LEDs for Pico Projectors

BA SID

18 April 2012

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Agenda

Introduction
LED requirements
Architecture of Projector Engine
Etendue
Chip Technologies
Light Extraction
Design Rules for LED
Optical Architecture
Converted Green
LED Drive Electronics
New Chip architecture
Summary

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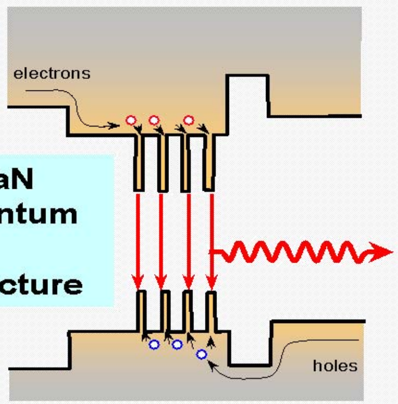
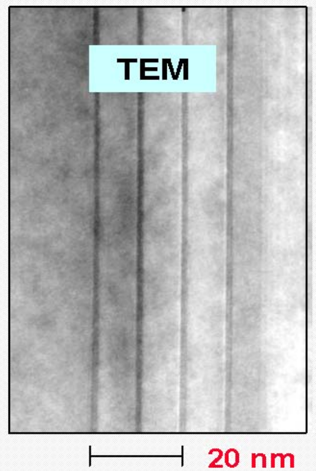
OSRAM – Vertically Integrated

* *

EPI





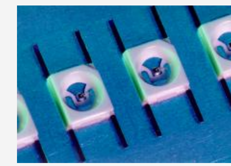
Conversion

chip

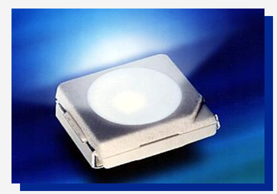
+

phosphor

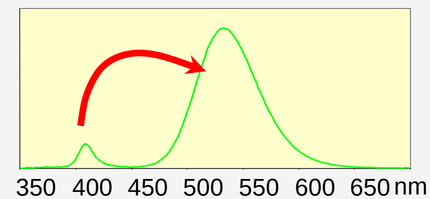
+



package



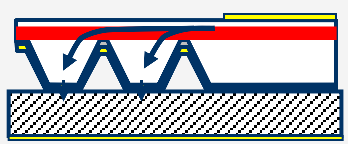
single chip device



emission spectrum

Chip Design

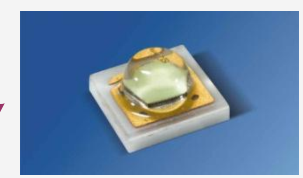
InGaAlP high optical power



InGaAlP thin film

Package Design

SMT-TOPLED®



power package

micro package

Definition of a Pico-Projector *

Size

Femtoportable:	0.2kg (0.44 lbs) or less
Picoportable:	0.21 kg (0.45 lbs) to 1kg (2.2 lbs)
Nanoportable:	1.01 kg (2.21 lbs) to 2kg (4.4 lbs)
Microportable:	2.01kg (4.41 lbs) to 3kg (6.6 lbs)
Ultraportable:	3kg (6.61 lbs) to 5kg (11 lbs)
Portable:	5kg (11.1 lbs) to 10 kg (22 lbs)
Conference:	10 kg (22.1 lbs to 15 kg (33 lbs)
Large Venue:	>15kg (33 lbs)

Definition offered by Dr. William Coggshall, president of Pacific Media Associates

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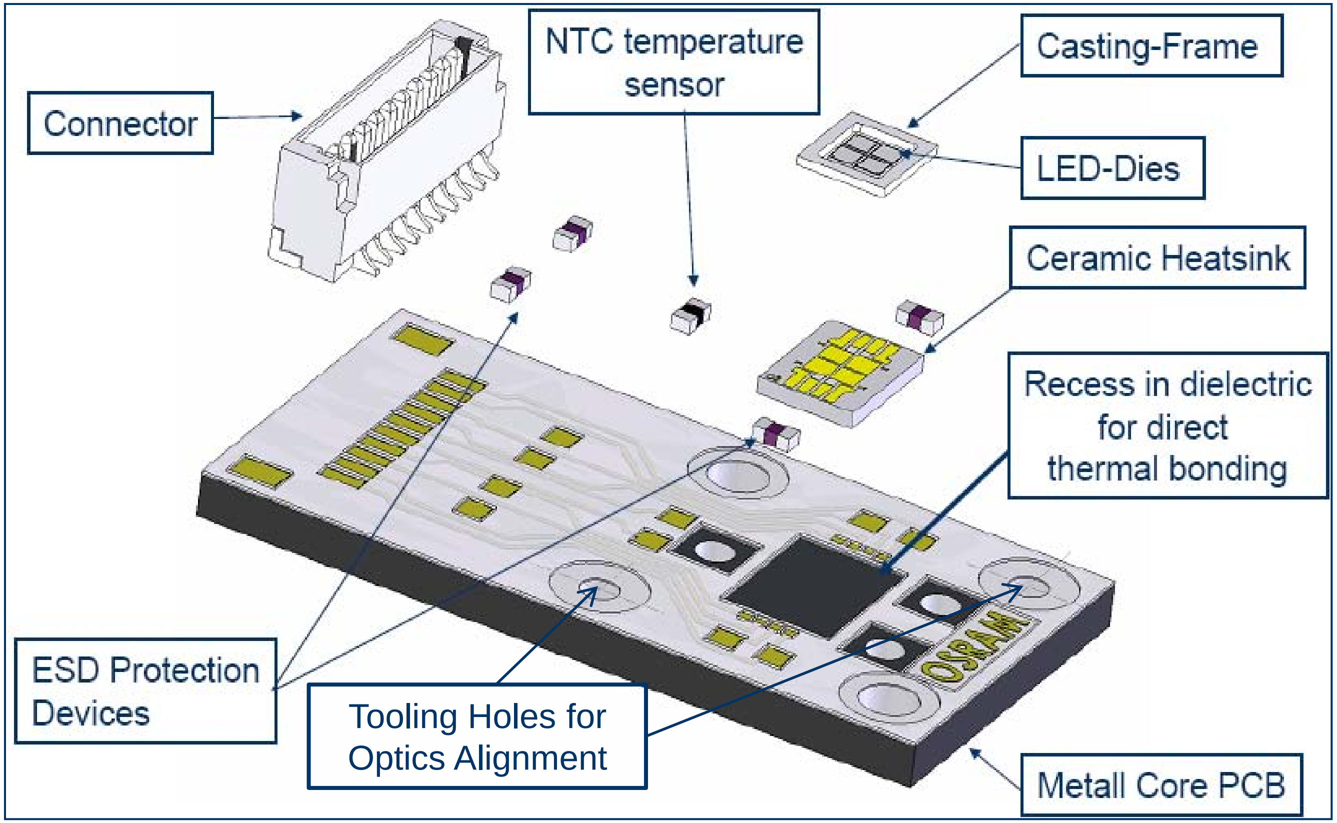
LED - Early Customer Requirements **

- High Luminance
- High efficiency
- Good thermal performance
- Accurate chip placement
- Auto alignment of optics
- Thermal sensor
- Easy connection
- Compact size



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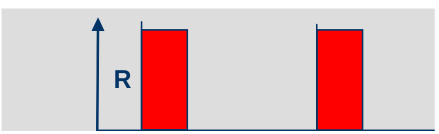
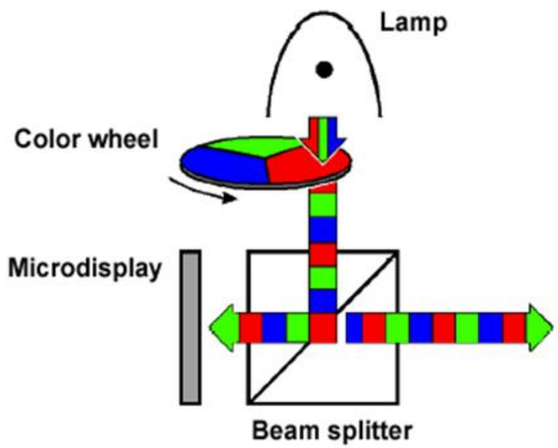
Projection System – Lamp to LED **



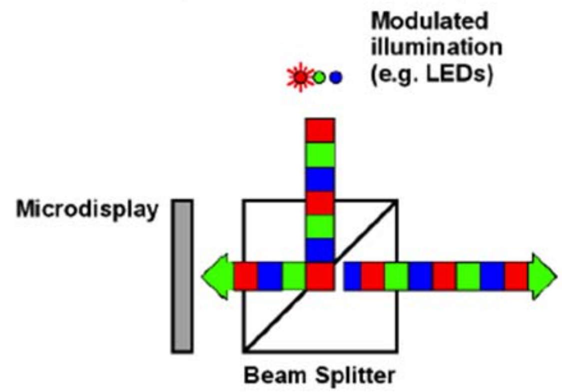
Conventional lamp

- 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.

