INNOVATIONS IN LED LIGHTING

Matthias Sabathil | Jan. 29, 2018 | DOE SSL R&D Workshop | Nashville

Light is OSRAM

Agenda

1. Status and outlook on LED efficacy → will the lumen race ever end?

2. Which LED innovations will take us beyond the lumen race?

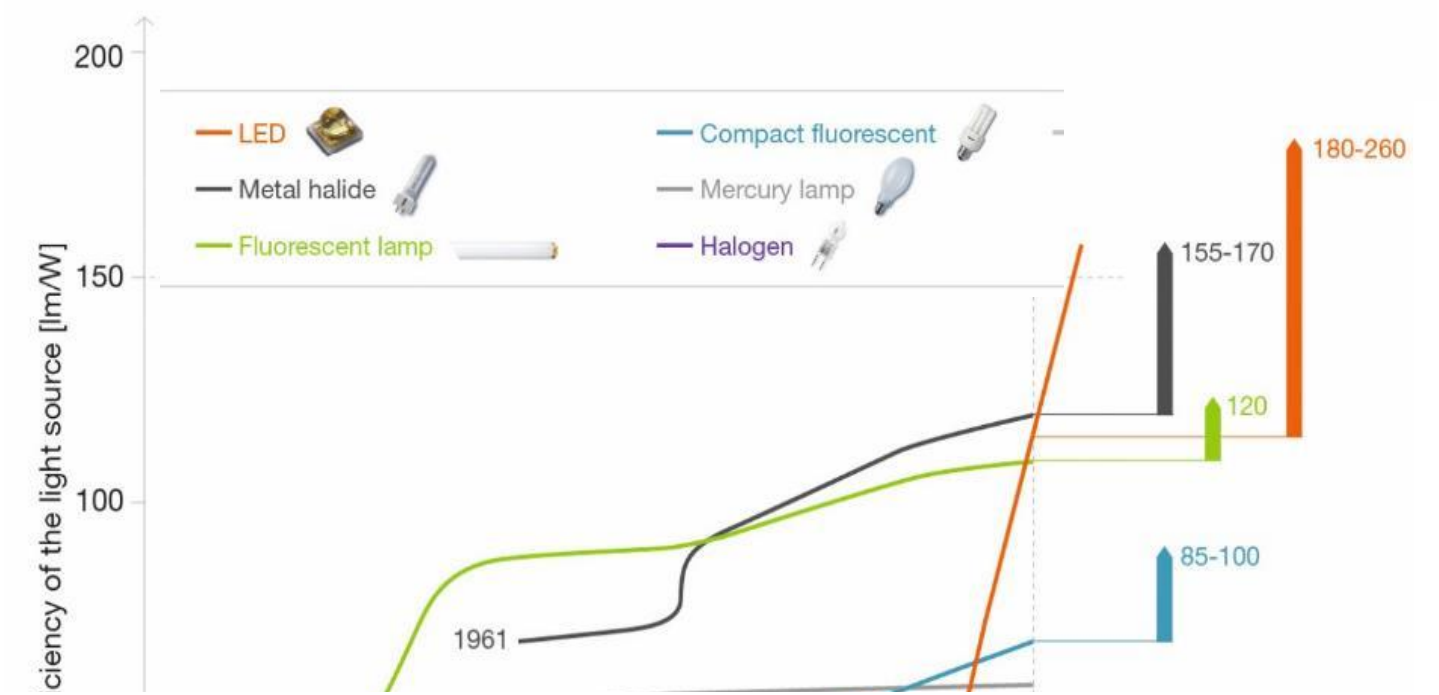
3. What will be the role of lighting in the interconnected & smart future?

4. Conclusion

Status and outlook on LED efficacy

→ will the lumen race ever end?

Where do we come from?
The solid state lighting revolution



13 years later

LEDs
are the
most efficient
light sources

- How far will LED technology take us?

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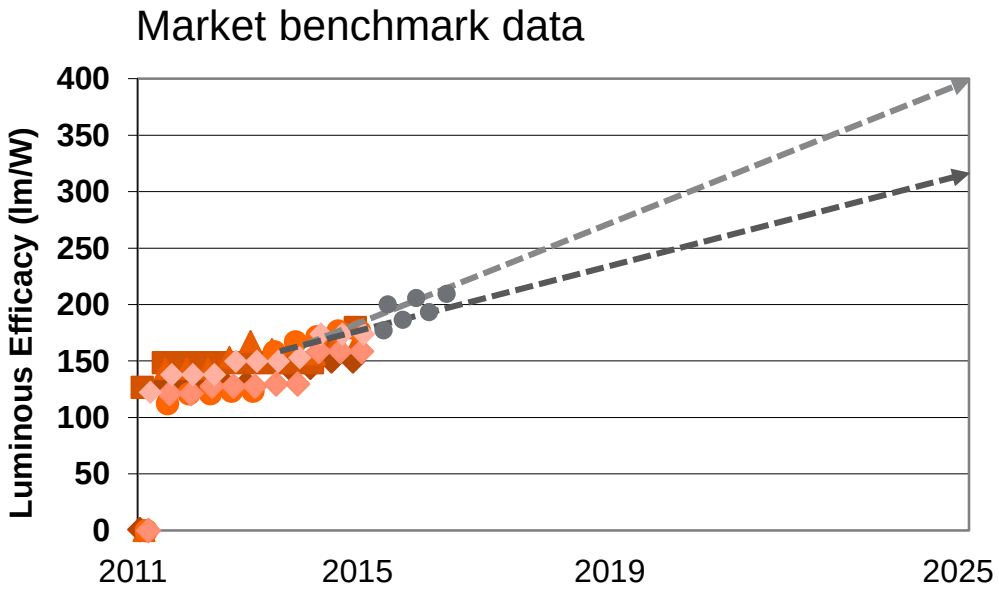
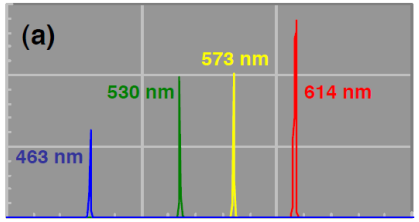
Where is the limit of LED efficacy?

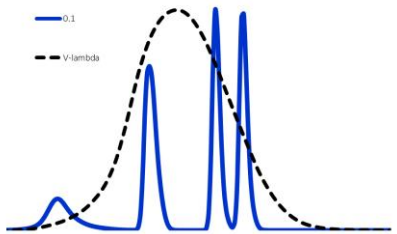


Theoretical limit for
direct emitters
3000K CRI >80
~400 lm/W



Tsao et al,
Sandia labs

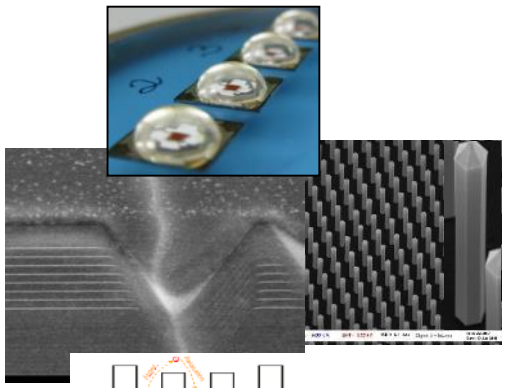
Theoretical limit for
phosphor converted
emitters
3000K CRI >80
~320 lm/W

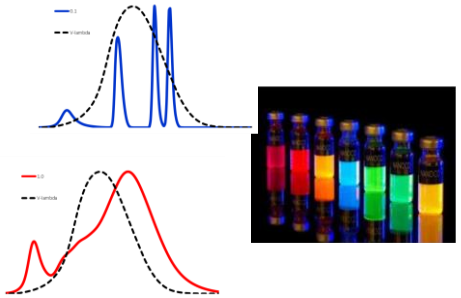


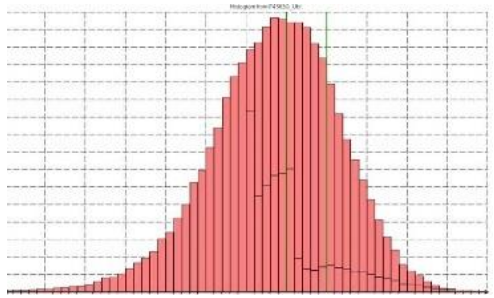
Still huge theoretical room for improvement

Which will be the main technology drivers?

Main drivers for reaching the limits





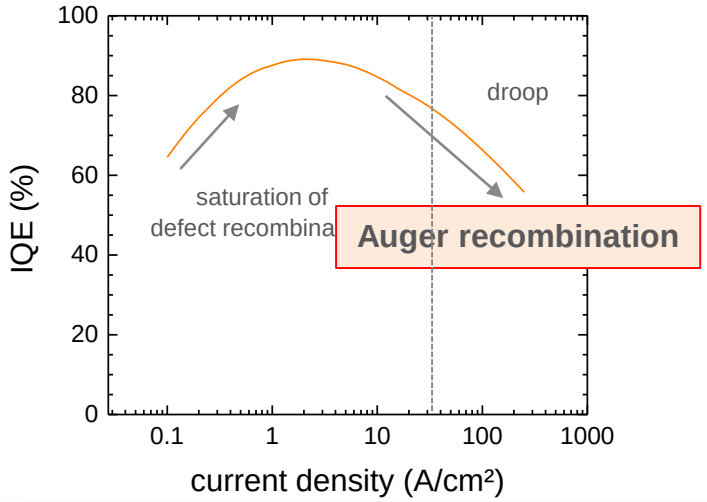


Advanced manufacturing concepts

Spectral efficacy

Material & System efficiency

Driver Material & System efficiency:
→ InGaN Droop

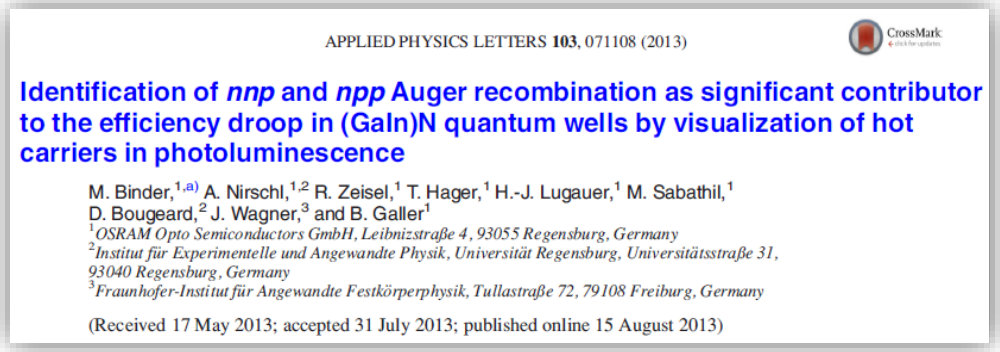


efficiency droop in InGaN/GaN LEDs

the IQE of InGaN-based LEDs features a pronounced current density dependence

→ **IQE is subject to efficiency droop**
~ 5 .. 40% internal losses depending on current density

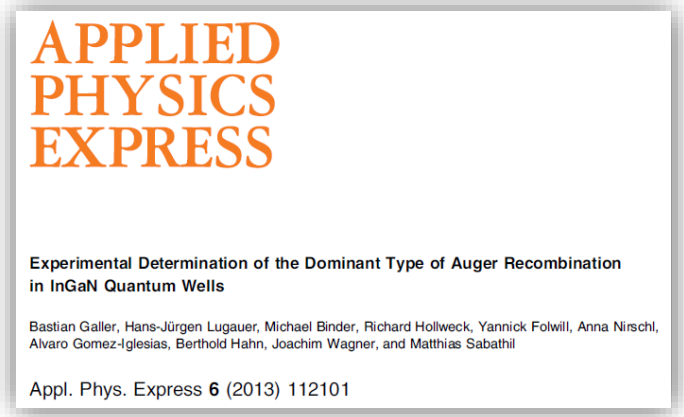
what is the physical mechanism of the *droop*?


