LEDs for Pico Projectors

BA SID

18 April 2012
Agenda

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OSRAM Opto Semiconductors - company overview

Northville
- Sales & Marketing NA East
- Application Center

Regensburg, Germany
- Global Headquarter-

Shanghai
- Sales China
- Marketing China
- Application Center

Yokohama
- Sales Japan
- Marketing Japan
- Application Center

Sunnyvale, CA
- Headquarters NA
- Sales and Service NA West

Penang
- Backend Plant
- Frontend Plant
- R&D Asia

Hong Kong
- Headquarters Asia
- Sales Asia Pacific
- Marketing Asia Pacific
OSRAM – Vertically Integrated

** Conversion **
- Chip
- Phosphor
- Package

** Emission Spectrum **
- Single chip device
- 350-650 nm

** Chip Design **
- InGaAlP high optical power
- InGaAlP thin film

** Package Design **
- SMT-TOLED®
- Power package
- Micro package
## Definition of a Pico-Projector

<table>
<thead>
<tr>
<th>Size</th>
<th>Weight Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femtoportable</td>
<td>0.2kg (0.44 lbs) or less</td>
</tr>
<tr>
<td>Picoportable</td>
<td>0.21 kg (0.45 lbs) to 1kg (2.2 lbs)</td>
</tr>
<tr>
<td>Nanoportable</td>
<td>1.01 kg (2.21 lbs) to 2kg (4.4 lbs)</td>
</tr>
<tr>
<td>Microportable</td>
<td>2.01kg (4.41 lbs) to 3kg (6.6 lbs)</td>
</tr>
<tr>
<td>Ultraportable</td>
<td>3kg (6.61 lbs) to 5kg (11 lbs)</td>
</tr>
<tr>
<td>Portable</td>
<td>5kg (11.1 lbs) to 10 kg (22 lbs)</td>
</tr>
<tr>
<td>Conference</td>
<td>10 kg (22.1 lbs to 15 kg (33 lbs)</td>
</tr>
<tr>
<td>Large Venue</td>
<td>&gt;15kg (33 lbs)</td>
</tr>
</tbody>
</table>

Definition offered by Dr. William Coggshall, president of Pacific Media Associates
LED - Early Customer Requirements

- High Luminance
- High efficiency
- Good thermal performance
- Accurate chip placement
- Auto alignment of optics
- Thermal sensor
- Easy connection
- Compact size
Projection System – Lamp to LED

Conventional lamp
- Uses a color wheel or Color Link Color Switch™
- Proven solution with high light output
- Shutter or compensation cell needed

LED based system
- High color purity.
- Solid state devices. Stable output & 30k+ hour life (10+ years @ 8hrs/day)
- Low voltage/5V supply.
- Pulsed operation – low power.

Color wheel is eliminated in LED based system.
Schematic of DMD based Sequential Color Projector Engine

- **DMD (Digital Micromirror Device)**
- **DLP® (TI)**
- **TIR prism**
- **Projection lens system**
- **Homogenizing optics (Fly’s Eye Array)**
- **Relay optics**
- **Mirror**
- **Dichroic filters/mirrors**
- **Red LED**
- **Green LED**
- **Blue LED**
- **Collection/Collimating lenses**
- **to screen**

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Opto Semiconductors

OSRAM
Schematic of a LCoS based Projector Engine

D. Darmon, J. R. McNeil, M. A. Handschy,
“LED-illuminated Pico Projector Architectures”,
SID 08 Digest, 170-173 (2008)
Etendue = area of the source times the **solid angle** of the system's **entrance pupil subtends** as seen from the source.

Due to etendue considerations there is a maximum usable light emitting area, defined by:

- Microdisplay size
- Microdisplay acceptance angle and projection lens F/#
- LED light collection angle by secondary optics (collection lens)

\[
E_{LED} = \pi \cdot n^2 \cdot A_{LED} \cdot \sin^2(\phi_{LED})
\]

\[
E_{system} = \pi \cdot A_p \cdot \sin^2(\phi_{system})
\]

\[
E_{LED} \leq E_{system}
\]
Thin Film LEDs – 1st release 2004

**

The reflective surface of the carrier eliminates substrate absorption
Features of ThinFilm (also ThinGaN) LEDs

Higher efficiency compared to volume emitter (extraction efficiency increased from 50% to 97%).