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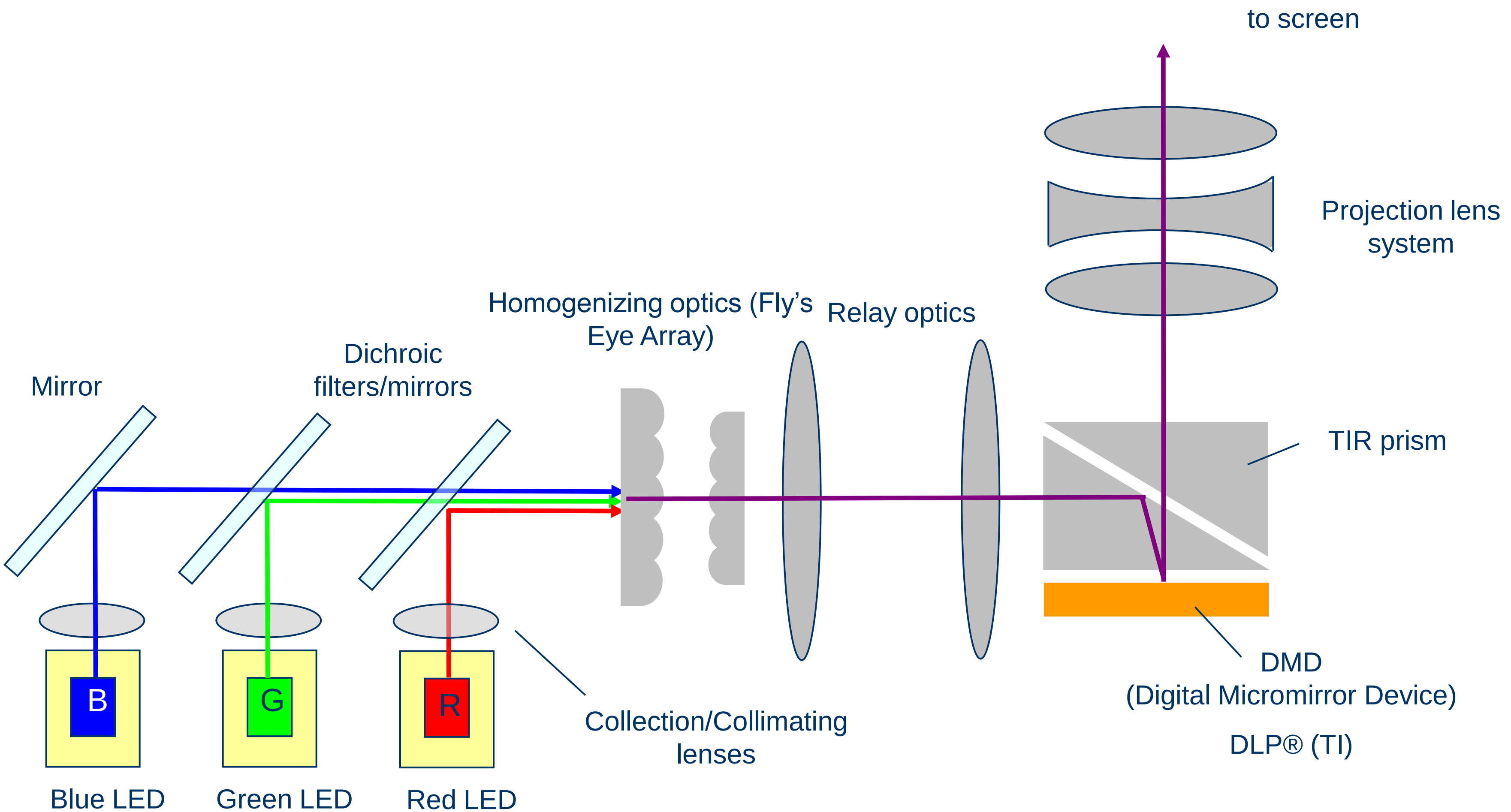
Schematic of DMD based Sequential Color Projector Engine



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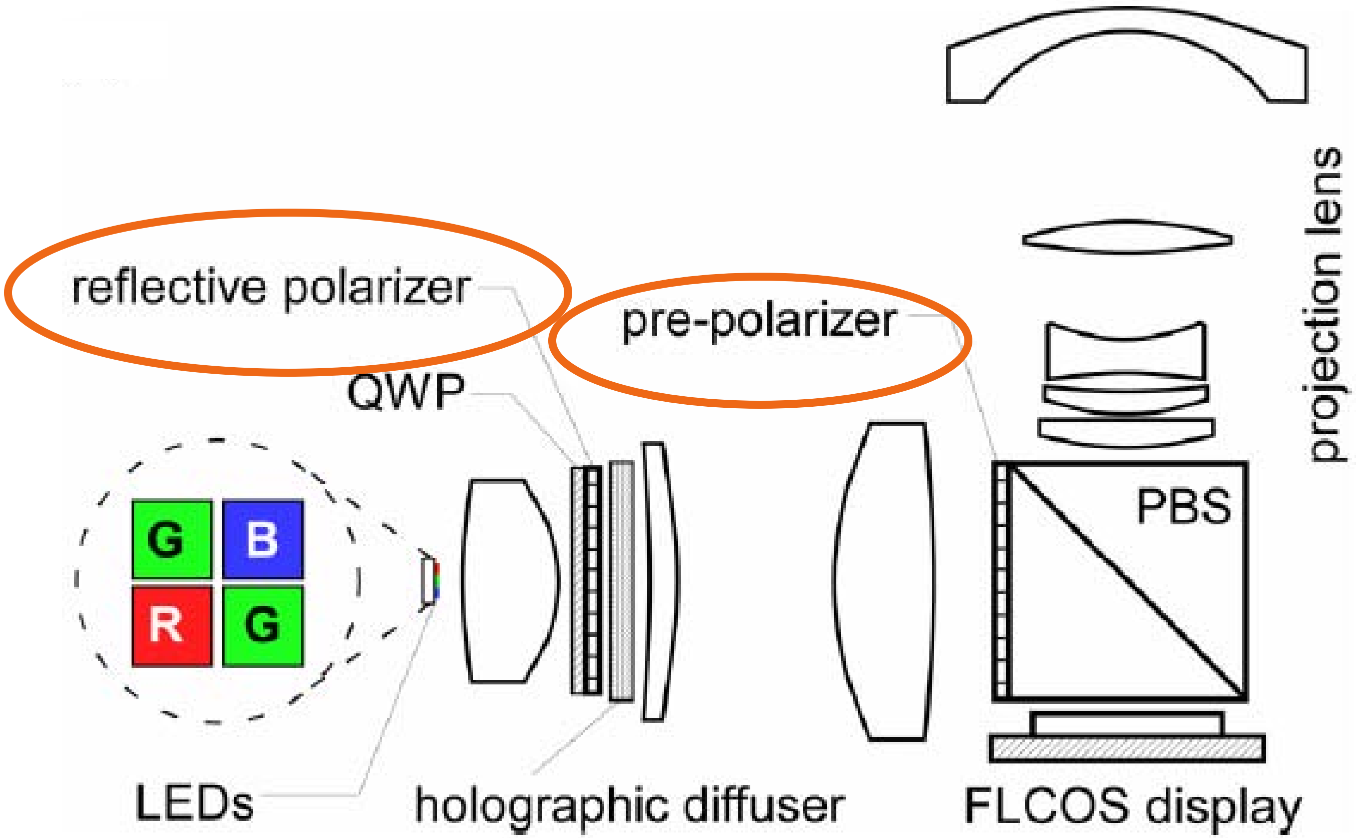
Schematic of a LCoS based Projector Engine



D. Darmon, J. R. McNeil, M. A. Handschy,

"LED-illuminated Pico Projector Architectures",

SID 08 Digest, 170-173 (2008)