APPLIED PHYSICS LETTERS **103**, 071108 (2013)

Identification of *nnp* and *npp* Auger recombination as significant contributor to the efficiency droop in (GaIn)N quantum wells by visualization of hot carriers in photoluminescence

M. Binder,[1,a)] A. Nirschl,[1,2] R. Zeisel,[1] T. Hager,[1] H.-J. Lugauer,[1] M. Sabathil,[1] D. Bougeard,[2] J. Wagner,[3] and B. Galler[1]
[1]*OSRAM Opto Semiconductors GmbH, Leibnizstraße 4, 93055 Regensburg, Germany*
[2]*Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstraße 31, 93040 Regensburg, Germany*
[3]*Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastraße 72, 79108 Freiburg, Germany*

(Received 17 May 2013; accepted 31 July 2013; published online 15 August 2013)


APPLIED PHYSICS EXPRESS

Experimental Determination of the Dominant Type of Auger Recombination in InGaN Quantum Wells

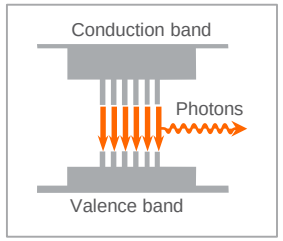
Bastian Galler, Hans-Jürgen Lugauer, Michael Binder, Richard Hollweck, Yannick Folwill, Anna Nirschl, Alvaro Gomez-Iglesias, Berthold Hahn, Joachim Wagner, and Matthias Sabathil

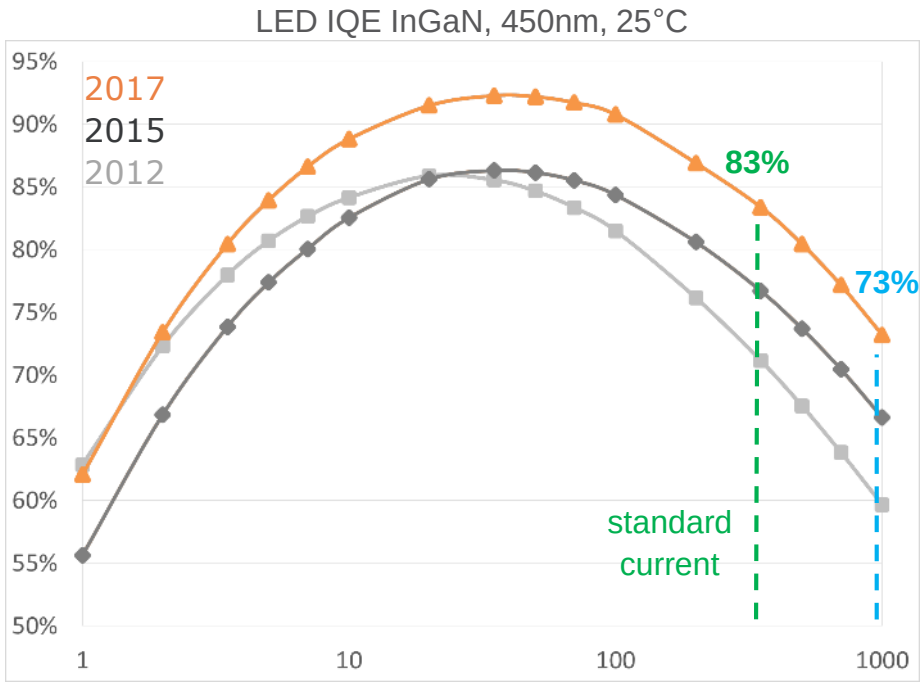
Appl. Phys. Express **6** (2013) 112101

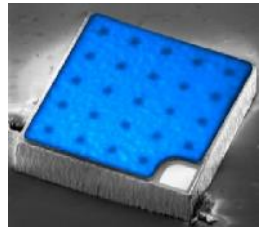
→ **fundamental mechanism, that can hardly be mitigated**

Driver Material & System efficiency:
Internal Quantum Efficiency InGaN from 2012 – 2017

Over the years leading edge epitaxy performance

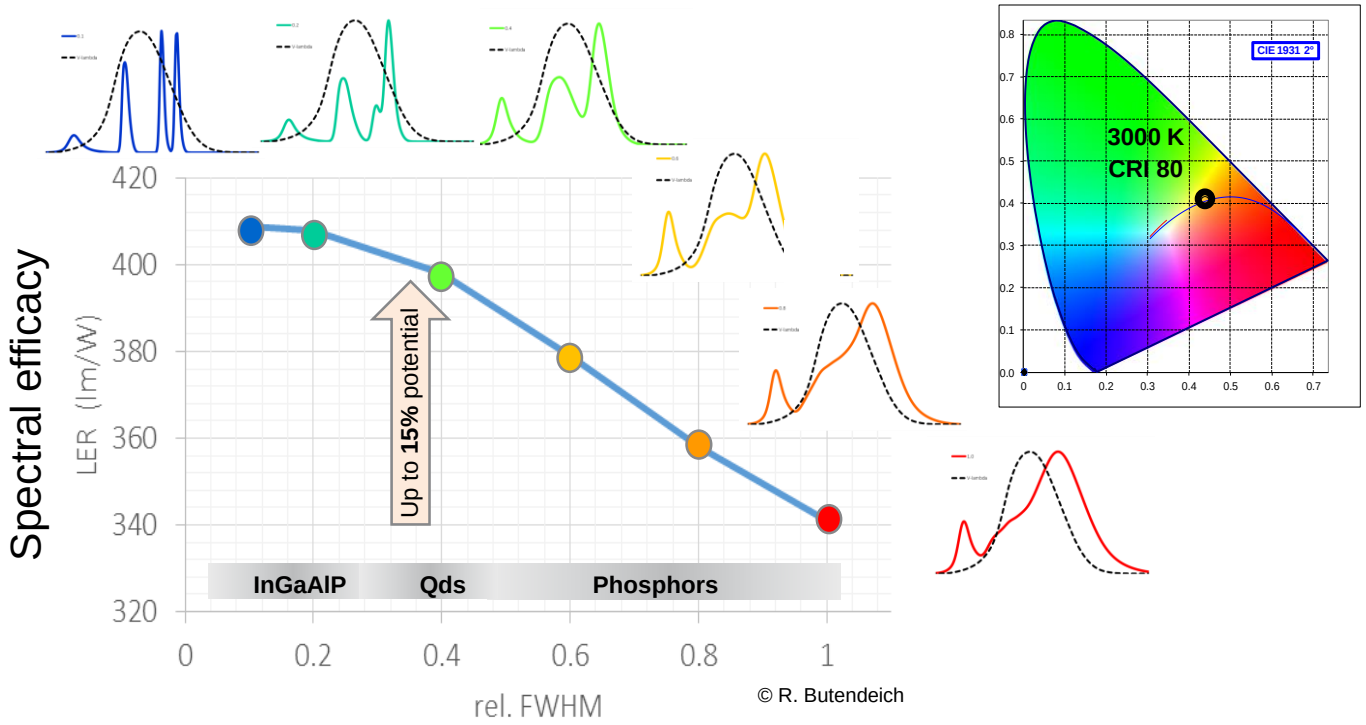






Significant improvements demonstrated - however droop remains biggest loss channel!

Driver spectral efficacy (LER): Narrow band phosphors



© R. Butendeich

OS well positioned via:

→ OSRAM internal Phosphor development

→ Exploring novel materials beyond conventional phosphors

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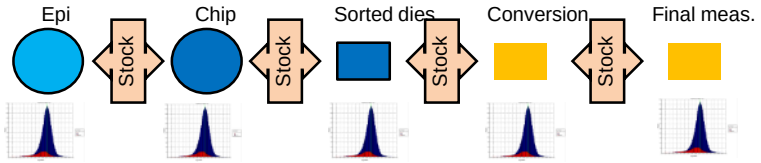
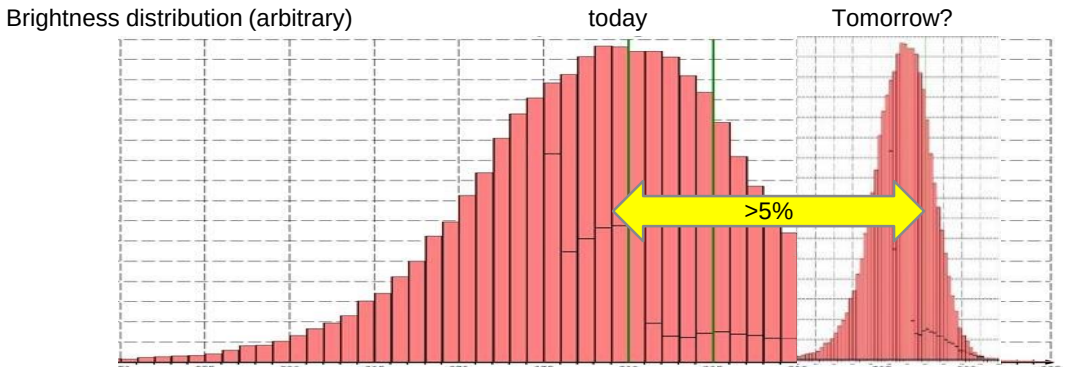
Driver advanced manufacturing concepts: Pushing the distribution to the limit

Complex process chain leads to large distribution



Datamining and Industry 4.0



Future manufacturing concepts needed for narrow distributions

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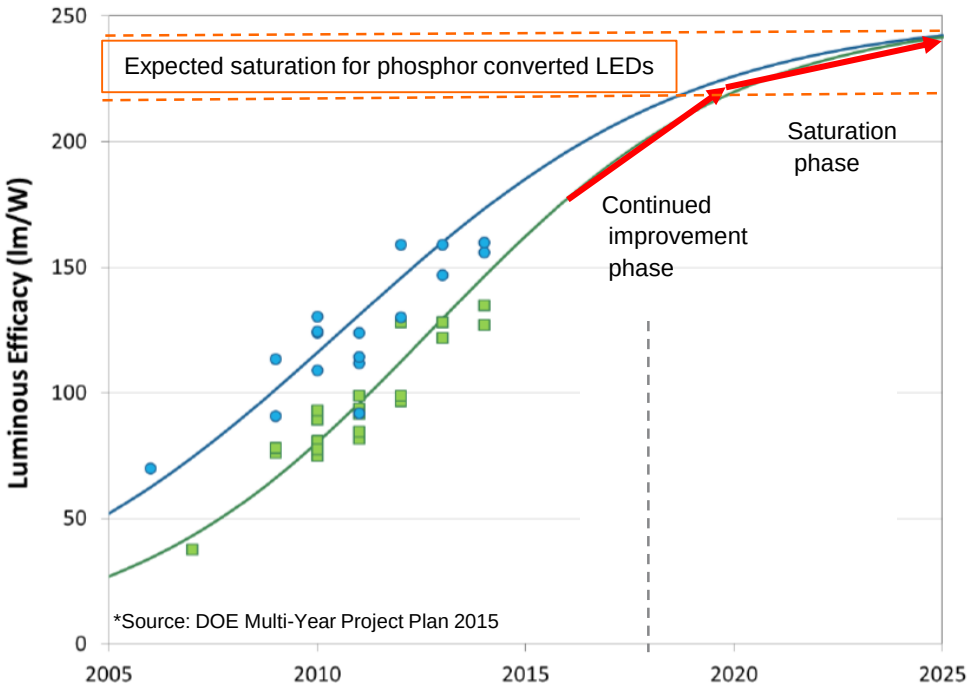
When will the lumen race end?
→ Ask DoE!

