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

- How far will LED technology take us?

13 years later
LEDs are the most efficient light sources
Where is the limit of LED efficacy?

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

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?

Market benchmark data

Tsao et al, Sandia labs
Main drivers for reaching the limits

- Material & System efficiency
- Advanced manufacturing concepts
- Spectral efficacy
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?

→ 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

OS well positioned via:
- OSRAM internal Phosphor development
- Exploring novel materials beyond conventional phosphors
Driver advanced manufacturing concepts: Pushing the distribution to the limit

Complex process chain leads to large distribution

Brightness distribution (arbitrary)
today Tomorrow?

Future manufacturing concepts needed for narrow distributions

Datamining and Industry 4.0
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

*Source: DOE Multi-Year Project Plan 2015
The end of the story for LED component development?
Is the World flat?

Current LED market is pretty two dimensional:

Let's 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
Which are the dimensions in LED application space?

→ There is much more photons can do than just lighting!
Example: Laser headlamp
High power blue laser diodes
Osram’s continuous performance progress

- Tremendous improvement of conversion efficiency and output power
- Enabler for new applications
Will converted LASERs be the ultimate luminance solution?

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

Master the Spectrum
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

- World’s first broadband IR phosphor solution
- Complete in-house development
- Very positive international reception
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
Innovations in LED lighting |
Osram Opto Semiconductors GmbH | Matthias Sabathil
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**Example:**
μAFS

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**Illumination**

**Visualization**

**Miniturization & System Integration**
Osram Opto Semiconductors first step into silicone/III-V 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: \( \mu \)LED display

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\( \mu \)-scale miniaturization + RGB

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*Yole Développement, 2017 MicroLED Displays Report*
What's next?
Future trend: µLED display

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

Yole Développement, 2017 MicroLED Displays Report
The next generation of smart LED components

Miniaturization

Integration: SiP & SoC

Spectral excellence

New generation of smart components for

Illumination
Visualization
Sensing
Irradiation
First step into future of digital lighting: LED evolves into smart component

LED component:
Lm/W, lm/$

Smart component:
e.g. Pixelated LED

Component System

More than Lumen

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

More than Lumen

Smart component:
e.g. Pixelated LED

LED component:
Lm/W, lm/$

Luminaire?
What will be the role of lighting in the interconnected & smart future?
Any novel LED technologies needed for General Lighting?

What about luminaires?

2000

2017

2025?
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?

LED today: Lm/W, lm/$

Luminaire today: Lm/W, lm/$

Smart component: e.g. EVIYOS

Smart luminaire: e.g. TVILIGHT

Intelligent platform + smart component
Merging of illumination, sensing and visualization

Component

System

More Lumen

More than Lumen
• What is the extra value of digital lighting?
One system – a lot of advantages

- 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
Detect and visualize free desks
Typical office occupation

08:30 am

11:00 am

03:30 pm

Unoccupied desks

Occupied desks

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

1000 Tunable White Luminaires

350 x PIR Multisensor with Presence detection and daylight management
Human Centric Lighting

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

71% of the respondents are feeling more energetic.

76% of the respondents are feel more happy.

50% of the respondents feel more healthy.
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
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

- Seamless integration of digital lighting via smart components & platforms

Gerd Leonhard
Thank you

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