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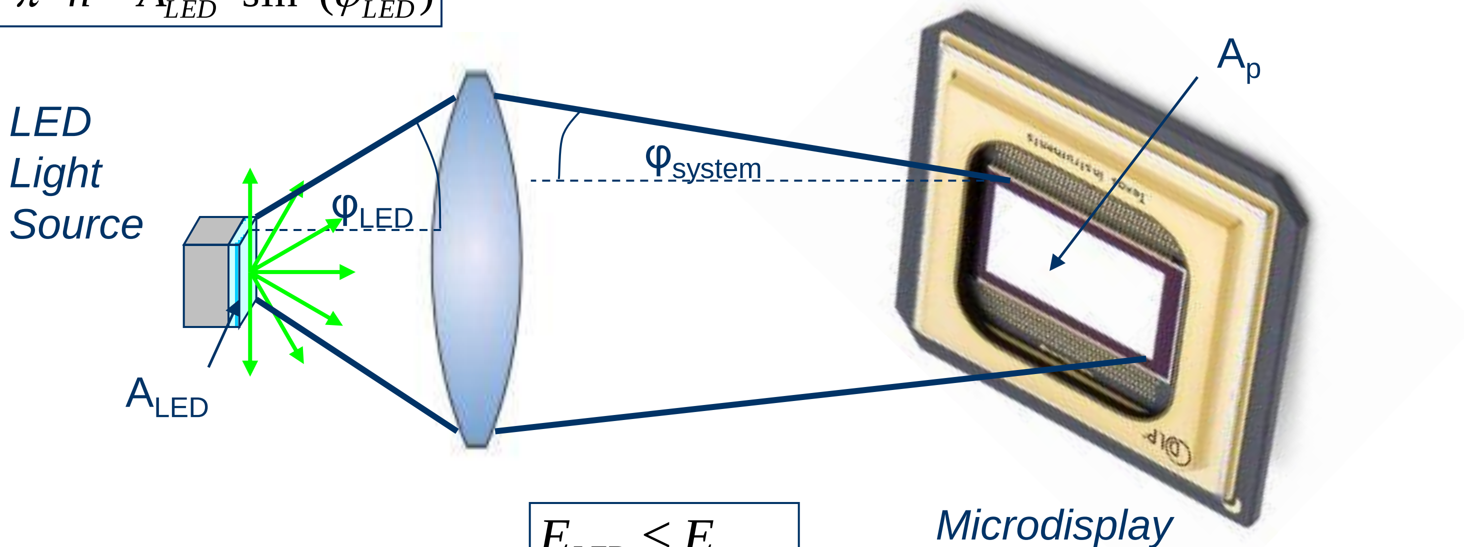
Etendue = area of the source times the solid angle of the system's entrance pupil subtends as seen from the source

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)

$$E_{LED} = \pi \cdot n^2 \cdot A_{LED} \cdot \sin^2(\varphi_{LED})$$

$$E_{system} = \pi \cdot A_p \cdot \sin^2(\varphi_{system})$$



$$E_{LED} \leq E_{system}$$

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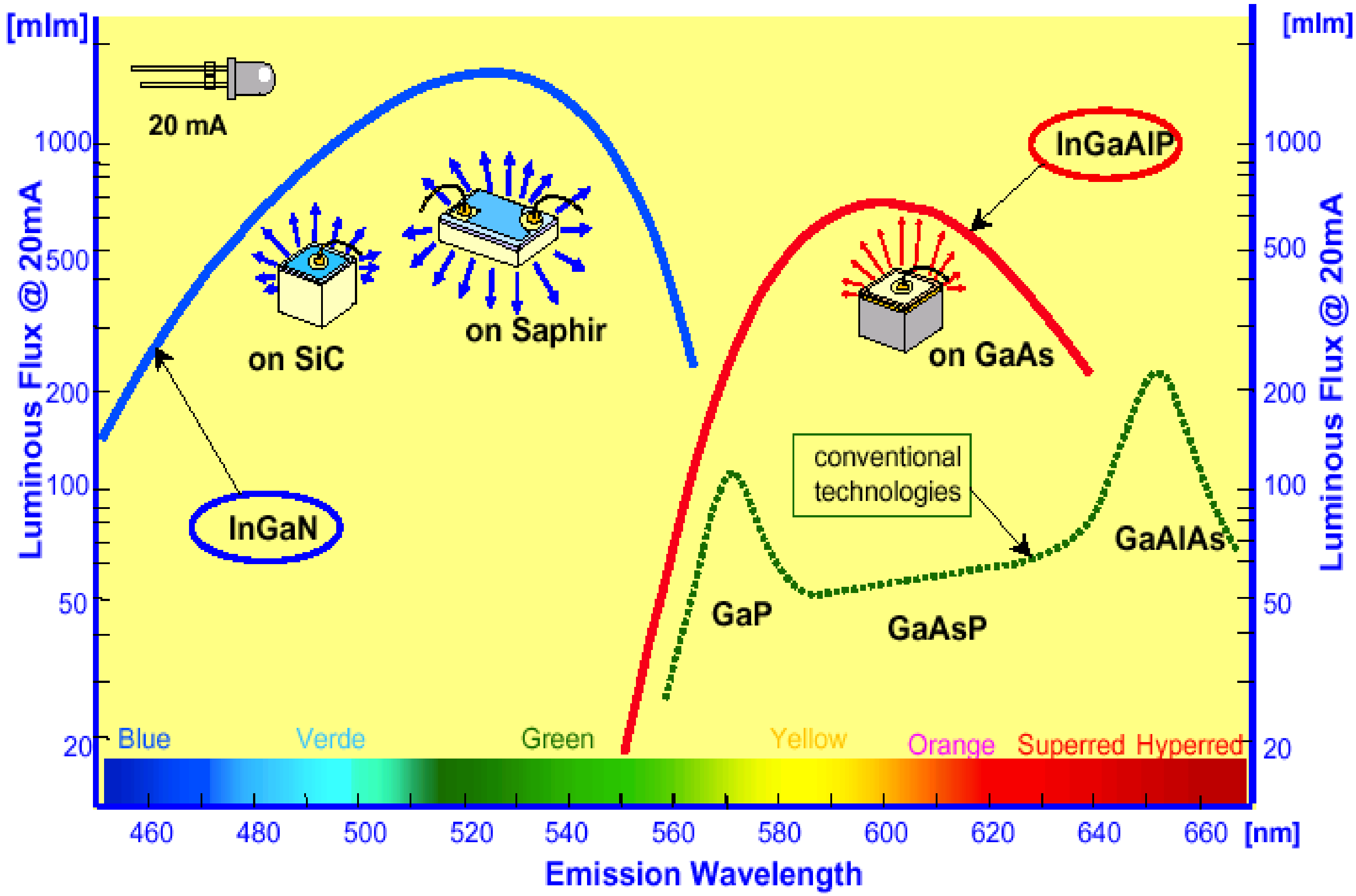
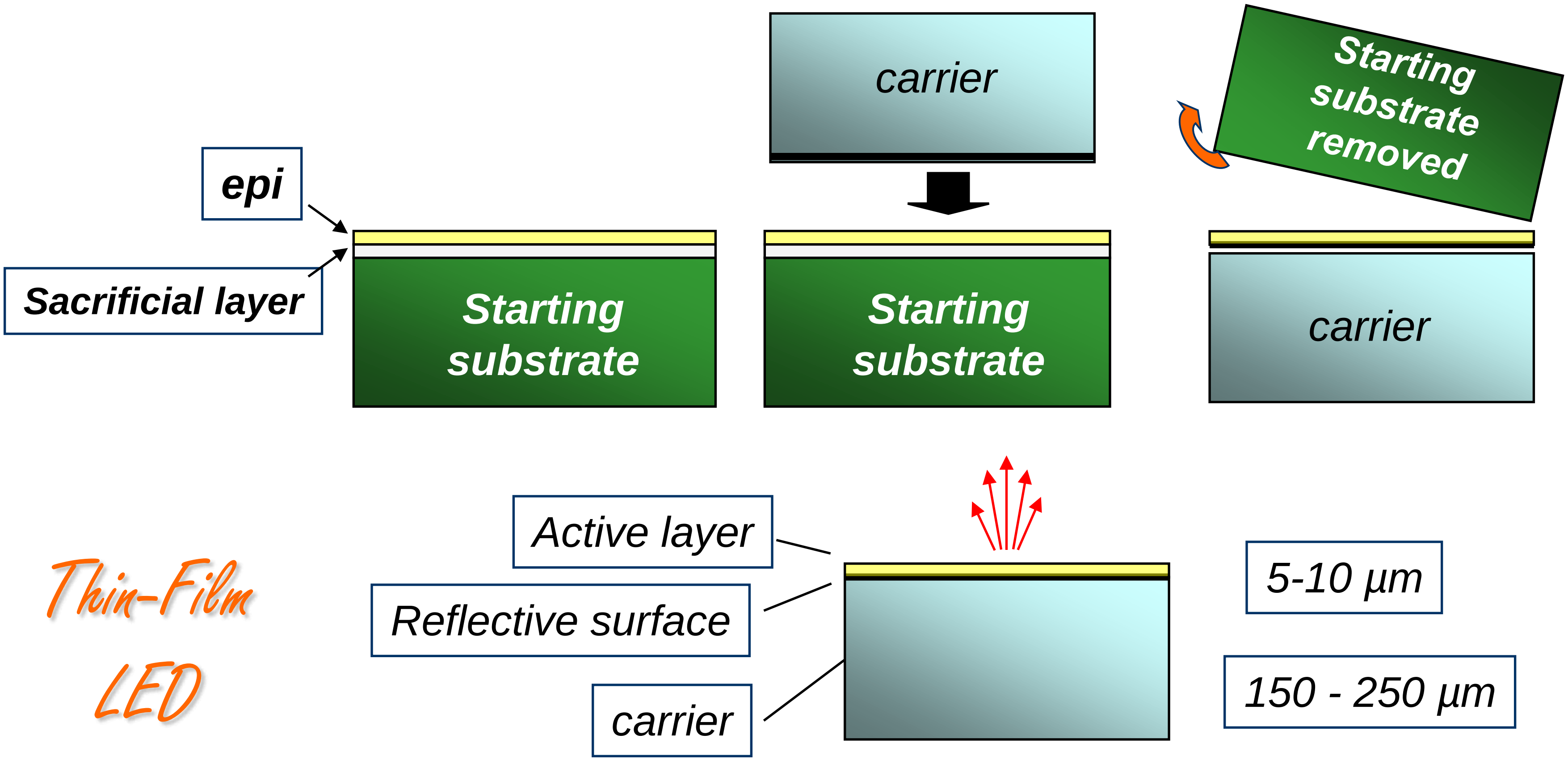
Chip Technologies