Lower Vf

Top emission only

- minimizes etendue (good for coupling to optics and light guides.
- Improved color shift over angle.

Scalable of output to chip area.
Light Extraction From A LED

Flux = 100 lm
Luminance = 100 nits

Flux = 100 lm
Luminance = 100 nits

Take 2 identical chips of 1mm² chip size
Design Rule #1 – *Chip on Air*  

Flux = 150 lm  
Luminance = 67 nits  
Etendue = 2.25

Flux = 93 lm  
Luminance = 93 nits  
Etendue = 1

Add dome lens optimized for extraction with $\bar{n} = 1.5$

Add cover glass with AR (anti-reflective) coating

=>$Design rule #1: Use “chip on air” i.e. no silicon encapsulation$
**Design Rule #2 – Use Largest Chip Size possible**

Chip efficacy (lm/W) is reduced with increasing current density (‘current droop’)

Red: ThinFilm based on AlInGaP material system  
Green, Blue: ThinGaN based on InGaN material system

Relative luminous efficacy is normalized to 100% @ 350mA/mm² corresponding to 350mA for 1mm (40mil) chip.

=> Design rule #2: Maximize chip size
Design Rule #3 – Don’t Exceed System Etendue

Maximum LED size based on system Etendue

\[
E_{LED} \leq E_{system}
\]

\[
n^2 \cdot A_{LED} \cdot \sin^2(\varphi_{LED}) \leq A_p \cdot \sin^2(\varphi_{system})
\]

\[
A_{LED} \leq \frac{A_p \cdot \sin^2(\varphi_{system})}{n^2 \cdot \sin^2(\varphi_{LED})}
\]

Only for a LED smaller than this max size all light can be guided through the optics system. For a LED larger than this max size part of the light is wasted.

=> Design rule #3:
Keep the chip size (emitting area) below the maximum limit defined by the optical systems Etendue.
Best efficacy is reached if etendue of LED equals that of the optical system.
Optimum LED Solution: Examples

Optimum LED for 3-channel illumination using various micro displays

<table>
<thead>
<tr>
<th></th>
<th>0.22 nHD, DMD</th>
<th>0.3 WVGA, DMD</th>
<th>0.21 WVGA, LCoS</th>
<th>0.28 720p, LCoS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>640 x 360</td>
<td>854 x 480</td>
<td>854 x 480</td>
<td>1280 x 720</td>
</tr>
<tr>
<td>Diagonal</td>
<td>0.22”</td>
<td>0.30”</td>
<td>0.21”</td>
<td>0.28”</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>16:9</td>
<td>16:9</td>
<td>16:9</td>
<td>16:9</td>
</tr>
<tr>
<td>F-Number</td>
<td>2.4</td>
<td>2.4</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Acceptance angle</td>
<td>12 deg</td>
<td>12 deg</td>
<td>16 deg</td>
<td>16 deg</td>
</tr>
<tr>
<td>Etendue</td>
<td>1.74 mm²sr</td>
<td>3.24 mm²sr</td>
<td>2.74 mm²sr</td>
<td>4.86 mm²sr</td>
</tr>
<tr>
<td>LED collection angle</td>
<td>+/-65 deg</td>
<td>+/-65 deg</td>
<td>+/-65 deg</td>
<td>+/-65 deg</td>
</tr>
<tr>
<td>Optimum Chip size (emitting area)</td>
<td>1.10mm x 0.62mm</td>
<td>1.50mm x 0.84mm</td>
<td>1.37mm x 0.77mm</td>
<td>1.83mm x 1.03mm</td>
</tr>
</tbody>
</table>
Product Portfolio for Projection