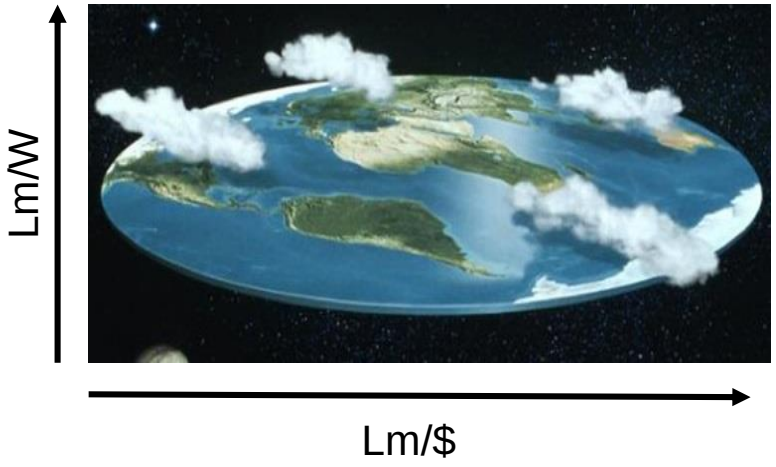


- Target for white LEDs: 240 – 250 lm/W
- 2-3 years continued improvement predicted
- Beyond 2020 entering saturation phase of marginal integral improvements

The end of the story for LED component development?

Is the World flat?

Current LED market is pretty two dimensional:

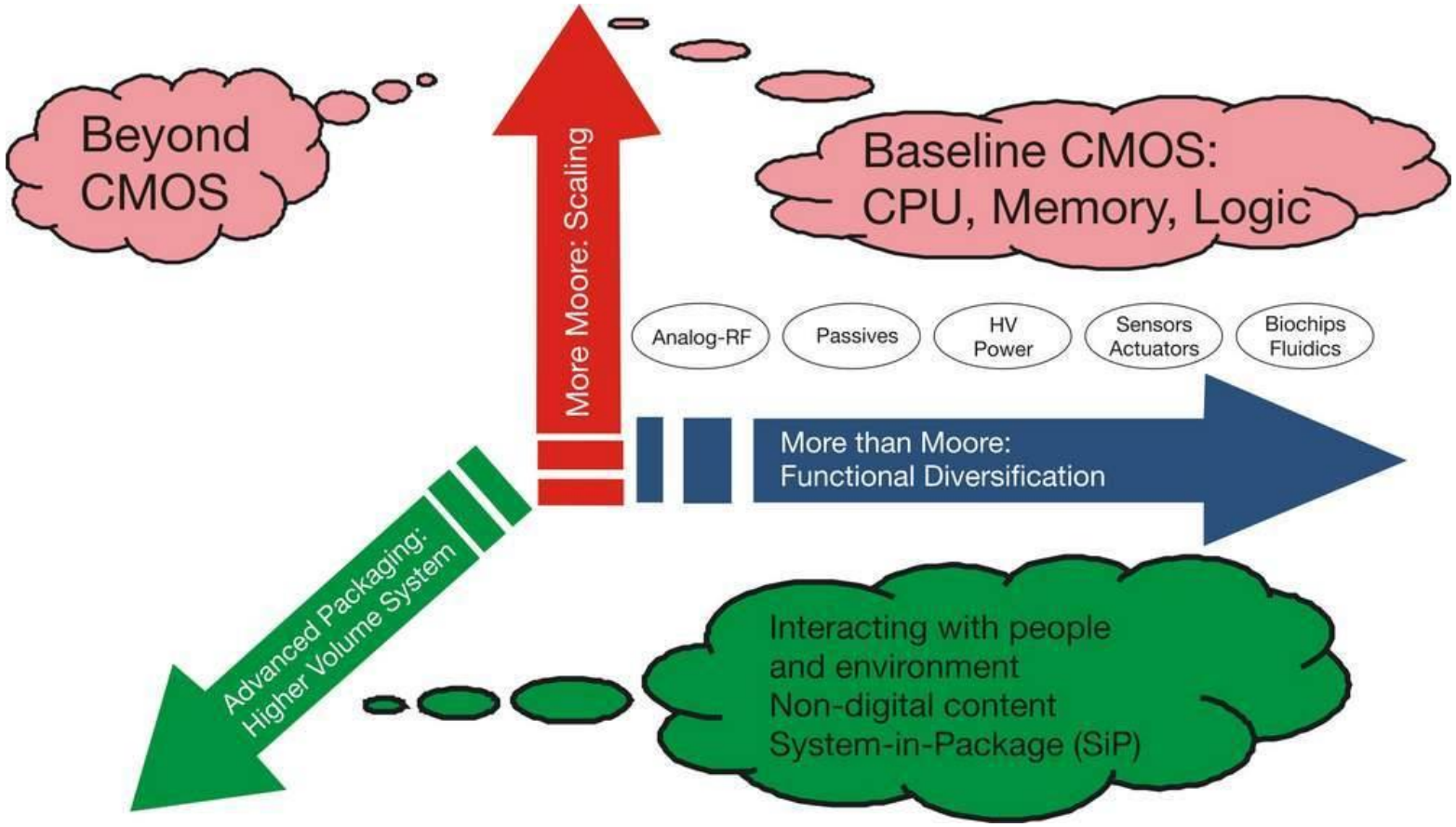


Lets explore the multidimensional future!

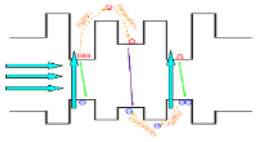
Which LED innovations will take us beyond the lumen race?

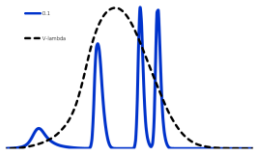
Technology dimensions:
Semiconductor Technology is multi-dimensional

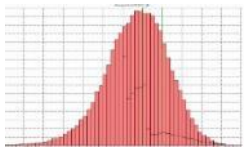
→ Let's learn from the silicon guys

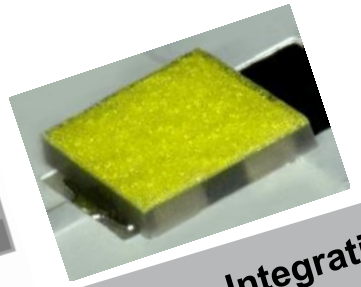


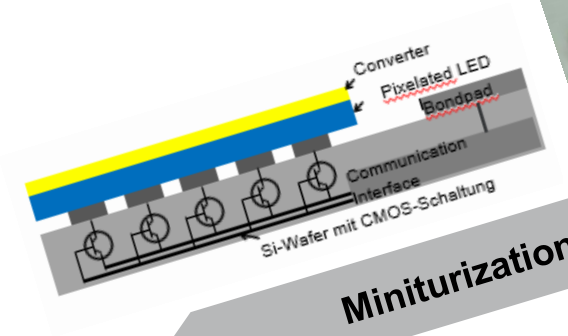
What could be the dimensions of LED Technology?
→ Look beyond lumen











Performance and efficiency

Master the Spectrum

Miniturization & System Integration

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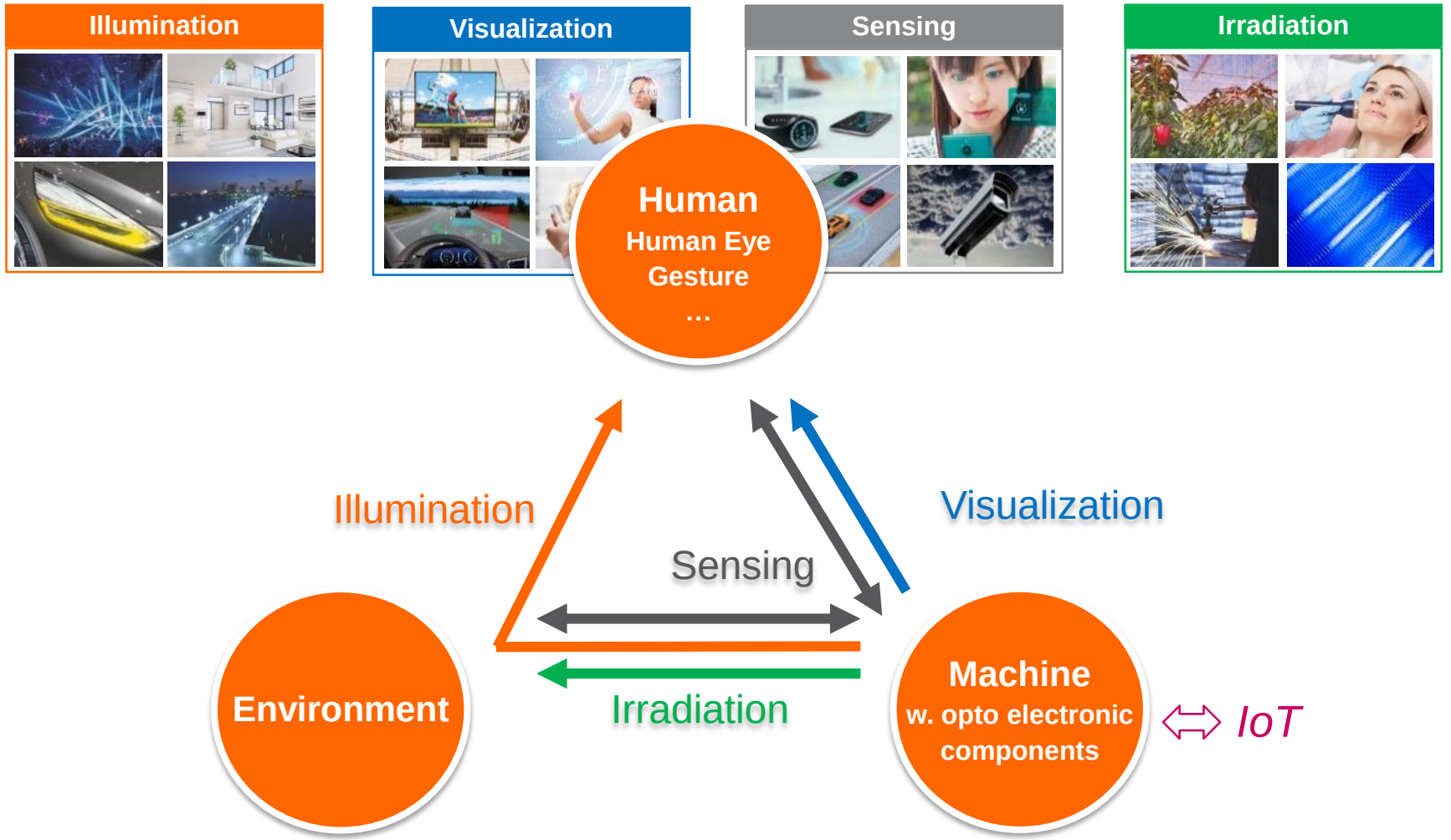
Which are the dimensions in LED application space?
→ There is much more photons can do than just lighting!