Thin Film LEDs – 1st release 2004 **



The reflective surface of the carrier eliminates substrate absorption

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Features of ThinFilm (also ThinGaN) LEDs **

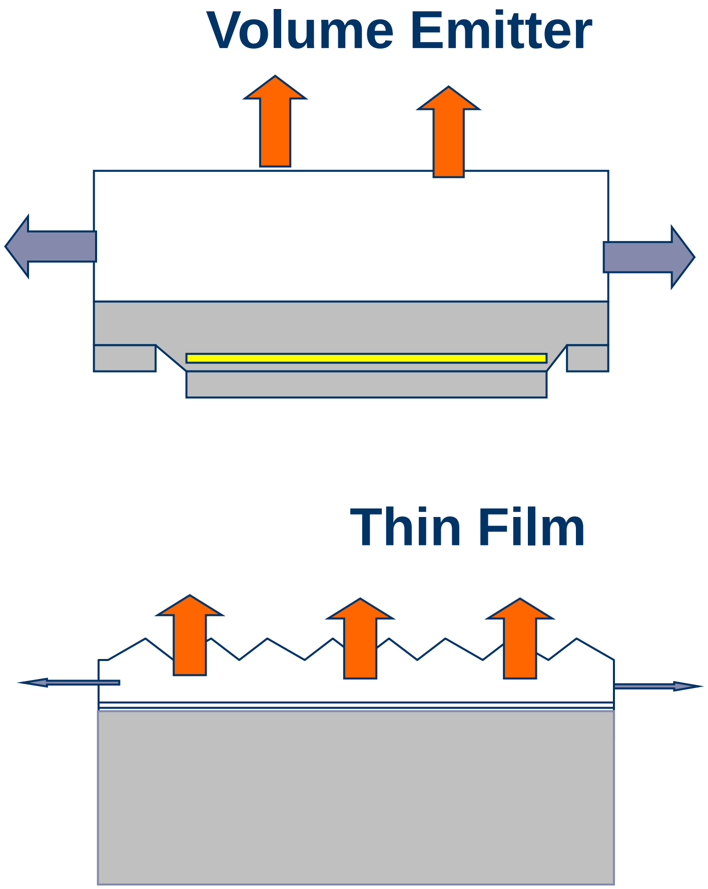
Higher efficiency compared to volume emitter (extraction efficiency increased from 50% to 97%).

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.



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Light Extraction From A LED **

Flux = 100 lm

Luminance = 100 nits

Flux = 100 lm

Luminance = 100 nits

Take 2 identical chips of 1mm^2 chip size

Design Rule #1 – *Chip on Air* **

Flux = 150 lm

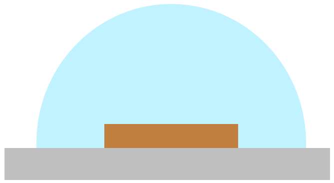
Luminance = 67 nits

Etendue = 2.25

Flux = 93 lm

Luminance = 93 nits

Etendue = 1



Add dome lens optimized for extraction with ñ = 1.5

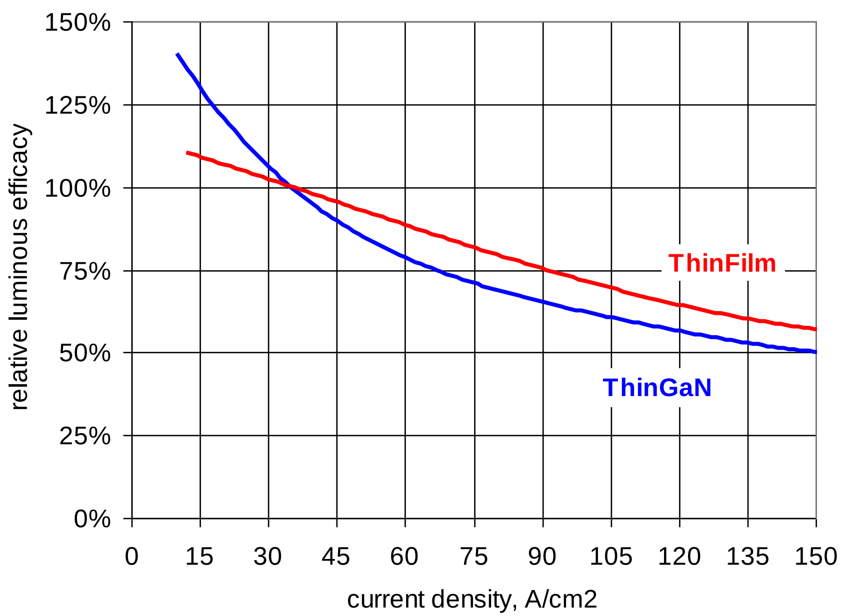
Add cover glass with AR (anti-reflective) coating

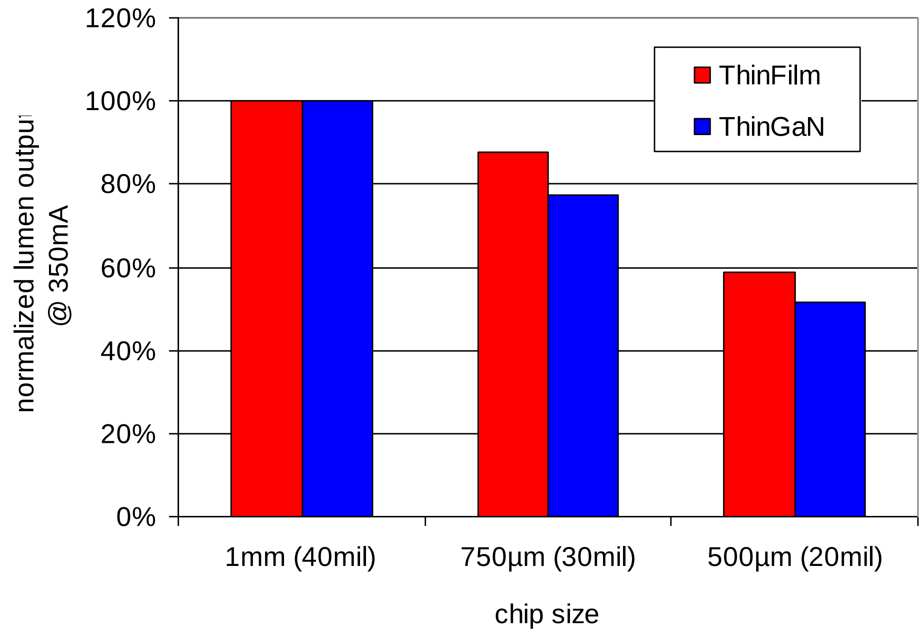
=> Design rule #1: Use “chip on air” i.e. no silicon encapsulation

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

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Design Rule # 3 – Don‘t Exceed System Etendue

Maximum LED size based on system Etendue

$$E_{LED} \le E_{system}$$

$$n^2 \cdot A_{LED} \cdot \sin^2(\varphi_{LED}) \le A_p \cdot \sin^2(\varphi_{system})$$

$$A_{LED} \le \frac{A_p \cdot \sin^2(\varphi_{system})}{n^2 \cdot \sin^2(\varphi_{LED})}$$

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.

