEAM, and EDGE are all well-known green certificates, but local certification in China is now building pace. Intelligent building certification is newer but with TIA and UL coming together to form SPIRE, this too will become more popular.

Looking at the economics of these potential improvements to buildings creates a premium for healthier, greener, and more intelligent buildings. In London, research has shown that certified buildings command a 4% premium for rental and sales relative to noncertified buildings in the same area [6].

From world events to world economics, the shape of buildings is changing, and the top building automation companies are taking note. We notice that in line with quarterly revenue reporting, the megatons of CO₂ saved for their customers are being reported along with emphasis on greener and healthier buildings. How these building automation companies will achieve these savings is through vast building digitization and digitalization, allowing intelligence all the way to the edge node, gathering



Figure 1: The funnel of influence for intelligent buildings.

more intelligent data, and generating more actionable insights across multiple building systems, allowing the opportunities to fine tune and optimize each buildings' performance to ensure maximum energy efficiency and maximum sustainability.

How to Achieve an Intelligent Building

Most buildings today have a building management system or BMS. These comprise of disconnected subsystems specific to the function they perform as stated in the introduction; that is, lighting, HVAC, access control, etc. To make these buildings intelligent, it is not just a case of gutting them and putting whole new infrastructure in; this would be too costly. It is up to the semiconductor industry to enable the retrofit market with technologies that can digitize the current infrastructure and connect separate building systems to each other. **Figure 2** is a good example of how multiple technologies and communications protocols could transform a legacy BMS system into an intelligent building.

Ethernet is a common protocol that enables our day-to-day life and businesses with high data rates, but it is limited in terms of the distance it can reach and the topologies it can support. What if we could run Ethernet and IP over simple cables, such as single twisted pair over a 1 km in distance? This would provide seamless connectivity all the way from the cloud to the edge node, converging the IT and OT worlds to break down the silos of existing systems where data may be gathered but

are not actionable nor generate valuable insights.

10BASE-T1L is a key technology to enable edge connectivity—this protocol allows the seamless connectivity from the cloud all the way to the edge node, allowing IP addressable edge nodes that, in turn, allow real-time actionable control from anywhere. Having such seamless control will result in lower cost of ownership as the networking is simplified, the data can be easily aggregated and interpreted, and installation and maintenance are also simplified. We can now add intelligence where there may have been simple analog sensing in the past. By digitizing the edge and generating more intelligent data, we can digitalize the entire building.

10BASE-T1L was ratified by the IEEE in 2019 as 802.3cg. Analog Devices is a member of this committee and was influential in driving this standard. The key elements of this standard are providing power and data over a single cable with a data rate of 10 Mbps—the cable in this case being a single twisted pair with the reach being 1 km. It's important to note that for retrofitting within a building, the existing twisted pair cabling can be used.

When this is compared to some of the existing infrastructure such as RS-485, we can see some valid improvements. The data rate is constant over 1 km, and it is not dependent on the distance as per RS-485. Moreover, the number of nodes is unlimited with 10BASE-T1L for data, whereas it's limited to 256 for RS-485. One key advantage is the provision of power over the same single twisted pair up to 52

W—in a similar way to POE, whereas it's limited to what we called engineered power with RS-485.

However, it is well understood that RS-485 still has a valid position in building automation for particular use cases. We also understand that buildings will not perform the full digital transformation overnight, so 10BASE-T1L needs to work alongside existing systems for the foreseeable future. Here we can see 10BASE-T1L giving seamless IP all the way to the edge working side by side with RS-485 and software configurable IOs for legacy architectures.

While the standard provides guidelines to ensure meeting the 1 km distance, there are no restrictions on using other cables with the understanding that the full distance may not be reached. Shielded and non-shielded cables are allowed, which means retrofitting is possible in most cases. It would be advantageous to identify exactly where there was an issue in 1 km of cabling. Any BMS system operator fully understands the effort involved in installing, commissioning, and maintaining a system with km of cables. Luckily, this is possible with 10BASE-T1L as it enables compliance and link quality testing as well as the ability to perform tests for the installation and maintenance of the cabling.