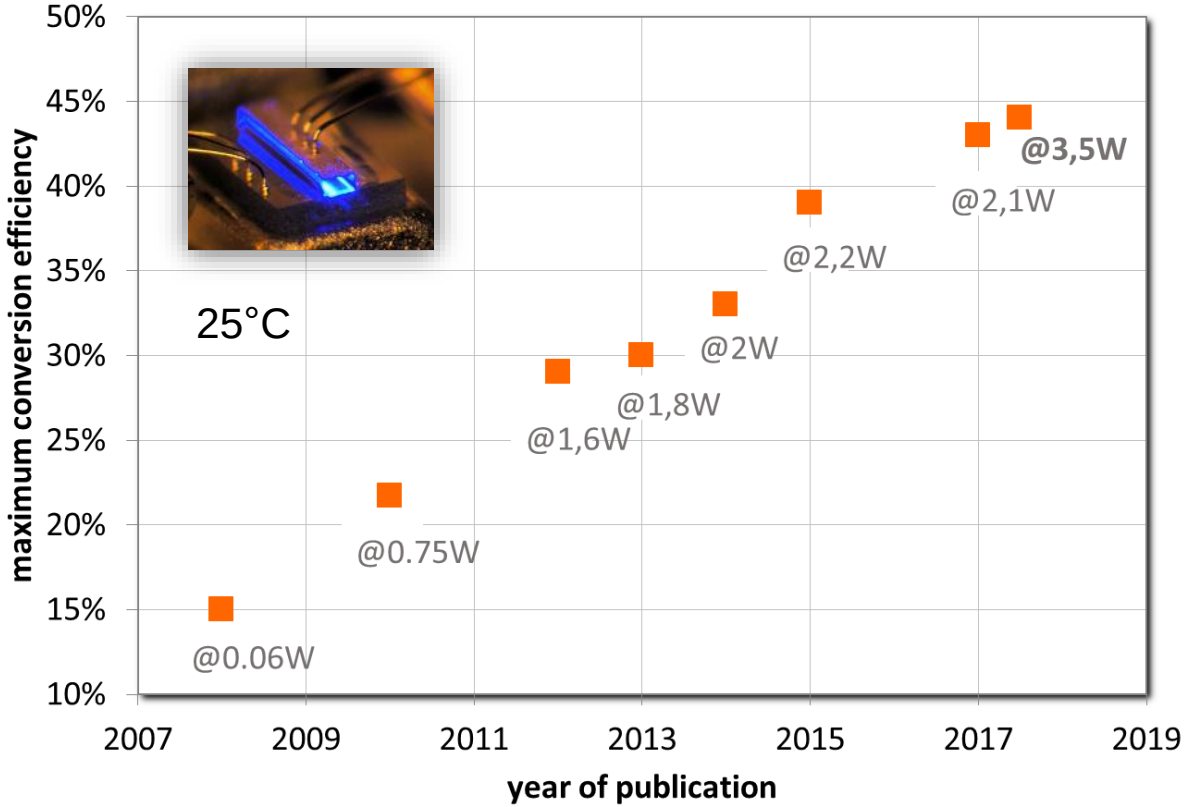
Illumination

Performance and efficiency

Example: Laser headlamp

High power blue laser diodes
Osram‘s continuous performance progress

Time line of Osram‘s published R&D-highlights from blue development



- Tremendous improvement of conversion efficiency and output power
- Enabler for new applications

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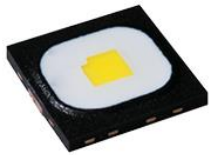
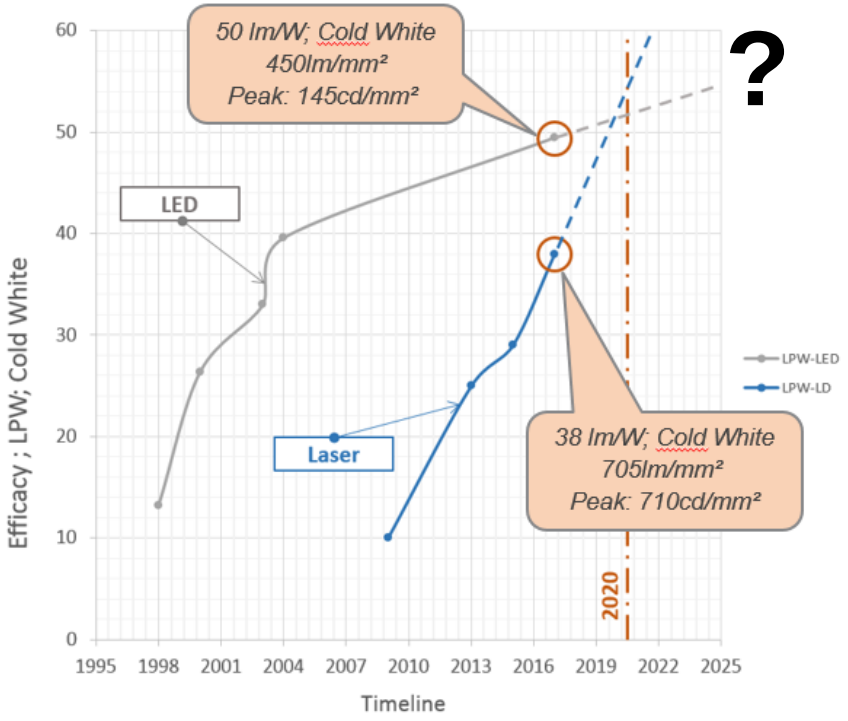
Will converted LASERs be the ultimate luminance solution?

System

Component





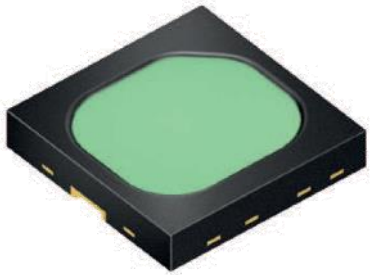
- Converted LASER light enables luminance of >1000cd/mm²
- If improvement trend of LASERs continues, LED gets some competition

Sensing

Irradiation

Master the Spectrum

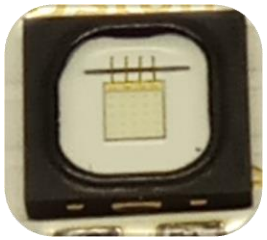
Example:
Broadband IR emitter



Broadband infrared emission via phosphor conversion
Basic principle

Phosphor converts e.g. blue light to broadband infrared emission

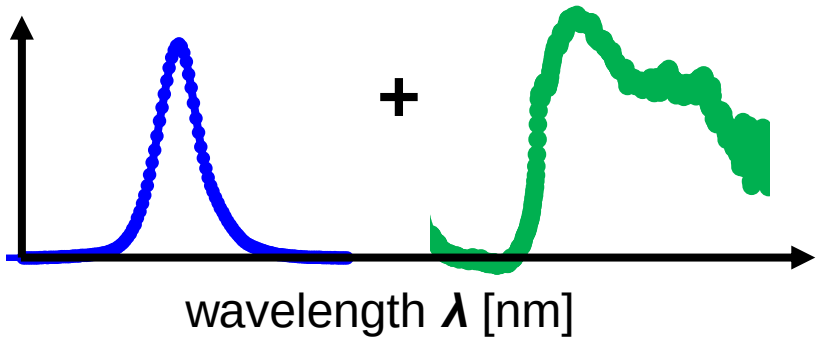
Combination of blue chip & phosphor conversion element

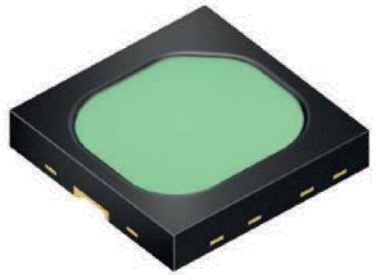


Blue chip (Oslon black flat)

+

Infrared phosphor





- World's first broadband IR phosphor solution
- Complete in-house development
- Very positive international reception

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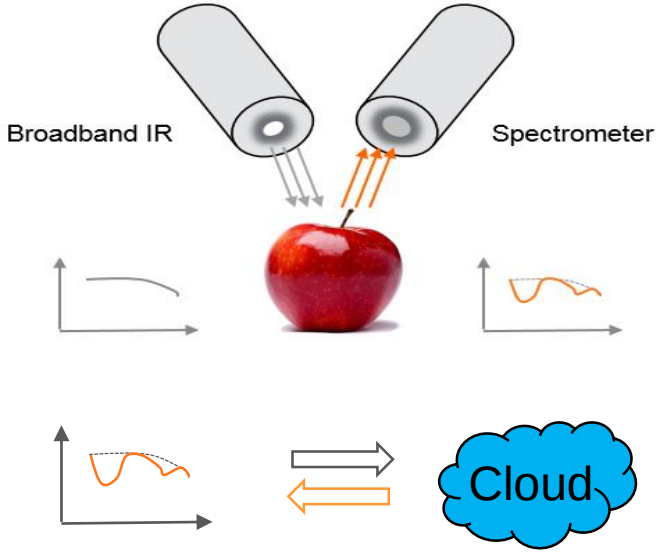
NIR spectroscopy as new technology differentiator for mobile devices and more…

How does it work?

1. Scan the **molecular makeup** of an object, like an apple
2. The device creates a **spectrum** specific to the object
3. This spectrum is then analyzed in a cloud



What could it be used for?

Analysis of:

- **Vegetables & Fruit:** Water content, carbs, calories
- **Dairy products:** Calories, fat, proteins, water
- **Bodyfat**
- **Medication validation**

… and much much more

The world's first infrared spectroscopy lab: Empower consumers to check what is in their food

Enabled by OSRAM's broadband infrared LED "SFH 4735"

→ Spectroscopy as new feature to **differentiate your application** from others!

Vision for future spectroscopy:

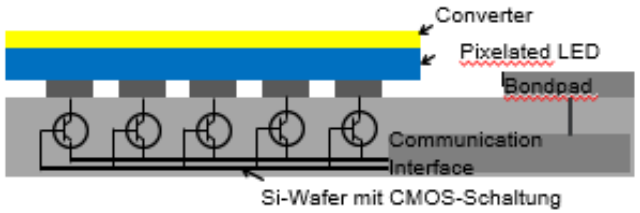
- Portable
- Affordable
- Easy to use by anyone
- Non invasive