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Optimum LED Solution: Examples

Optimum LED for 3-channel illumination using various micro displays

	0.22 nHD, DMD	0.3 WVGA, DMD	0.21 WVGA, LCoS	0.28 720p, LCoS
Resolution	640 x 360	854 x 480	854 x 480	1280 x 720
Diagonal	0.22”	0.30”	0.21”	0.28”
Aspect ratio	16:9	16:9	16:9	16:9
F-Number	2.4	2.4	1.8	1.8
Acceptance angle	12 deg	12 deg	16 deg	16 deg
Etendue	1.74 mm^2sr	3.24 mm^2sr	2.74 mm^2sr	4,86 mm^2sr
LED collection angle	+/-65 deg	+/-65 deg	+/-65 deg	+/-65 deg
Optimum Chip size (emitting area)	1.10mm x 0.62mm	1.50mm x 0.84mm	1.37mm x 0.77mm	1.83mm x 1.03mm

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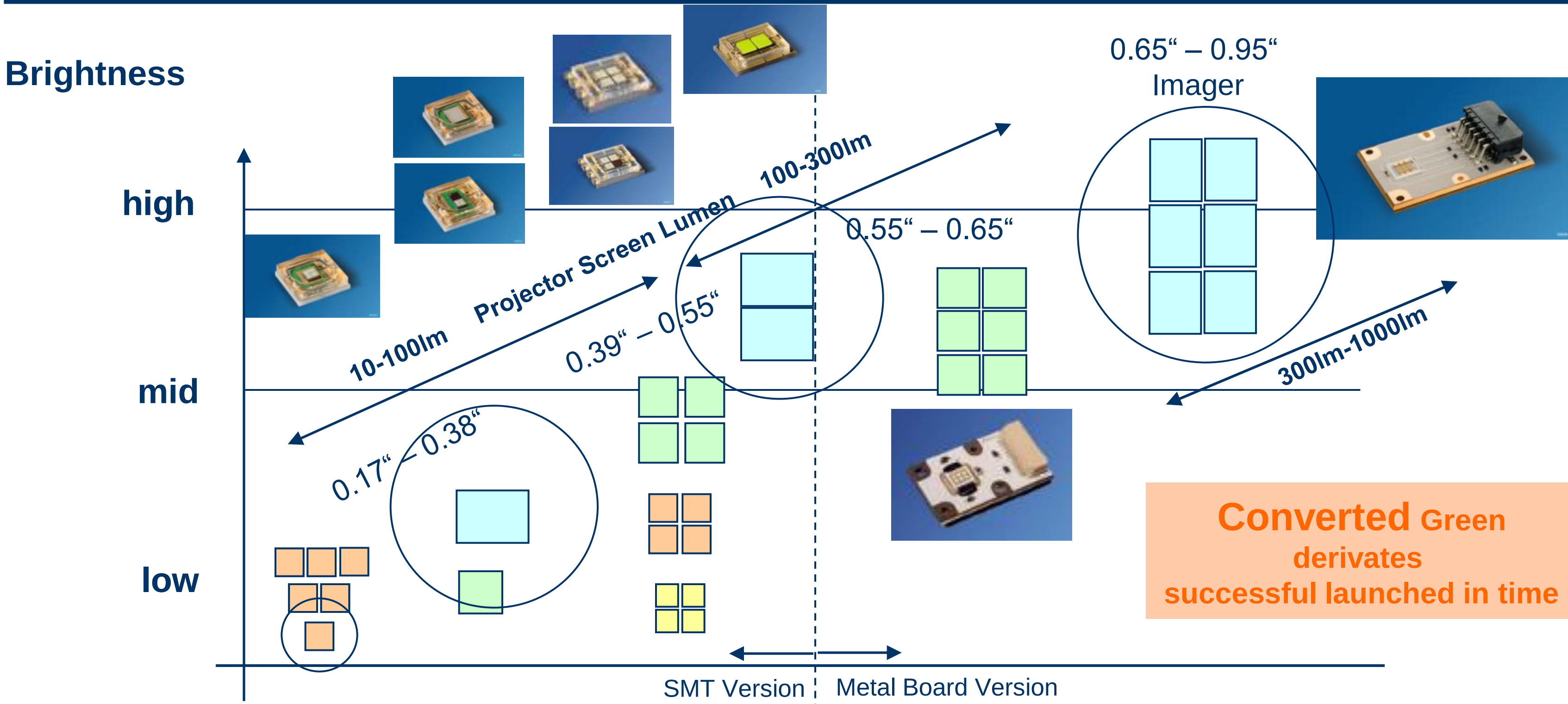
Product Portfolio for Projection



Converted Green
derivates
successful launched in time

OSTAR Compact		OSTAR SMT	OSTAR Projection	OSTAR Power Projection
3x 750um RGB 2x 750um RB, GB 1x 750um R,G,B CG	1x 2mm² R,G,B,UW 1x 1mm² R,G,B CG	4x 1mm² R,G,B,RGB,UW 4x 0.75mm RGB 4x 0.5mm RGB 2x 2mm² R,G,B + CG	6x 1mm² R,G,B,RB,RGB,UW	6x 2mm² R,G,B CG

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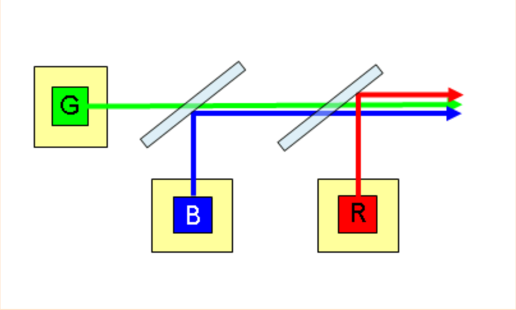
Optical Architecture: Overview

3-channel



3 discrete LED devices

Pros:

-Maximum etendue/lumens per color

-Good color uniformity

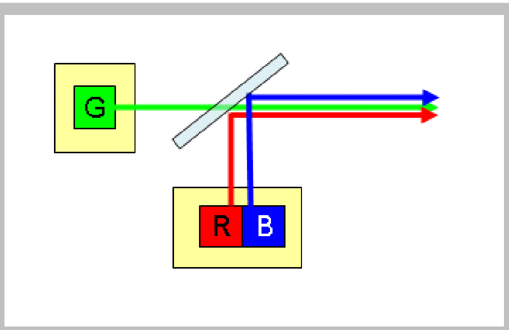
Cons:

-Large engine size

-High BOM

-Many components needed

2-channel



2 discrete LED devices

Pros:

