Main drivers for LED in modern illumination systems

Dr. Ulrich Steegmüller
Advanced Concepts and Engineering
## Agenda

### LLFY System Design Workshop, San Diego CA

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<td>Examples for architectural lighting</td>
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A New Era of Lighting is appearing at the Horizon: Solid State Lighting

- LEDs provide unique advantages:
  - High energy efficacy:
    - LED component: 80 – 100 lm/W today;
      > 150 lm/W in near future
    - LED lamps: ~ 100 lm/W (in ~ 3 - 5 years)
  - High system efficiency (directional light):
    - 70 – 85 % luminaire efficiency
  - Long lifetime:
    - 30,000 – 50,000 hrs of life
  - Easy switching and dimming
  - Instant on/off
  - Mercury-free
  - High functionality
  - Freedom of design
LED = Light where it should be!

LEDs are reaching their target by using less lumen: less energy consumption!

- 30% of light is wasted
- Light pollution is disturbing residents
- Birds and other animals can be disturbed too.

Conventional system

Light, where it not should be!

- Perfect usage of the lumens → high application efficiency
- Uniform distribution of light → improved safety, less fatigue for drivers
- Birds and other animals don`t get disturbed
High Light Quality & Efficiency
The Application Determines the Right Balance

### CRI 70
Power Champ
- High efficiency
- About 15% brightness gain compared to CRI 82
- Outdoor, Industrial

### CRI 82
Economic Champ
- Combination of efficiency and color quality.
- Office, Home

### CRI 95
Color Champ
- Excellent color quality
- CRI95, R9 >50, R13 >90
- Shop, Museum

- Color Quality
- Efficiency, TCO
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Introduction

Every LED application requires the following:

**Optical Solutions**
- Optical elements that shape the emitted light to achieve desired beam patterns. Secondary optics, optic plate, etc.

**Thermal Solutions**
- High power LED’s generate heat which affects their optical and electrical characteristics as well as lumen maintenance/lifetime. The heat must be transferred away from the LED by the mounting substrate, thermal interface materials and heat sink to the ambient air.

**Electronic Solutions**
- An electrical circuit controls LED operation in the application. A LED driver providing constant electrical current improves color and brightness performance. LED brightness can be regulated by PWM (Pulse-Width Modulation) or other current control techniques.
# LED Lighting System Integration

## System with Lamps
- Lamp
- Power Supply
- Luminaire

## System with LEDs
- LED
- Optics
- Board Assembly
- Heat sink
- Power Supply
- Luminaire
LED Components

Light Emitting Diodes as a light source are available in many different packages, colors and brightness levels; with or without integrated optics.
Optics

Manufacturing of secondary optical elements has to meet precise requirements (e.g. surface quality, shape accuracy) resulting from optical simulation.
Example Optical Characteristics of Lighting-Class High Power LEDs

Golden Dragon Plus
170° Viewing Angle

Golden Dragon Oval Plus
Oval Beam

OSLON SSL
80° / 150° Viewing Angle
OSLON SSL
General product features

- Primary lens with sophisticated beam angle
- Excellent lifetime due to silicone and ceramic materials
- Ultra-compact footprint for high density arrays
- Compact secondary optics
- Highly efficient Power chip
- Low thermal resistance $R_{th}$ for improved thermal management
OSLON SSL
Sophisticated radiation patterns

The OSLON SSL family is the industry leading platform which offers optimized radiation patterns for any kind of lighting application.

**NEW**

80°
Maximized light fraction in narrow beam

150°
Maximized light fraction under wide angles

Best-in-class radiation pattern for
- lens applications
- directional luminaires

Best-in-class radiation pattern for
- reflector applications
- color mixing light engines
- flood and diffuse applications
OSLON SSL
Sophisticated radiation patterns

OSLON SSL LED's direct the light where it's needed most!

Symplifying optical designs

Improving optical efficiency

80°

150° NEW

Light where it's needed most

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### OSLON SSL version overview

- Sophisticated versions for every kind of lighting requirement – in both 80° and 150°

<table>
<thead>
<tr>
<th>Product target</th>
<th>LCW .CC (color champ)</th>
<th>LCW .EC (eco champ)</th>
<th>LCW .PC (power champ)</th>
<th>LUW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product target</strong></td>
<td>Warm/neutral white Maximized light quality</td>
<td>Warm/neutral white Best compromise CRI and flux</td>
<td>neutral white Maximized flux</td>
<td>Cool white Maximized flux</td>
</tr>
<tr>
<td><strong>CCT range</strong></td>
<td>2700-4000K</td>
<td>2700-5000K</td>
<td>4000 – 5000K</td>
<td>6000 – 6500K</td>
</tr>
<tr>
<td><strong>Typ. CRI</strong></td>
<td>95</td>
<td>82</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Premium Indoor Lighting, e.g. Shop</td>
<td>various Indoor Lighting, e.g. Office</td>
<td>Outdoor Lighting Industrial Lighting</td>
<td>Outdoor Lighting Industrial Lighting</td>
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</table>
Supporting the entire white CCT-range (2700-6500K) with optimized CRI’s:

- **LCW.CC**
  - CRI95
  - 2700-4000K

- **LCW.EC**
  - CRI82
  - 2700-5000K

- **LCW.PC**
  - CRI70
  - 4000-5000K

- **LUW**
  - CRI70
  - 6000-6500K
Thermal Solutions

- **Substrate materials**
  - Thermal substrate materials (e.g. metal core PCB) provide primary heat spreading, heat transfer to the heat sink, electrical connection to the driver, and mechanical mounting.