Illumination

Visualization

Miniturization & System Integration

Example:
µAFS



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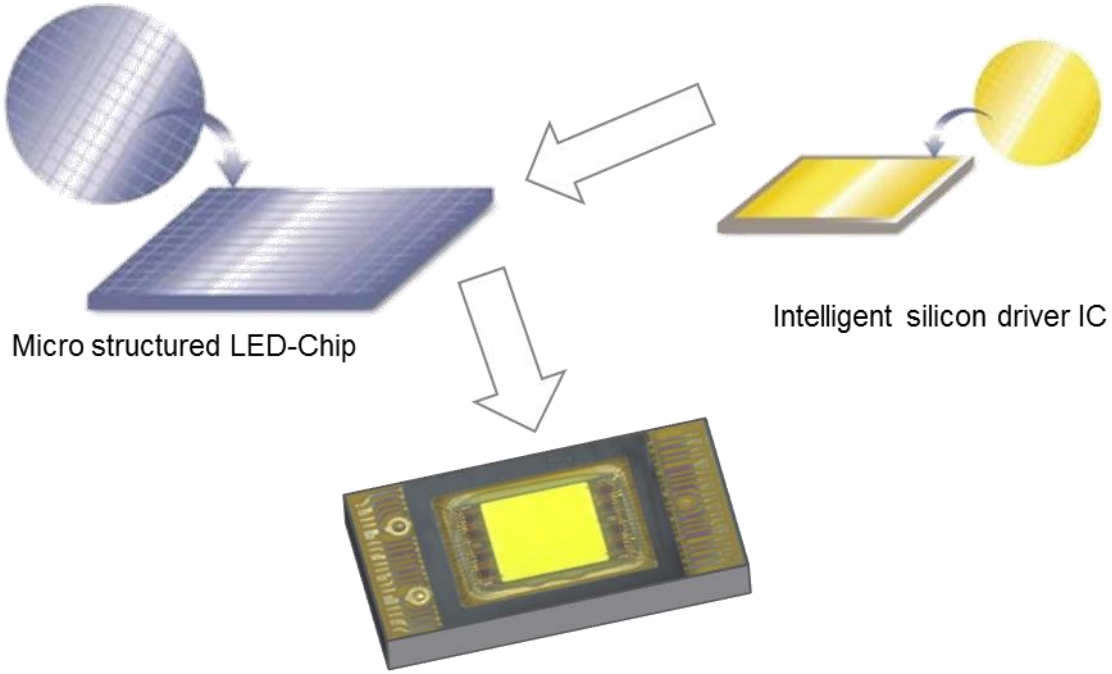
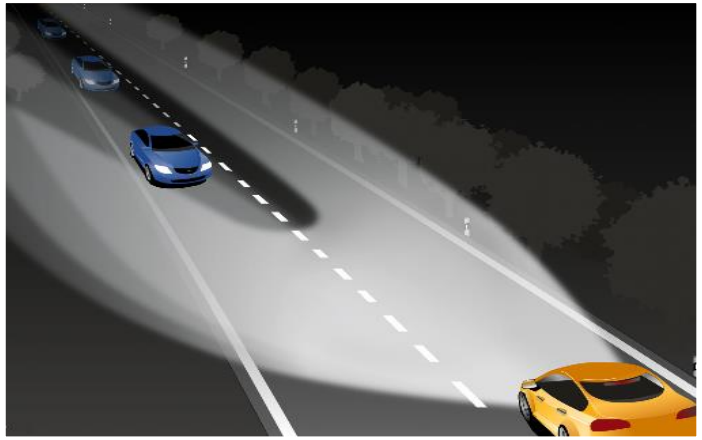
Osram Opto Semiconductors first step into silicone/IIIV integration: Research project “µAFS” for automotive applications

High-res and intelligent system for precise control of light distribution without complex electronics.

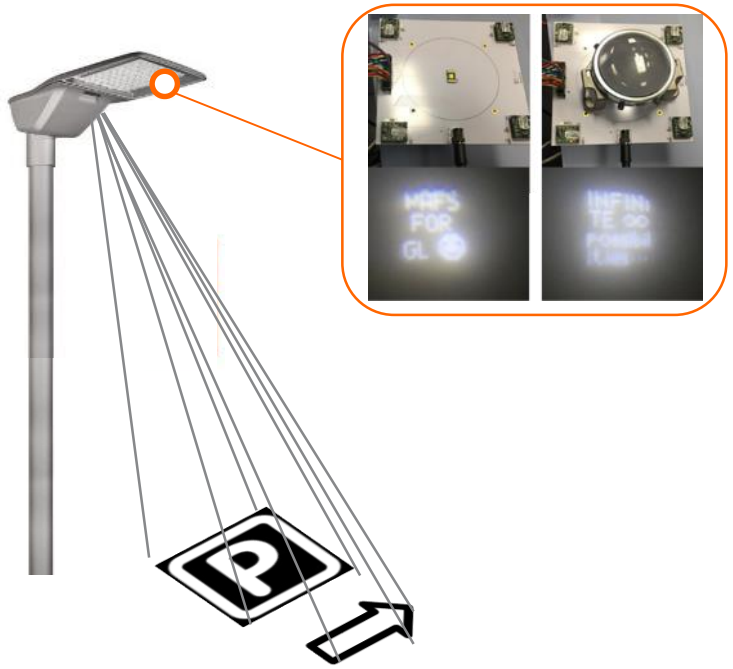




- Micro-structured LED chip
- Intelligent Si substrate
- High resolution active matrix LED array
- **1024 pixel in 4mm x 4mm**
- **>3000lm light source, 3 lm per pixel** @ 11mA
- SMT component

Towards smart components in illumination
EVIYOS for General Lighting

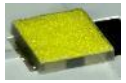
Adaptive Illumination



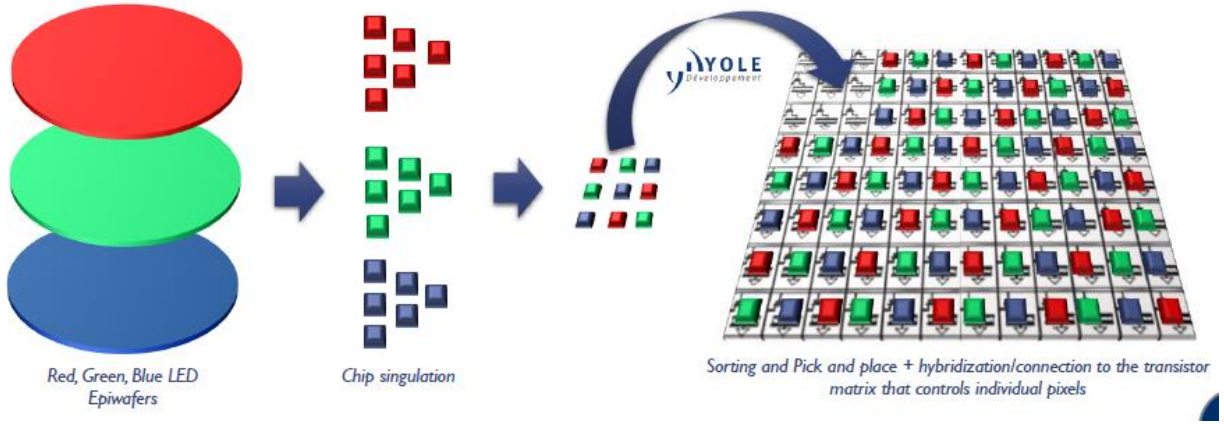
Information Display

Integrated pixel technologies enable novel applications in illumination and visualization

Further miniaturization: µLED display

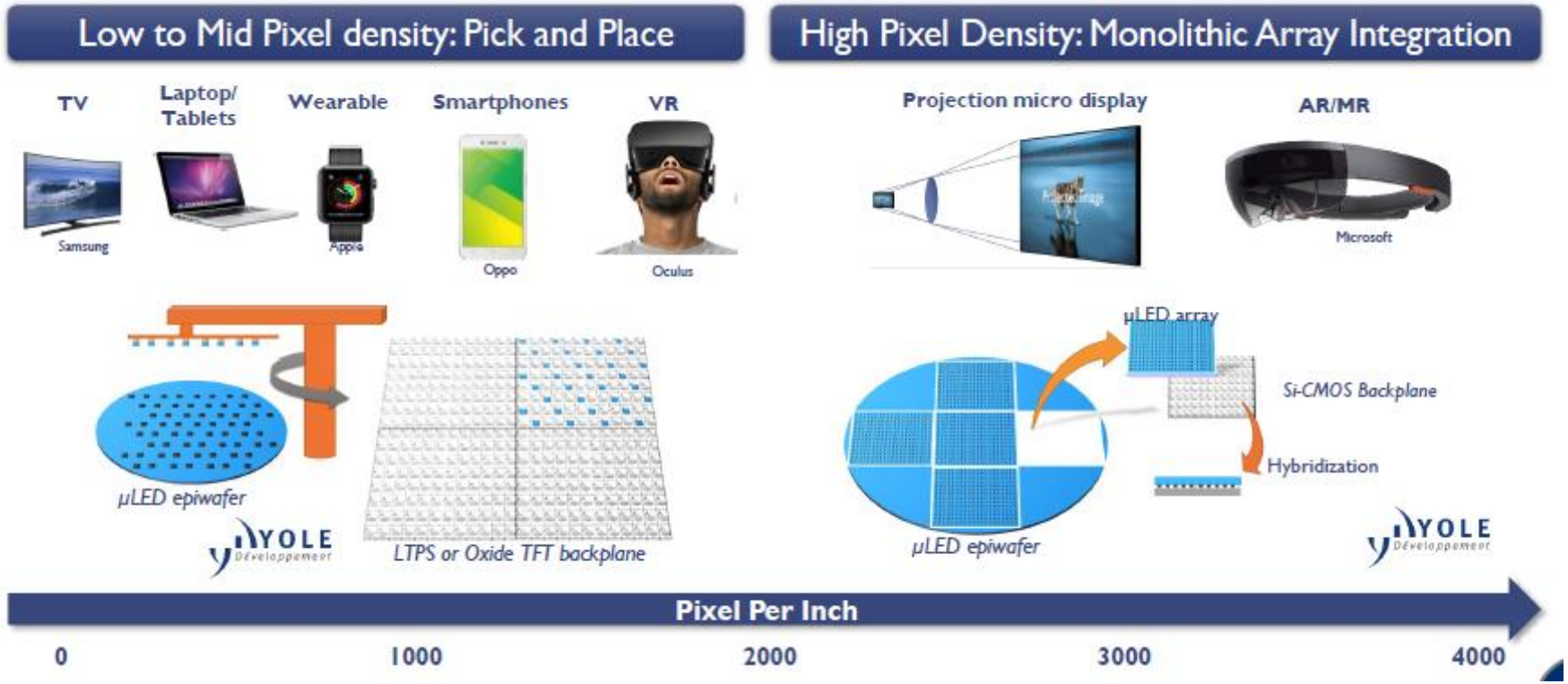
<<100µm 

µ-scale miniaturization + RGB



Yole Développement, 2017 MicroLED Displays Report

Whats next?
Future trend: µLED display

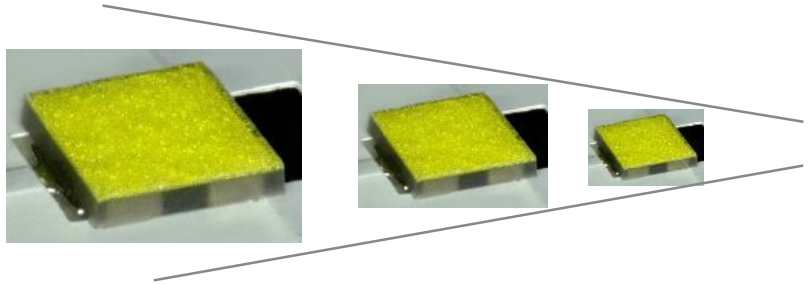


Yole Développement, 2017 MicroLED Displays Report

Miniaturization and integration paths the way to new aera of display and projection technology

The next generation of smart LED components

Miniaturization



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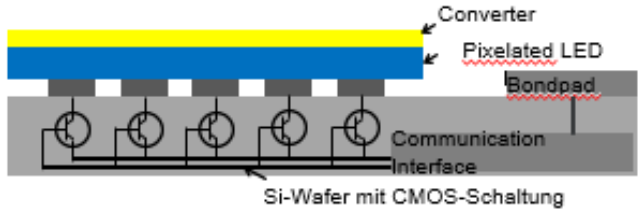
Integration: SiP & SoC