Brightness

high

mid

low

OSTAR Compact
3x 750um RGB
2x 750um RB, GB
1x 750um R,G,B

CG

OSTAR SMT
1x 2mm² R,G,B,UV
1x 1mm² R,G,B

CG

OSTAR Projection
4x 1mm² R,G,B,RGB,UV
4x 0.75mm RGB
4x 0.5mm RGB
2x 2mm² R,G,B

CG

OSTAR Power Projection
6x 2mm² R,G,B

CG

Converted Green derivates successful launched in time
Optical Architecture: Overview

3-channel

3 discrete LED devices

Pros:
- Maximum etendue/lumens per color
- Good color uniformity

Cons:
- Large engine size
- High BOM
- Many components needed

2-channel

2 discrete LED devices

Pros:
- Reduced engine size
- Reduced BOM
- Only 1 dichroic filter element needed

Cons:
- Colors in 2in1 pkg have limited etendue
- Color homogenization needed

1-channel

1 LED device only

Pros:
- Reduced engine form factor
- Reduced BOM
- No dichroic filters needed

Cons:
- Low etendue/lumens for each color
- Color homogenization needed
3-Channel Illumination

Emitting area of optimum and standard LED chips for various imager panels

LED emitting length, mm

LED emitting width, mm

- 0.22 nHD DMD
- 0.3 WVGA DMD
- 0.21 WVGA LCoS
- 0.28 720p LCoS
### System Settings

<table>
<thead>
<tr>
<th>Microdisplay panel:</th>
<th>0.30” WVGA DMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illumination architecture</td>
<td>2-channel G + RB</td>
</tr>
<tr>
<td>LEDs</td>
<td>G 1mm + RB 2x 750µm</td>
</tr>
<tr>
<td>Frame rate</td>
<td>120Hz</td>
</tr>
<tr>
<td>Color overlap</td>
<td>no color overlap</td>
</tr>
<tr>
<td>Target whitepoint on screen Cx/Cy</td>
<td>0.29/0.33</td>
</tr>
<tr>
<td>Total optical efficiency</td>
<td>23% (G), 25% (RB)</td>
</tr>
<tr>
<td>Solderpoint temperature Ts</td>
<td>60°C</td>
</tr>
</tbody>
</table>

### Schematic

![Schematic Image](image-url)
“Green Gap”

![Graph showing internal efficiency and wavelength for InGaN and InGaAlP.]

- **InGaN**
- **InGaAlP**
Green is generally Limiting Color in a Display. **

Ceramic Based Converted Green for Higher Lumens

**

Brightness (Luminous Flux)

![Brightness Graph](image)

Spectral Curve @ 1.4A

![Spectral Curve Graph](image)
Spectral Curves – RGB vs Converted Green

- **Amber**
- **True Green**
- **Blue**
- **V-lambda**
- **Converted Green**

The graph shows spectral curves for different colors, with the x-axis representing wavelength in nm and the y-axis representing optical intensity normalized to max=1.
Usability of the Light by cutting Blue and Red

Content of luminous flux within WL-range:
90% in 500…600nm
81% in 510…590nm

Blue and Red are cut by typical multi-channel light engines
LED Drive Electronics

Ideal Solution:

• Single chip solution with multi-channel control.
• Serial interface for drive control
• Onboard non-volatile memory to store calibration data
• Accommodate Vf differences of AlInGaP vs. InGaN
• Permit color overlapping.
New Chip Architecture: UX3

UX3 current spreading utilizes vias which don’t reach top surface.
New Chip Architecture: Eliminating Droop

Performance of new high current chip design in Dragon +

- 601.4 mW @ 350 mA
- 1966 mW @ 1.4 A
- 3199 mW @ 3 A
Summary

High Efficiency Pico-Projector Design is possible:

• Select the highest efficacy LED available:

• Select the appropriate optical architecture

• Provide adequate thermal management

• Drive electronics selection for cost, efficacy and size.
Thank you

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