Conclusion

The need to turn buildings intelligent is important to cut down on excess carbon emissions as global warming has already led to the extinction of multiple species on our planet. If we are not careful, we could

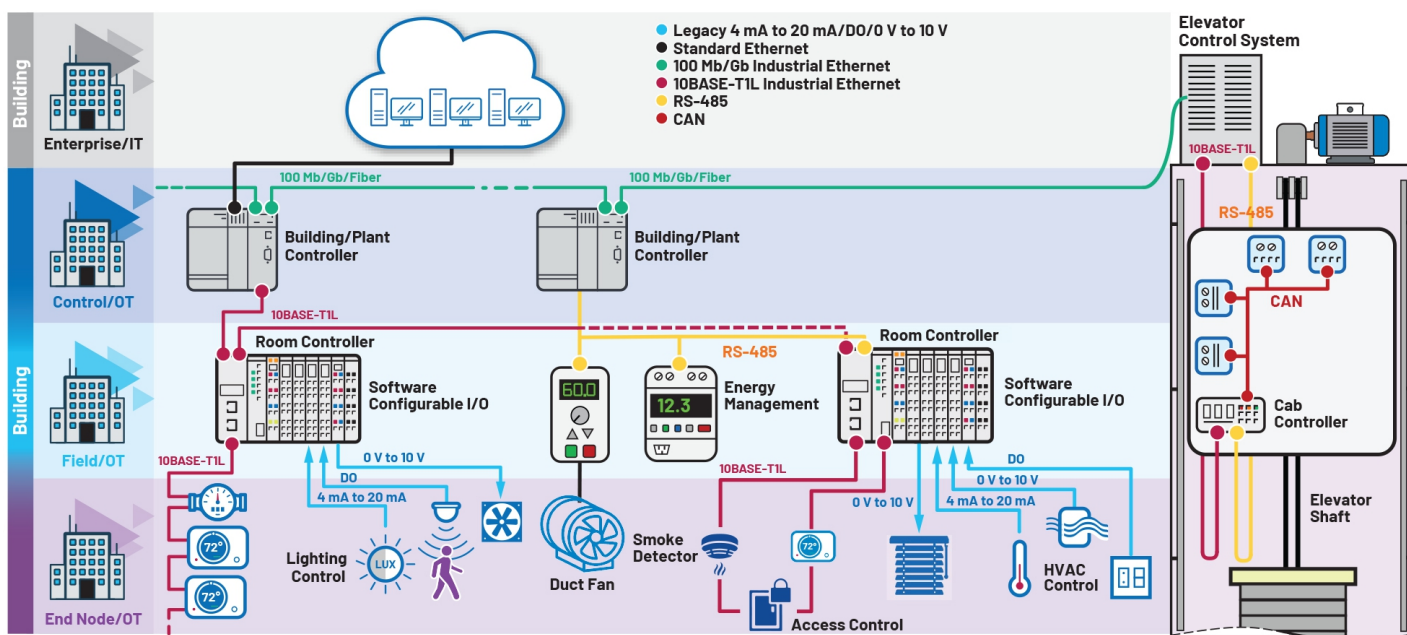


Figure 2: Intelligent building infrastructure.

be next [7]. Intelligent BMS provide the data needed to make decisions around: sustainability and efficiency, communication, building control and automation, worker health and safety, and security. This in turn improves the levels of health and safety, sustainability, resilience, and economics of the buildings market. ■



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Barry Mulligan is a marketing manager for the Intelligent Buildings and Infrastructure Group at Analog Devices Limerick, primarily focusing on expanding ADIs influence in the Intelligent Building Market. He has worked at ADI since 2016. His previous engineering roles include transceiver applications engineer for 5G base stations and supply chain planner for the RF product range at ADI. He also worked as a mechanical, electrical and plumbing engineer for design consultants Arup before joining ADI and spent a year working in Minnesota for Windlogics, a wind energy consultancy firm. He can be reached at barry.mulligan@analog.com.

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