Spectral excellence

=

New generation of smart components for

Illumination

Visualization

Sensing

Irradiation

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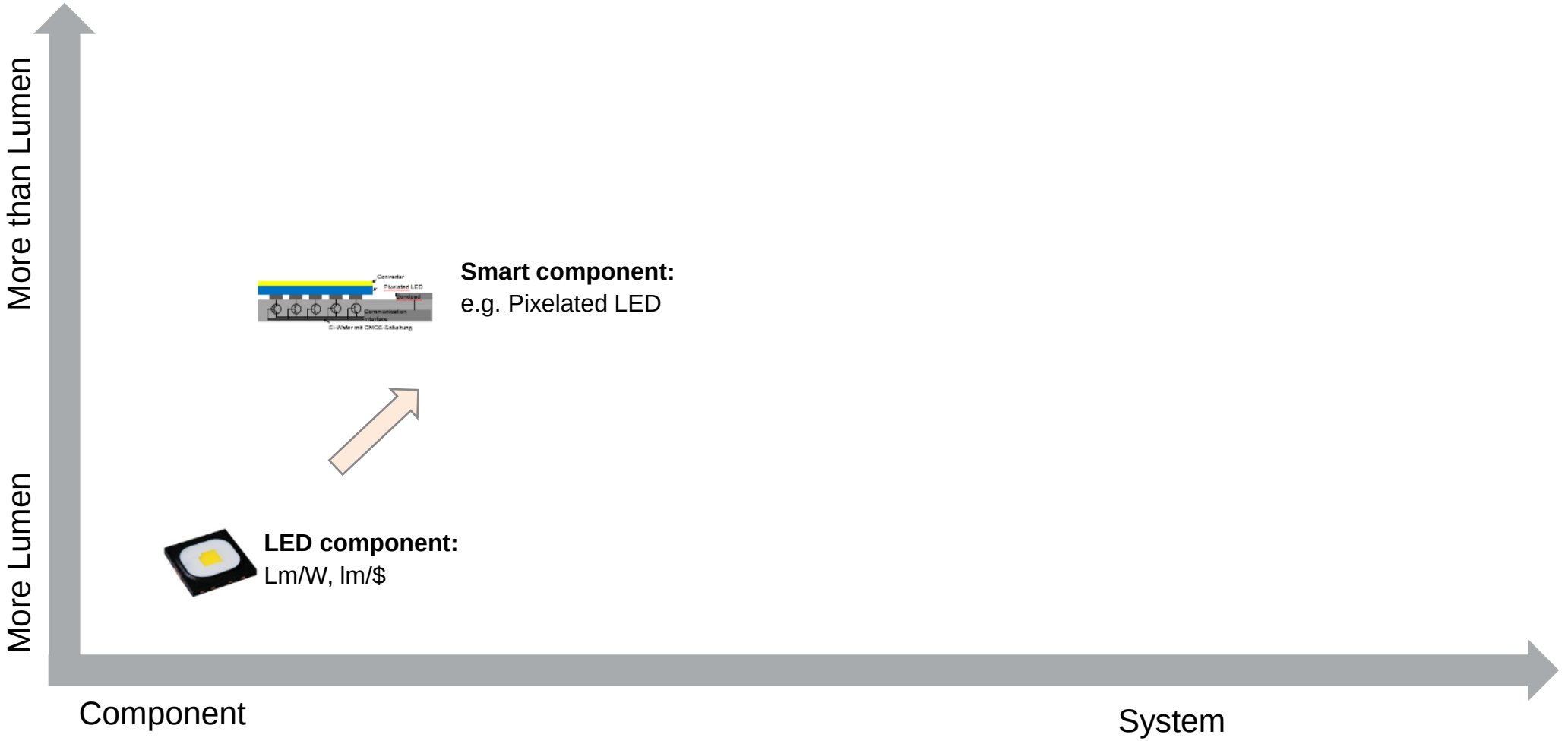
First step into future of digital lighting: LED evolves into smart component



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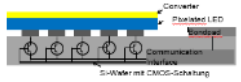
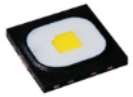
First step into future of digital lighting:
→ What about luminaires?



Smart component:
e.g. Pixelated LED



LED component:
Lm/W, lm/$

Luminaire ?

More than Lumen

More Lumen

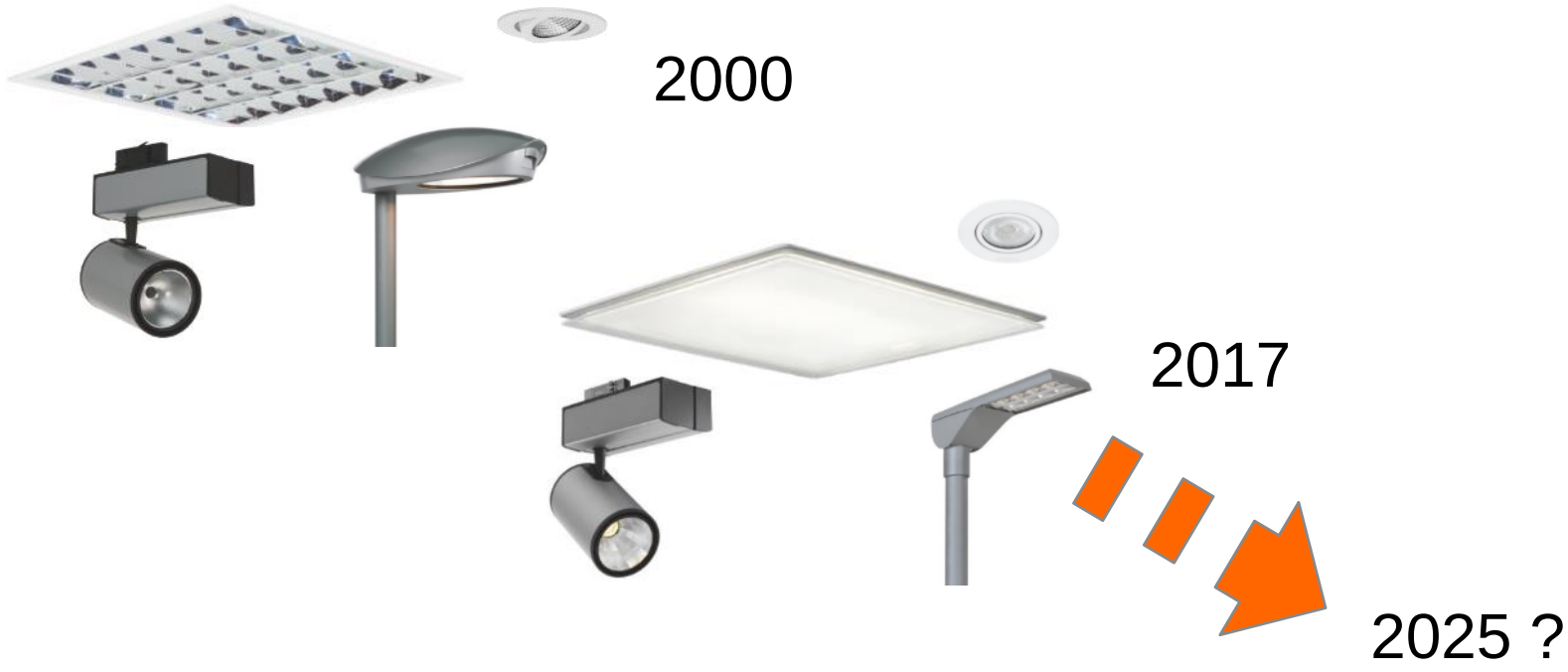
Component

System

What will be the role of lighting in the interconnected & smart future?

Any novel LED technologies needed for General Lighting?

What about luminaires?



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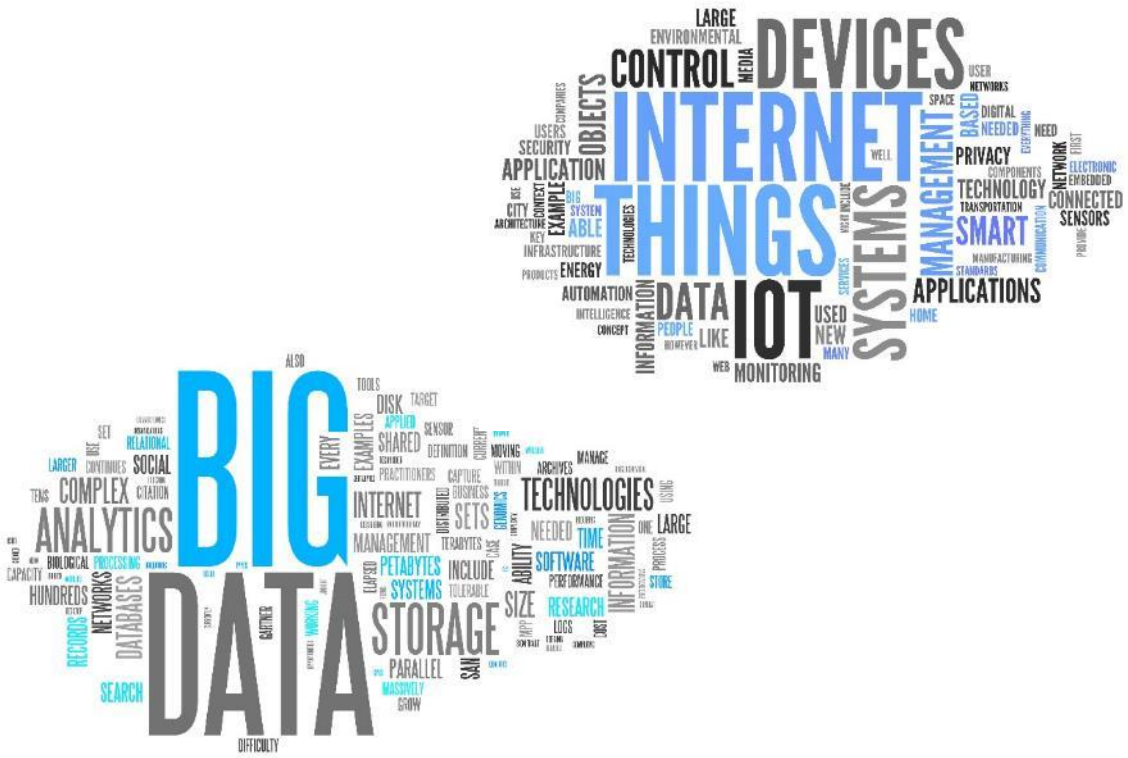
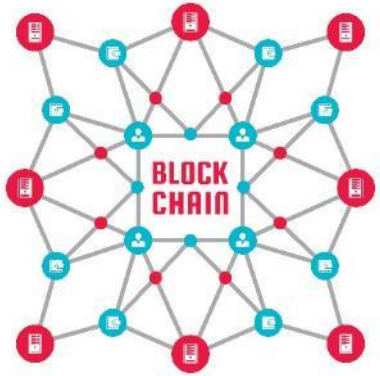
Lets see what digitalization means for lighting?