-Reduced engine size

-Reduced BOM

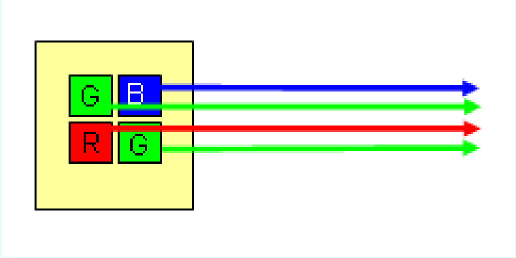
-Only 1 dichroic filter element needed

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

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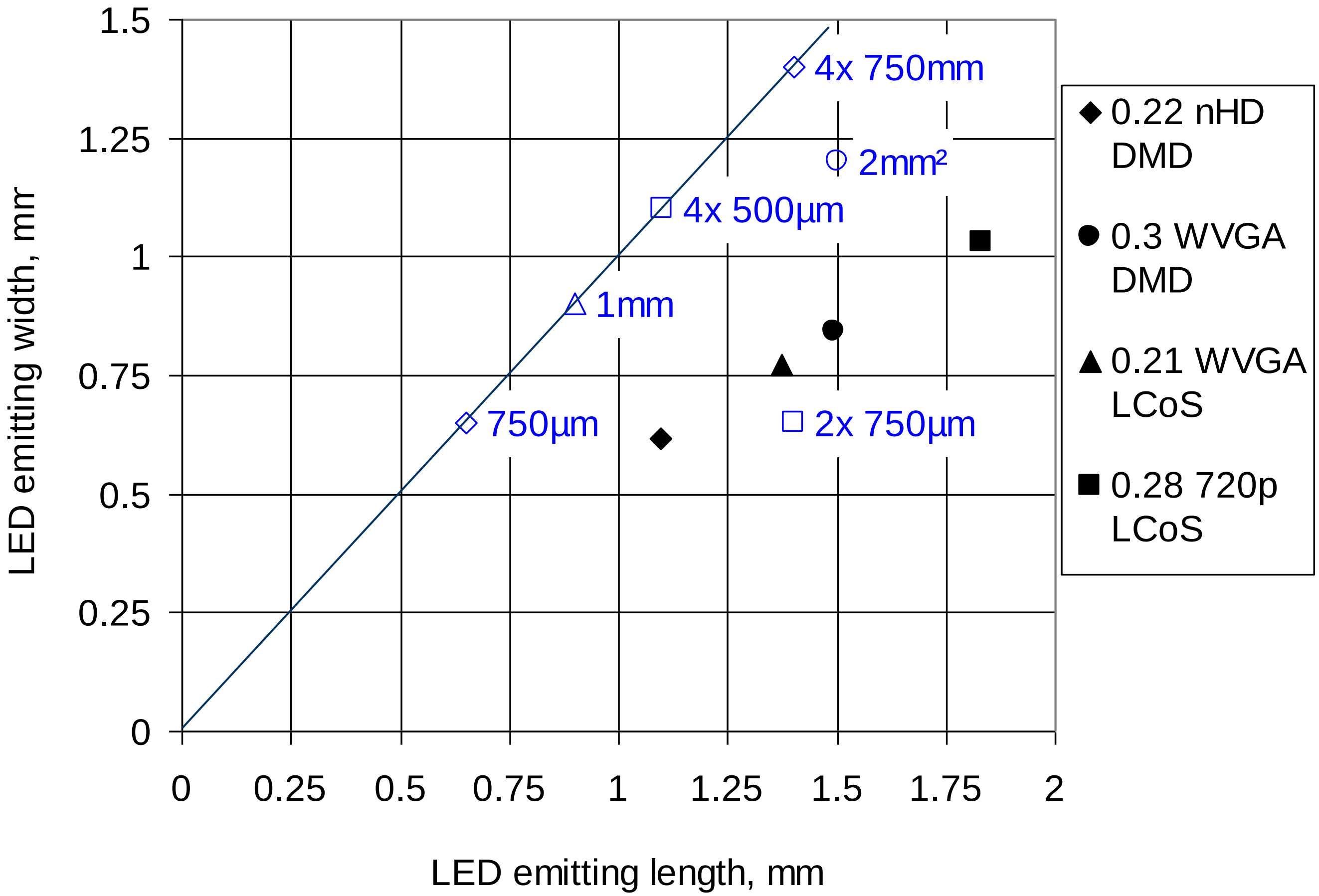
3-Channel Illumination

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

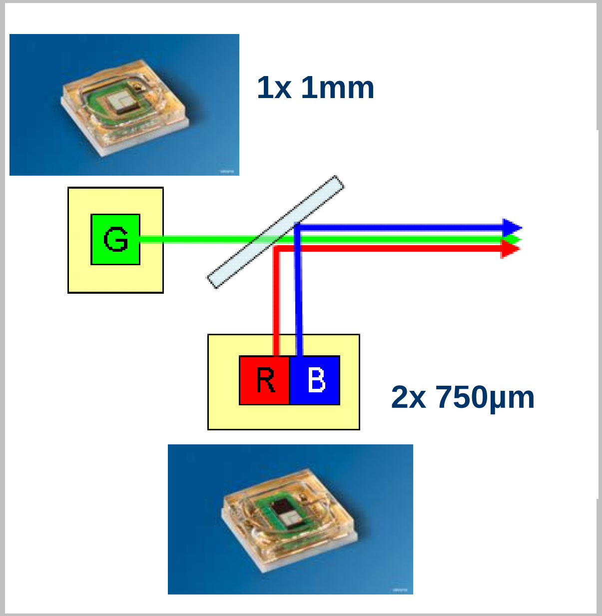


2-Channel Illumination with 0.30” WVGA DMD

System Settings

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

Schematic



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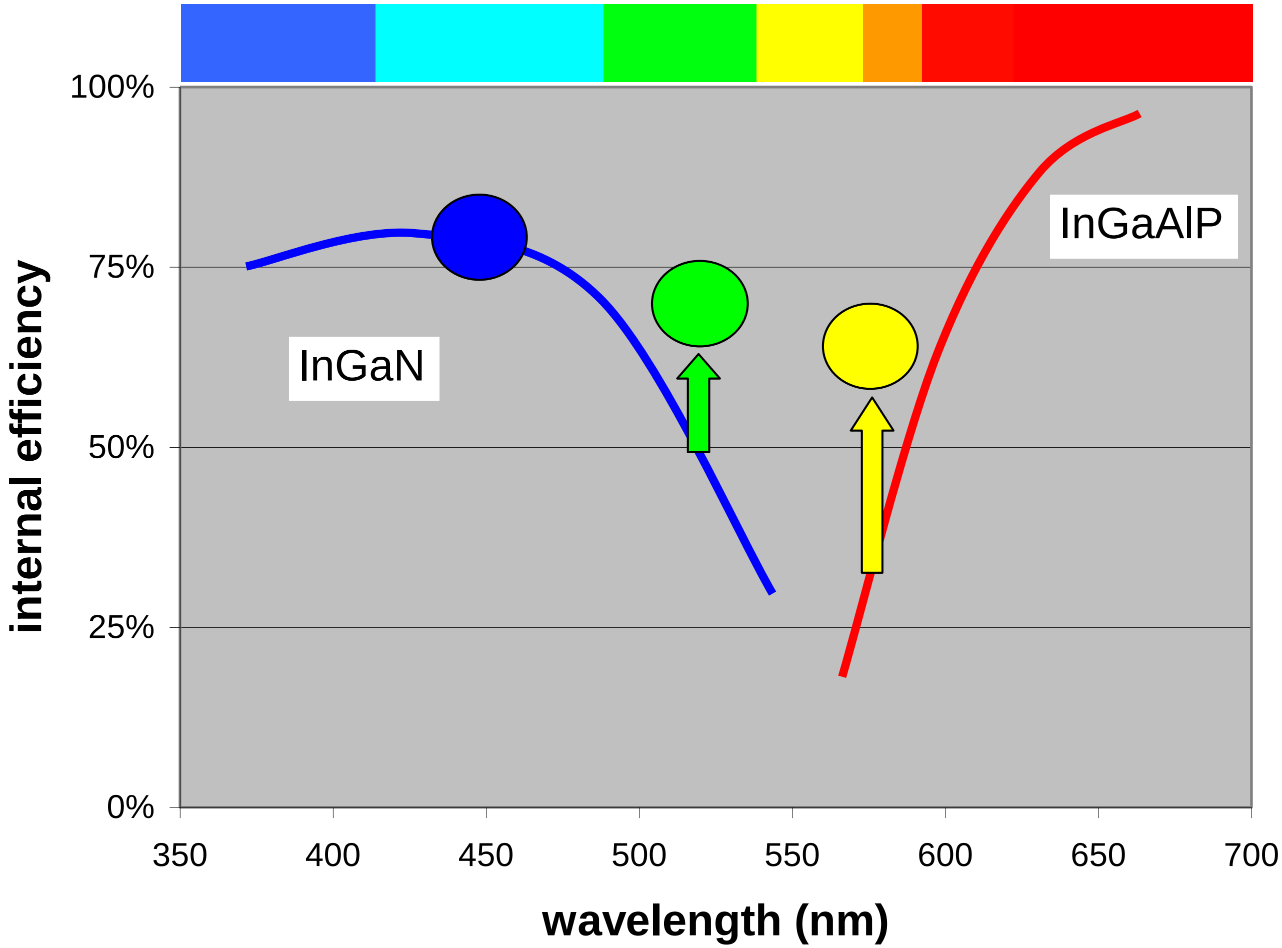
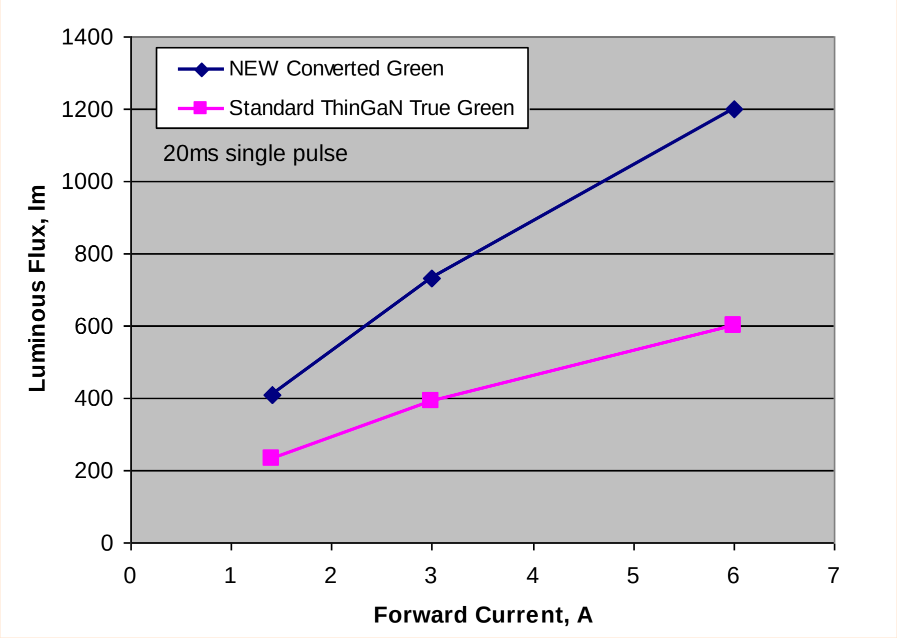
“Green Gap”