- **Interface materials**
  - Thermal interface materials (e.g. film or thermal grease) improve heat dissipation and electrical isolation.

- **Heatsink engineering & manufacturing**
  - Heat sinks dissipate heat to the ambient environment.
Why is thermal design important for LEDs?

Goal 1 – To ensure LED’s reliable operation with no catastrophic failure.  
By preventing LEDs from exceeding the maximum permissible junction temperature repeatedly within the required ambient temperature range.

Goal 2 – To ensure LED’s life time with no significant early degradation.  
By preventing LEDs from being over-driven within the required ambient temperature range.

Goal 3 – To optimize LED’s optical performance.  
By driving the LEDs at the maximum possible current within the required ambient temperature range. (minimum thermal degradation)

Good thermal design minimizes LED Junction Temperature $T_j$ to maximize LED’s “useable” light output and life time.
The Effects of a change in Junction Temperature (Tj)

LED Junction Temperature  \(\uparrow\)  

Forward Voltage  \(\downarrow\)  
Dominant Wavelength  \(\uparrow\)  
White Chrom. Coordinates  \(\downarrow\)  

Relative Vorwärtsspannung\(^2\) Seite 17
Relative Forward Voltage\(^2\) page 17  
\(\Delta V_F = V_F - V_{F(25 \, ^\circ C)} = f(T_j), I_F = 350 \, mA\)  

Relative Lichstrom\(^2\) Seite 18
Relative Luminous Flux\(^2\) page 18  
\(\Phi_L/\Phi_{L(25 \, ^\circ C)} = f(T_j), I_F = 350 \, mA\)
What Impacts LED’s Junction Temperature $T_J$?

$$T_J = T_A + (R_{thJS} + R_{thSA}) \cdot P_{LED}$$

$$T_J = T_S + R_{thJS} \cdot P_{LED}$$

$$P_{LED} = V_f \cdot I_f$$

- $R_{thJS}$ (junction-solder point)
- $R_{thSB}$ (solder point-board)
- $R_{thBA}$ (board - ambient)
- $P_{LED}$ LED power dissipated
Thermal Resistance - LED $R_{thJS}$
(junction to solder point)

LED Package | $R_{thJS}$ (datasheet) | Max. Current $I_f$
--- | --- | ---
Advanced Power TOPLED | 40-60 K/W | 250 mA
Golden Dragon Plus LED | 6.5 K/W | 2 A
OSLON SSL | 7 K/W | 2 A
Electrical Solutions - Drivers and LED Ballasts

- **IC driver**
  - Driver ICs provide a constant current supply to and electrical control of the LED.

- **Driver circuit**
  - Integrated solution (a.k.a ballast) offers plug & play solutions to drive the lighting system.
Points to Remember

• The “useful light output” from an LED is defined at a specific forward current and target junction temperature, taking its thermal degradation into account.

• All three aspects must be managed for best efficiency
  1. OPTICAL - Highest optical efficiency requires the least number of LEDs in the system
  2. ELECTRICAL - Drive the LED with a constant current supply to allow operation at or near the maximums to keep the LED count low
  3. THERMAL - Keep the junction temperature as low as practicable to maintain light output and lifetime

![Diagram showing the relationship between light, electrical power, and heat.]
## Agenda

**LLFY System Design Workshop, San Diego CA**

1. Why LED, consideration about efficacy and directivity
2. LED as part of a well designed system
3. Examples for outdoor applications
4. Examples for indoor applications
5. Architectural lighting
City illumination and safety aspects

Color quality and uniform illumination are not only aesthetic aspects, but contribute to the safety feeling of people

Comparison

LED Illumination / High pressure sodium

- LED using more than 50% less energy as HPS lamps
- better visibility even with lower lux levels
- annual savings of 10,000 kWh, reduced maintenance
- Better safety feeling due to better recognition of trees and faces
- Very good color rendering of nature (green colors)
- increased safety by more homogeneous illumination
- less tiring of the eye by „striped“ inhomogeneous streets
Comparison LED illumination vs HPS

Green trees because of higher CRI

120W
Excellent visibility with LED light

HPS is causing higher glare

250W
Energy consumption increase, visibility decreased
Area Light Reference Design

Integrated Module +

Heatsink Solution

Electrical Solution

Optical Solution

Luminaire recommended installation
## Area Light Reference Design Partners

Visit us at: [www.LEDLightforyou.com](http://www.LEDLightforyou.com)