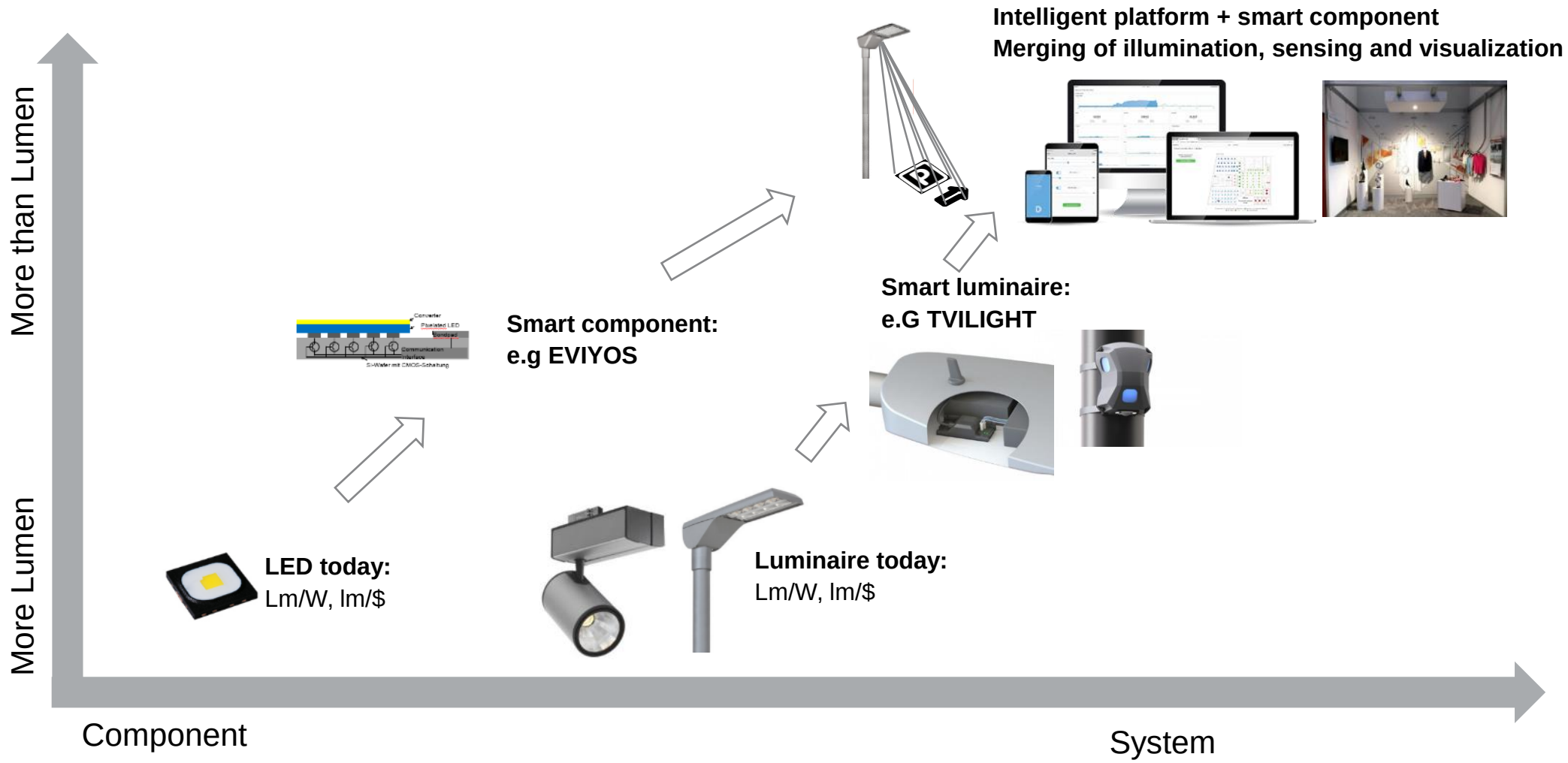
Lets start with some Buzzword bingo!





Ideas for lighting and blockchain welcome ;)

How might the digital future of lighting look like?



OSRAM
Opto Semiconductors

- What is the extra value of digital lighting?

Retail

Industry

Smart City

Dynamic

One system – a lot of advantages

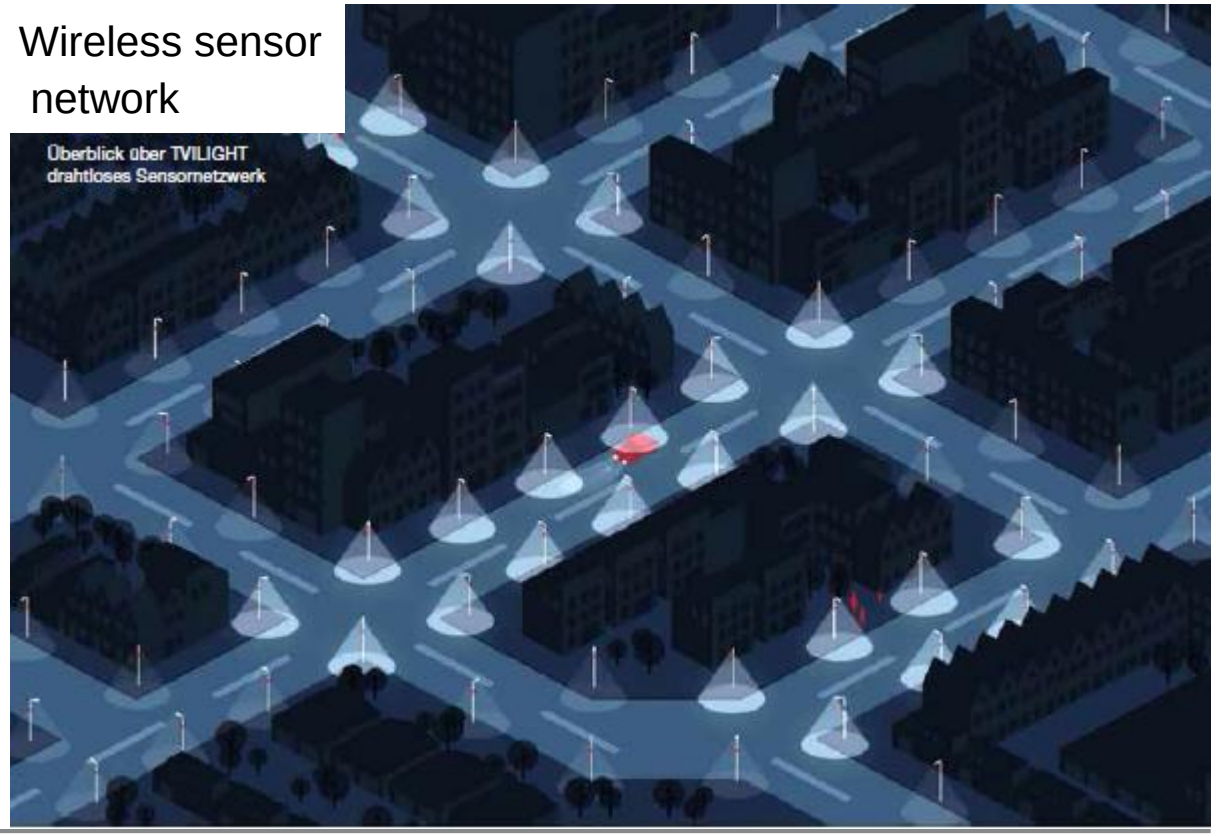
TVILIGHT

EMPOWERING INTELLIGENCE

- Precise energy calculations
- Automatic failure reports
- Map-based visualisations
- Precise real-time data
- Concise information
- Continuous support
- Completely wireless communication

Intelligent street lighting

Wireless sensor network



Retail

Industry

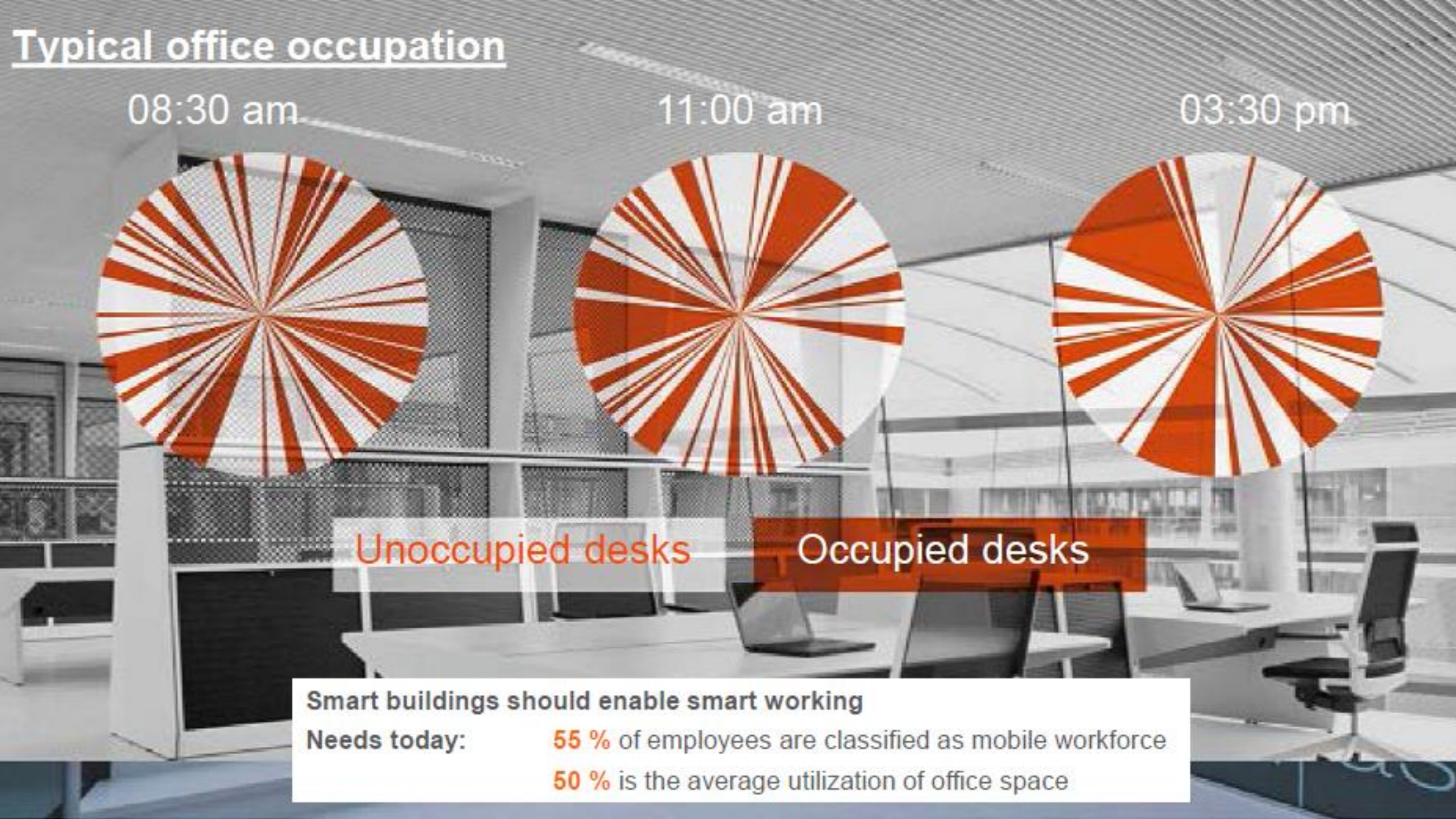
Smart City

Dynamic

OSRAM
Opto Semiconductors


Detect and visualize
free desks

Typical office occupation



Smart buildings should enable smart working

Needs today:

55 % of employees are classified as mobile workforce

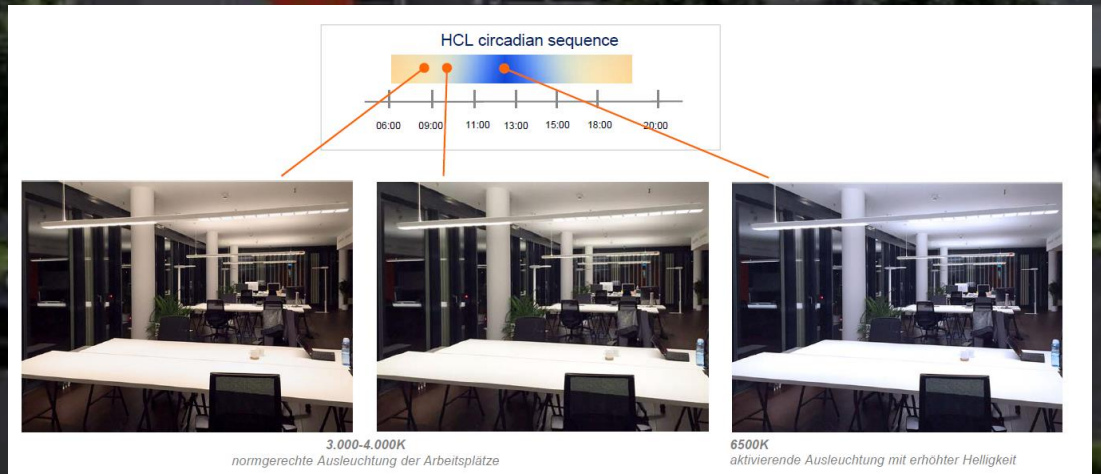
50 % is the average utilization of office space