100%
75%
50%
25%
0%
internal efficiency
InGaN
InGaAlP
350
400
450
500
550
600
650
700
wavelength (nm)

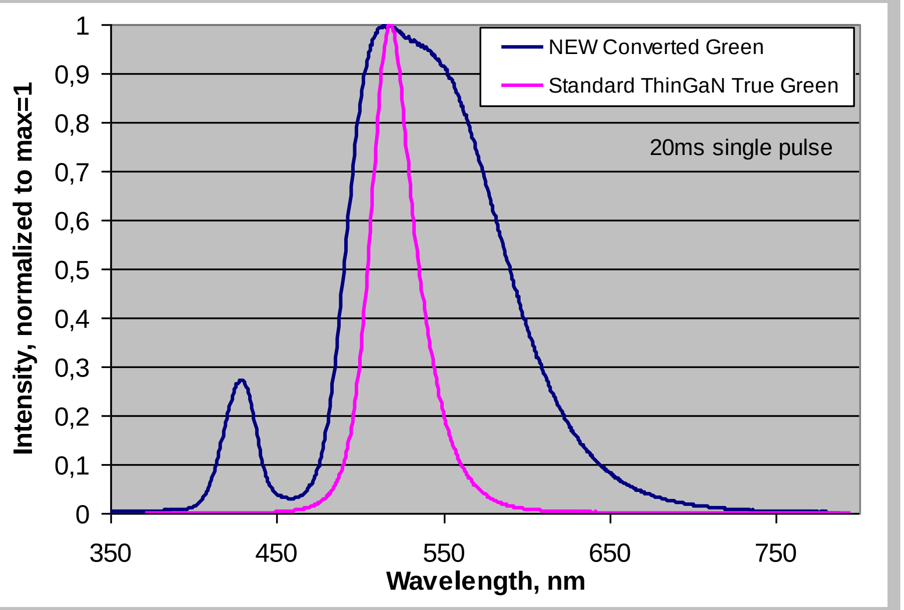
Green is generally Limiting Color in a Display. **

Ceramic Based Converted Green for Higher Lumens

Brightness (Luminous Flux)



Spectral Curve @ 1.4A



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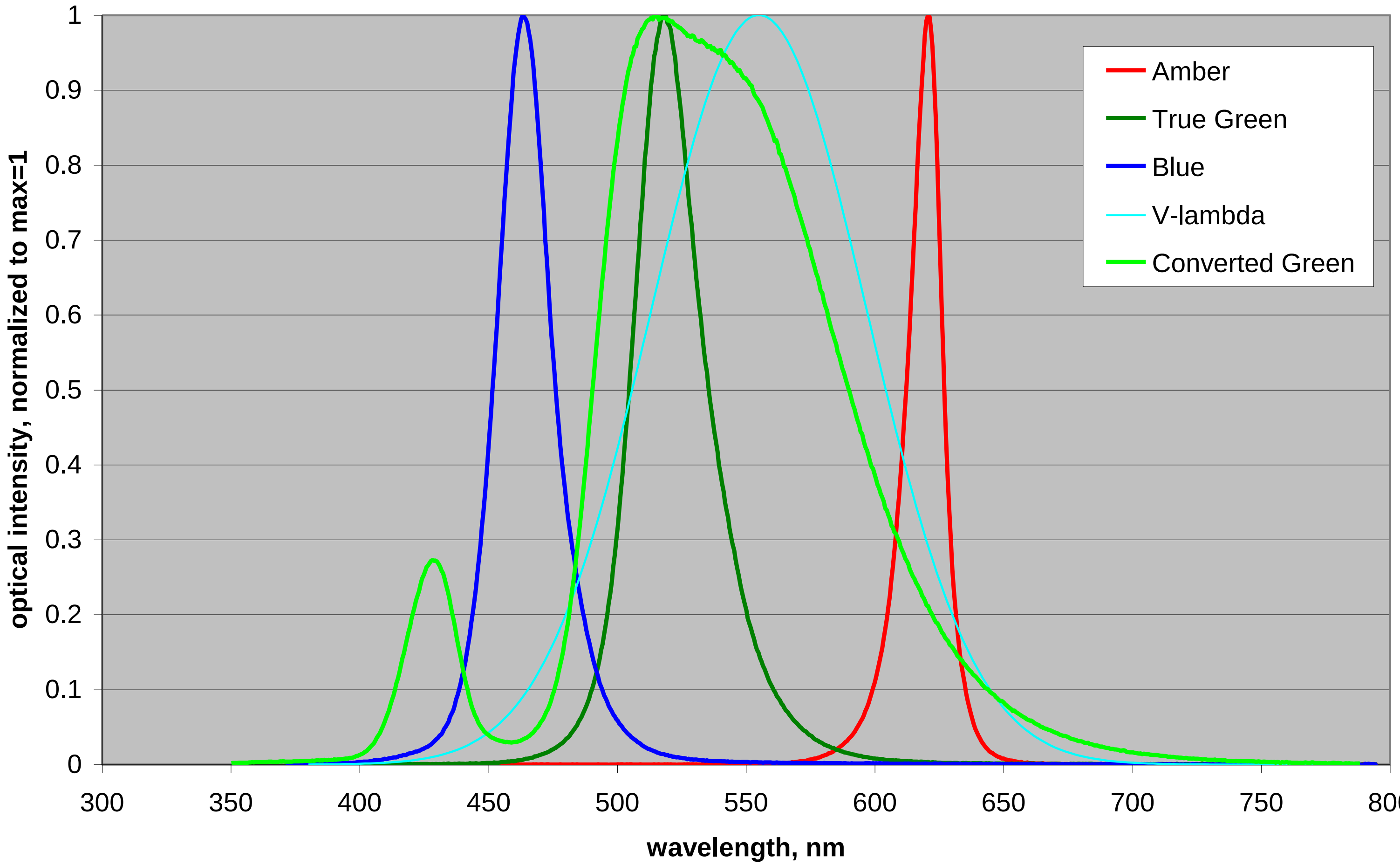
Spectral Curves – RGB vs Converted Green