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<tr>
<th>Solution</th>
<th>LED Light for you Partner</th>
<th>Website</th>
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<tr>
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<td><img src="https://via.placeholder.com/150" alt="Thermal" /></td>
<td><img src="https://via.placeholder.com/150" alt="Thermal" /></td>
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<tr>
<td><strong>Thermal</strong></td>
<td><strong>Metalcore Printed Circuit Board (PN 804200), Thermal Interface Material (Hi-Flow 225F-AC)</strong></td>
<td><img src="https://via.placeholder.com/150" alt="Thermal" /></td>
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<tr>
<td><strong>Electrical</strong></td>
<td><strong>LED Power Supply (1072 model series)</strong></td>
<td><img src="https://via.placeholder.com/150" alt="Electrical" /></td>
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<td><img src="https://via.placeholder.com/150" alt="Streetlight module" /></td>
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GALED Street Lamp Installation in South Korea

South Korea Invests in Energy Efficiency with Installation of GALED Street Lamps Featuring OSRAM Golden DRAGON Plus LEDs

- LED-based 80W/150W PRAUS street lighting prototype projects installed to replace Metal Halide lamps and Natrium lamps
- optimized CRI: increase from around 30 to over 65 improving night visibility
- average annual energy savings is estimated by GALED to be over 55%
- Golden DRAGON LEDs consume 80% less electricity than incandescent lamps
- LEDs can last for up to 50,000 hours giving longer service intervals and reducing maintenance cost
OSRAM LEDs in YangTze river tunnel
Post Top Retrofits installed in USA and Canada

- ‘The 40W LED system contains 66 Golden Dragon Plus LEDs from Osram Opto Semiconductors and delivers light only where needed, minimizing light trespass and disruption to an application’s surroundings and neighbours.’ ~ LEDs Magazine

- CASE STUDY: Lansing City Street Lights
  Lansing, Michigan Historical Nature and Charm.

- OSRAM SYLVANIA DELIVERS NEW LIGHT TO A HISTORIC CAPITOL
  Company Introduces Next Generation Post Top Fixture LED Retrofit Kit to the Pennsylvania State Capitol

- MAINE GOVERNOR FLIPS THE SWITCH ON OSRAM SYLVANIA LED RETROFIT LAMPS AT PINELAND FARMS
  Installation of Post Top Fixture LED Retrofit Kit Saves Energy and Enhances Light Quality
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University of Notre Dame  Legends Downlighting

Golden Dragon Plus

- Legends, a campus restaurant and ale house located at the University of Notre Dame in Notre Dame.
- Downlighting powered by Golden Dragon Plus.
- MODA LIGHT down lights throughout its dining facilities.
- ~82% in energy savings from the previously installed fixtures.
- The installation of MODA LIGHTs at the campus restaurant met both the University’s goals of quality lighting and energy efficiency.

Source: www.modalight.com
LED Lighting In Retail

- Phoster Industries LED Down Lights with OSRAM Opto Semiconductor Golden DRAGON Plus LEDs help major retailers reduce energy consumption and preserve inventory.
- Installations at Macy’s and Dillards
- Lighting energy consumption in the bedding department was reduced by 85%
- Maintenance and lamp replacement cost drastically reduced
Offices in government building Germany, existing illumination with 500 lx at working area

- Luminaire: 4 pcs. With 84W each
  Reflector aluminium white
- No sensors
- Power consumption per office: 4 x 84 W P = 336 W
- Min illumination at working areas
  $E_m = 490 \text{ lx}$
- Average illumination at working areas:
  $E_{mA} = 510 \text{ lx}$
- Energy consumption at 2250 h/a: 756 kWh/a
- CO$_2$ Emission: 453 kg
LED in office illumination – Energy savings already by today

LEDs with intelligent light management

- Intelligent management with detection of ambient light and presence of employees
- Reduction of energy consumption from 100% to 20% only

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<th>Connected rating</th>
<th>Energy consumption [kWh/a]</th>
</tr>
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<tr>
<td>Standard T5 (500 lx)</td>
<td>4 x 84 W = 336 W</td>
<td>756</td>
</tr>
<tr>
<td>LED solution (500 lx) + light management</td>
<td>1 x 105 W = 105 W</td>
<td>236</td>
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Typical applications in public areas

LED in exterior applications:

- Streetlighting
- Tunnel, bridges
- Parks
- Public places
- Parking areas
- Bus-/train stops

LED in interior applications:

- Public buildings
- Schools
- Event halls
- Parking garages
- Entrance halls
- Train stations, airports
- Museum
Golden fountain at Beijing olympic games
Union Investment Bank Frankfurt

OSRAM Golden DRAGON, a scenic spot at financial district, Frankfurt

- Changing colors
- Flexible arrangement of illumination
- Robust installation
City beautification with white Power TOPLED®

Place du Molard, Geneva / Switzerland
LEDs and city marketing

LED light can set new accents to your streets and places. Make visitors and citizens feel comfortable and entertained!

City marketing and beautification

Intelligent light management systems
- dynamic installations for entertainment and aesthetics
- modern and intelligent city light – dimmable and switchable
- guiding visitors to the most beautiful places with light

Safety and security

Safety as an individual feeling
- LED lighting leads to better recognition of colors and people
- better recognition of people leads to higher safety feeling
- crime statistics can be reduced by good white LED light
Thank you for your attention!
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