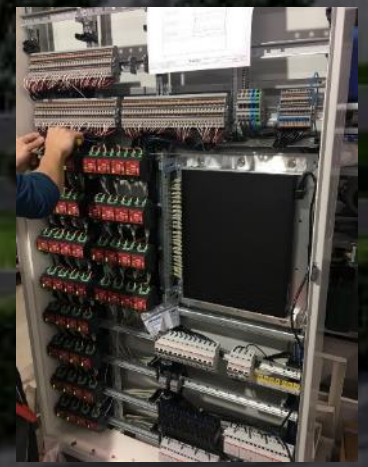
OSRAM OS Headquarter
Biggest Human Centric Lighting Project in the world

ecue SYMPHOLIGHT

1000 Tunable White Luminaires

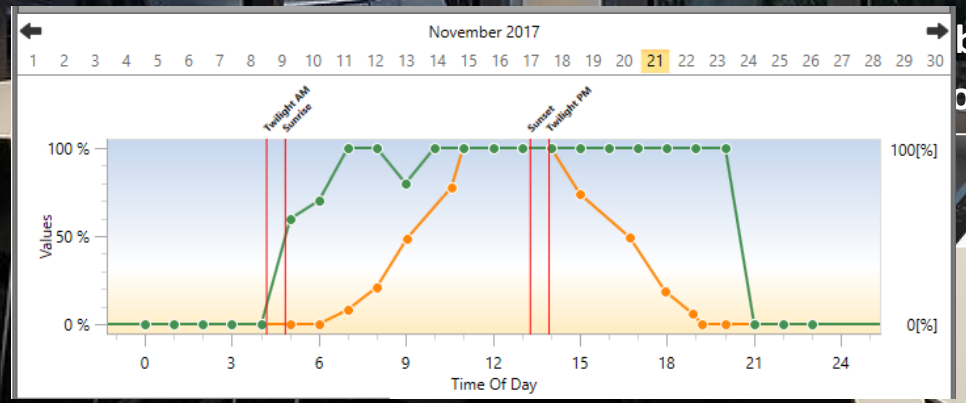
350 x PIR Multisensor with Presence detection and daylight management





ecue SYMPHOLIGHT
Human Centric Lighting

- Optimize light quality
- Increase energy efficiency
- Improve productivity
- Improve maintenance efficiency



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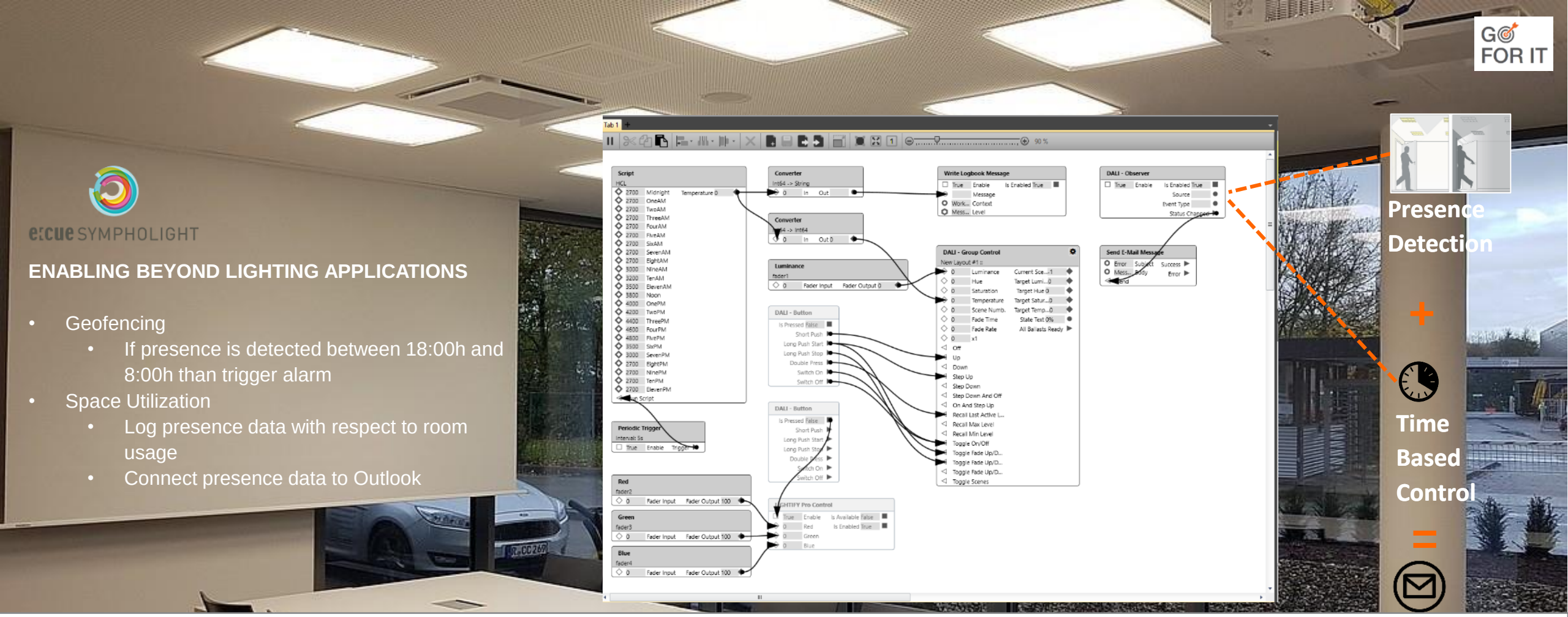

GO FOR IT
ecue SYMPHOLIGHT
ENABLING BEYOND LIGHTING APPLICATIONS
• Geofencing
• If presence is detected between 18:00h and 8:00h than trigger alarm
• Space Utilization
• Log presence data with respect to room usage
• Connect presence data to Outlook
Presence Detection
+
Time Based Control
=


BIG
DATA


INTERNET
THINGS
DEVICES
IOT


AI

What is the extra value of digital lighting?

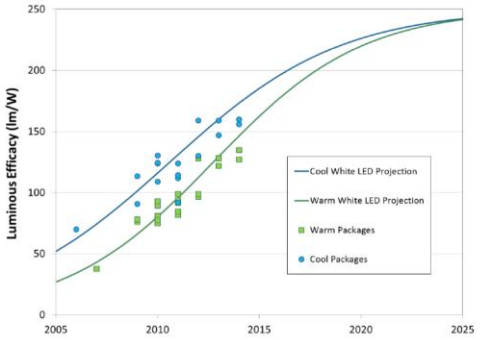
- Lighting efficiency ~ 1€ / m²

- Space efficiency ~ 10€ / m²

- Personell efficiency ~ 100€ / m²

Digital lighting will enable enormous value beyond pure lighting .

Conclusion – How to drive LED innovation in the future?

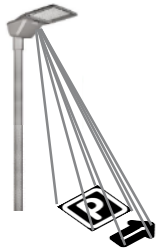


- Continue to push technology
- Prepare for development in saturation

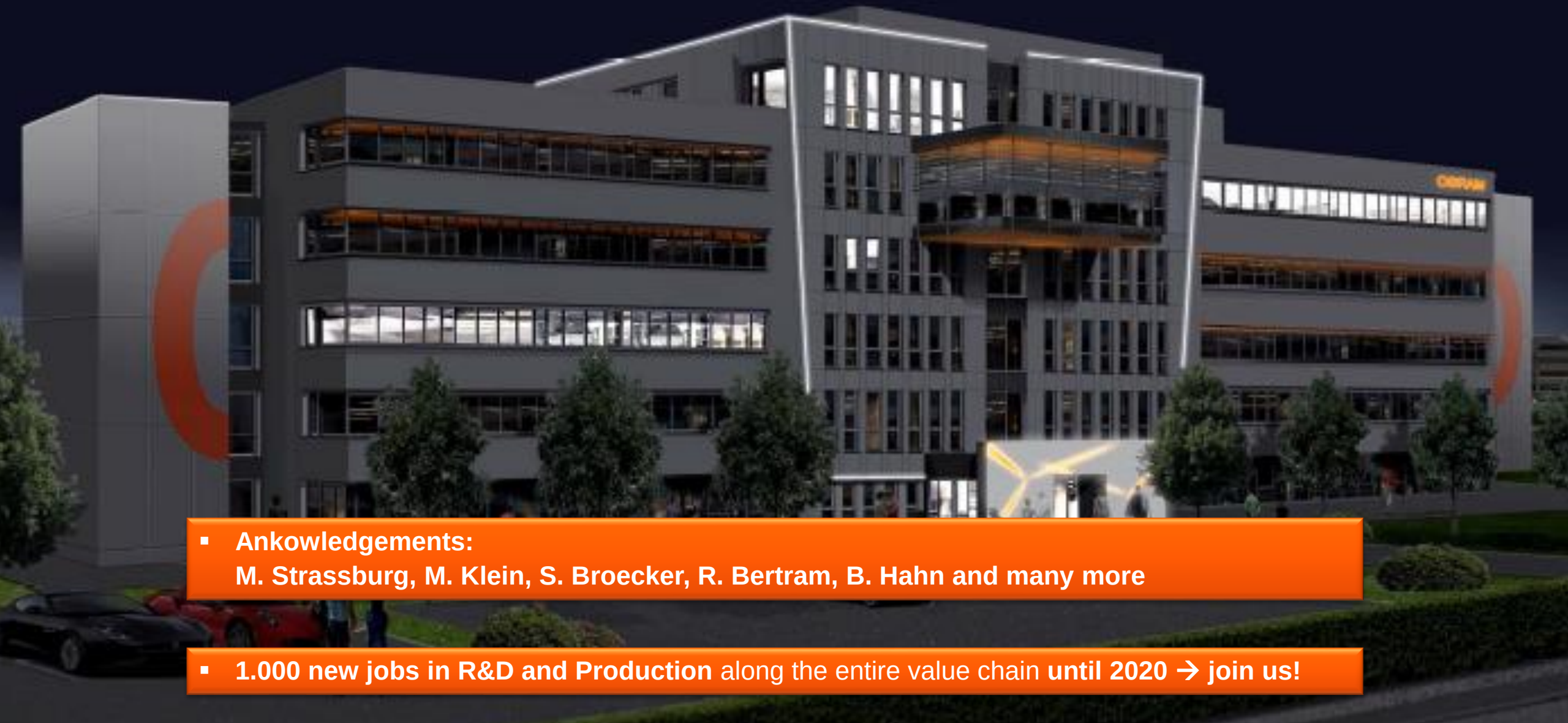
- Deliver smart building blocks
  for a combinatorial world enabling novel applications

Gerd Leonhard

- Seamless integration of digital lighting
  via smart components & platforms



Thank you



- **Ankowledgements:**
  M. Strassburg, M. Klein, S. Broecker, R. Bertram, B. Hahn and many more

- **1.000 new jobs in R&D and Production** along the entire value chain **until 2020 → join us!**