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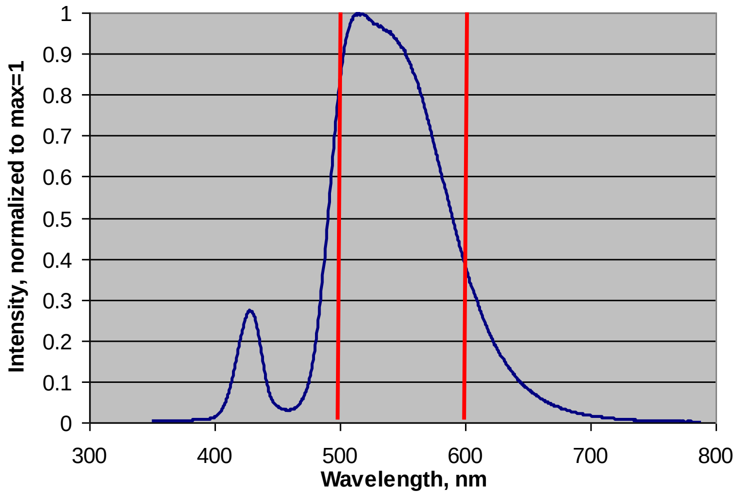
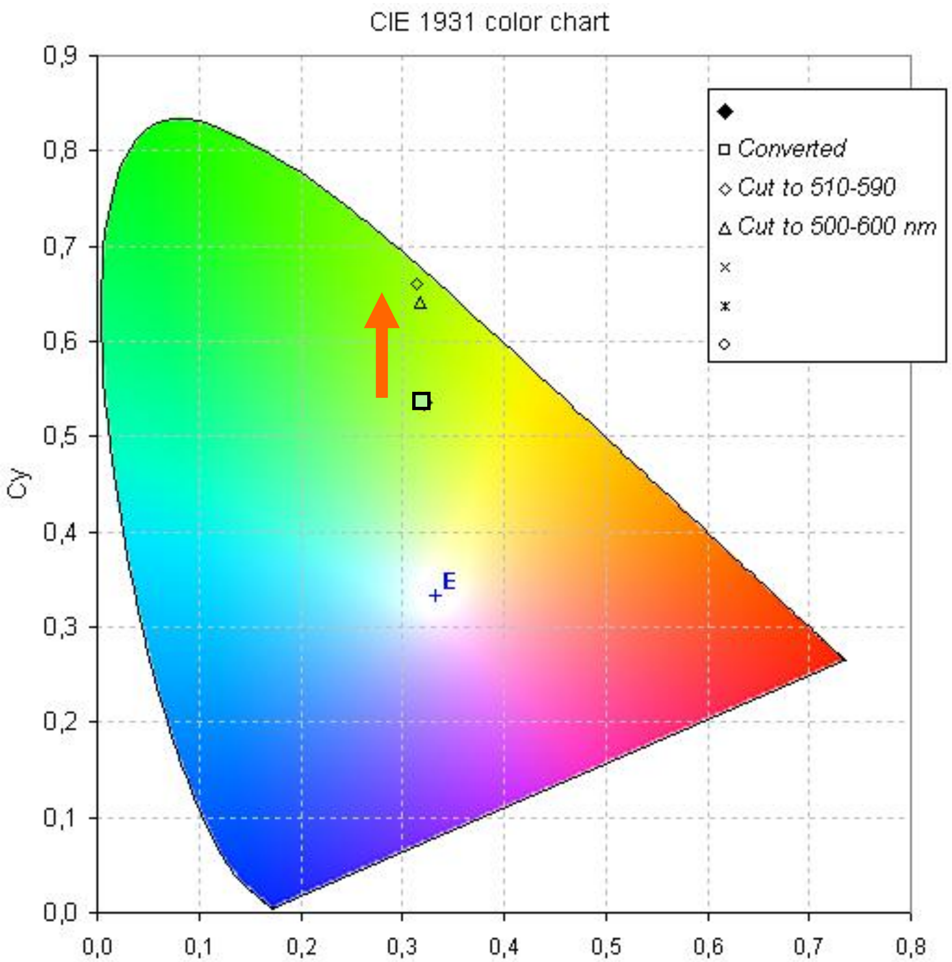
Usability of the Light by cutting Blue and Red **





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

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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.

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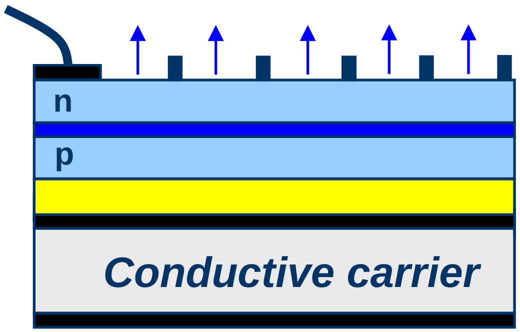
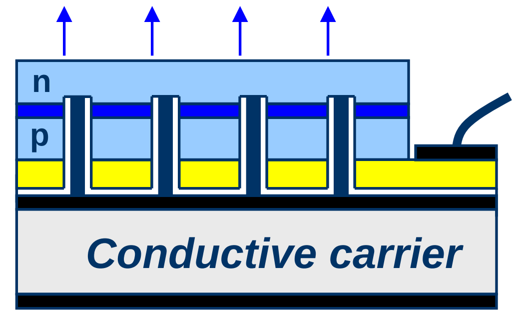
New Chip Architecture: UX3

**

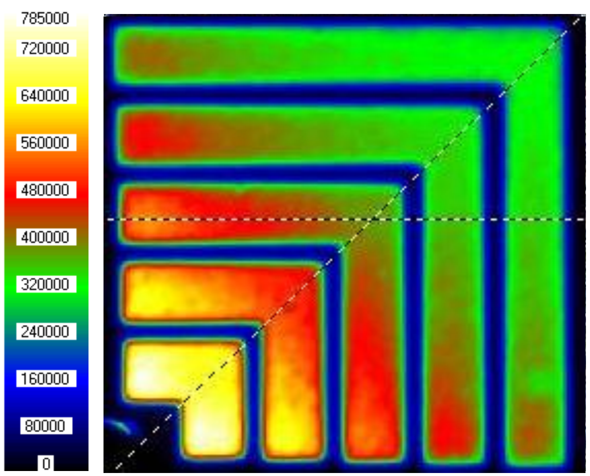


Cross sectional view

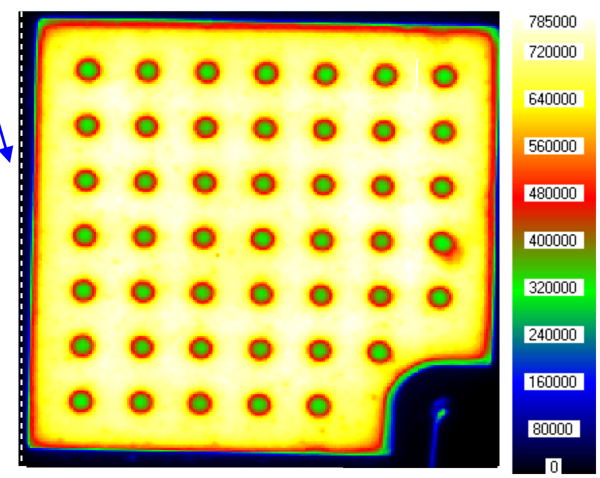
UX3 current spreading utilizes vias which don't reach top surface.



Cross sectional view



Luminance @ 1,4 A



Luminance @ 2,8 A

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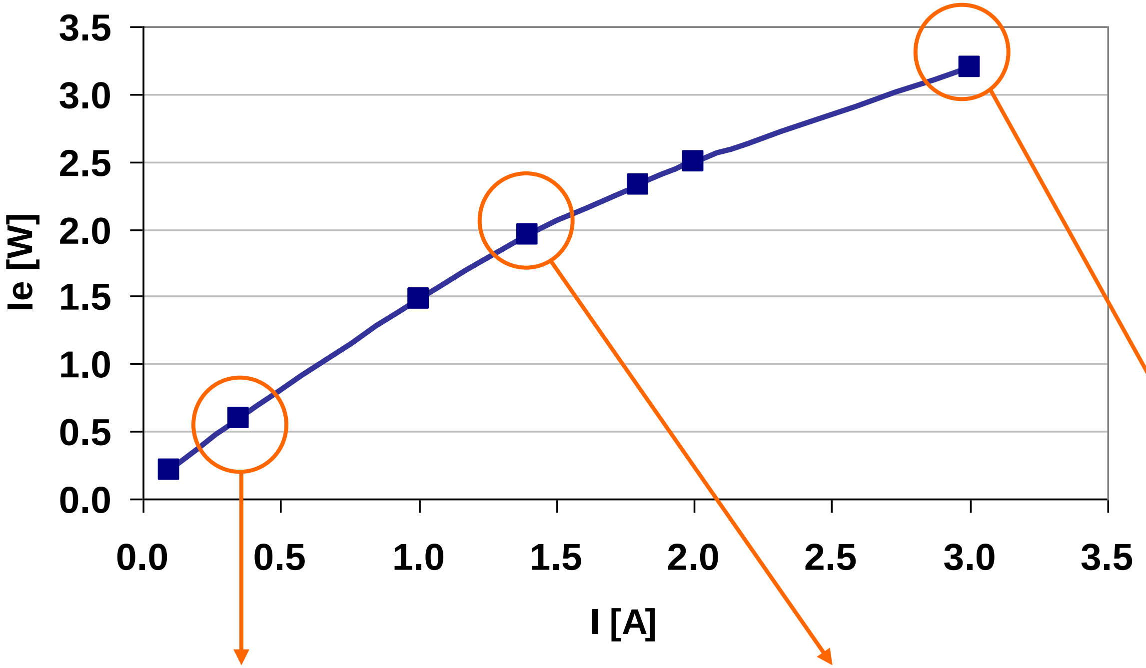
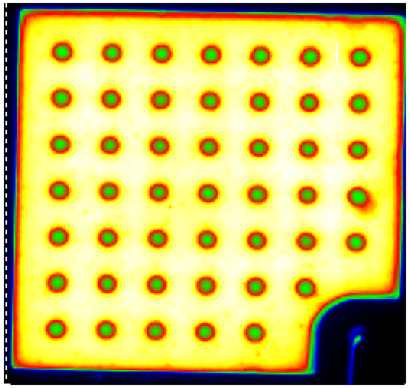
New Chip Architecture: Eliminating Droop

Performance of new high current chip design in Dragon +





601,4 mW @ 350 mA **1966 mW @ 1,4 A** **3199 mW @ 3 A**

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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

Presented by

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