Light source technology for optical control

DOE Lighting R&D Workshop

Dr. Oleg Shchekin, VP Technology R&D, LUMILEDS
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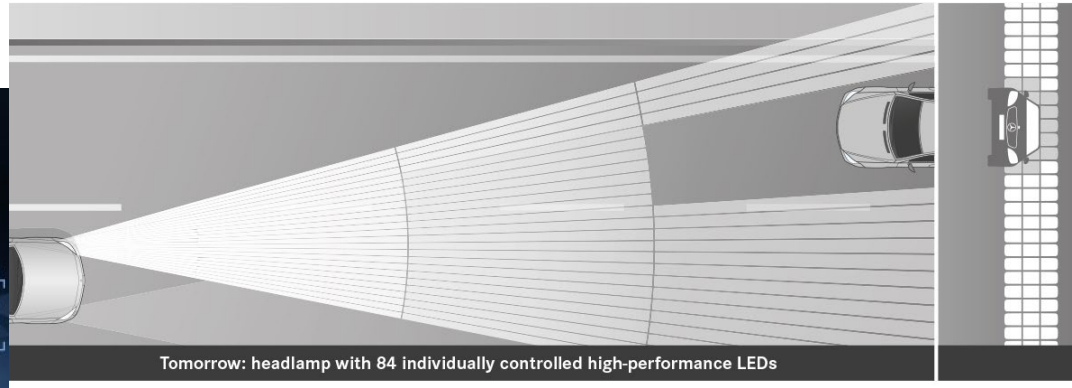
Contents

- Trends in automotive headlighting
  - Transition from low/high beam to digital headlighting and LED technology that enables it

- Functional integration in general illumination
  - Low glare
  - Light engines with dynamically controllable light distribution

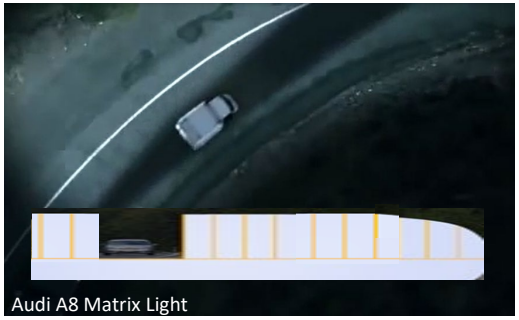
From Low/High Beam to Digital Headlighting



Tomorrow: headlamp with 84 individually controlled high-performance LEDs

Digital Headlighting Roadmap

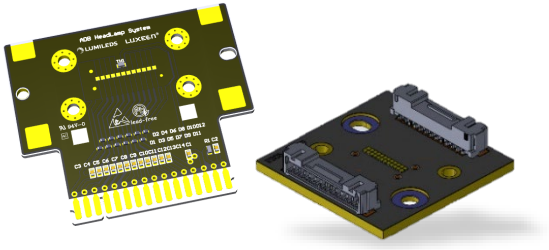
Basic ADB Matrix



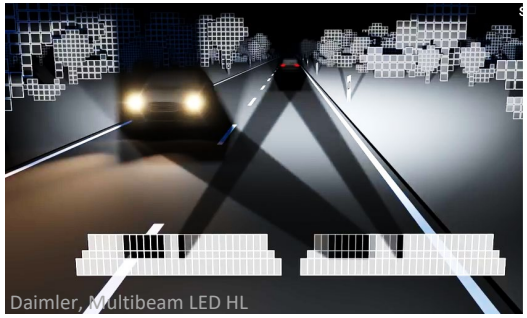
ADB Glare free high-beam

with horizontal beam segmentation

~10-25 LEDs



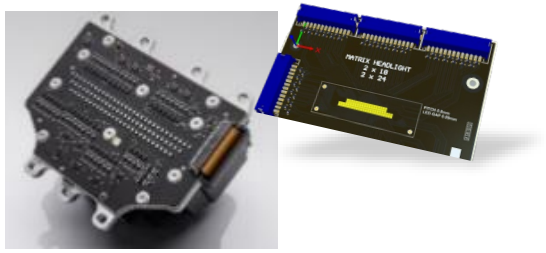
Advanced ADB Matrix



ADB LED Matrix

additional vertical segmentation

~100-200 LEDs



HD Digital Beam

DIGITAL HL

high resolution

~ 1K -1M pixels

Application Key Requirements

Resolution

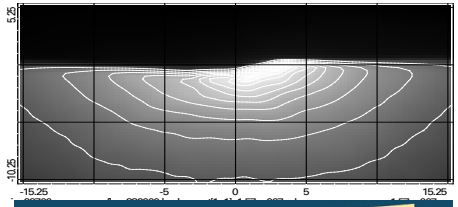
- **Glare free high beam**
  - Not glare others: 1 pixel on/off automatic high beam; 5-25 pixel : already very good
  - Not be glared by reflections and traffic signs , higher usage, smoother switching: horizontal and vertical segmentation 50-200 pixel in >= 3 rows
- **Lane marking:** ≤0.1°
- **Object highlighting:** ≤ 0.1°, ability to boost
- **Symbol projection**
  - Very simple >2000 pixel; Good > 10000 pixel; Very good > 20.000 pixel
- **Cut-off line shaping:** ≤ 0.25° (Very simple) : ≤ 0.1° (good)
- **Leveling:** ≤ 0.1°
- **Swiveling of hot spot**
  - wide angular range covered by matrix, resolution does not need to be high

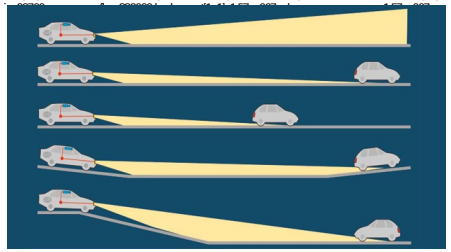
Luminance

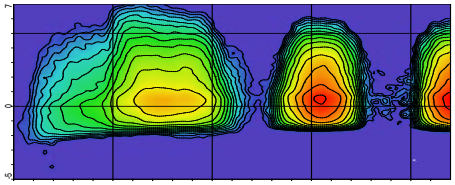
- ~80MNIT for lens sizes 45mm diameter and/or better beam performance
- >110MNIT for lens sizes 40mm and/or better beam performance

Contrast/Crosstalk

- Intensity less than 625cd in the gap (legal limit) want less than 400cd

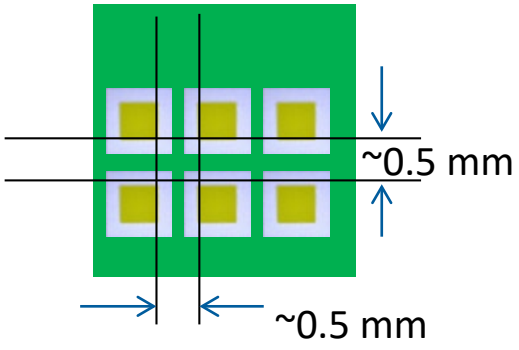


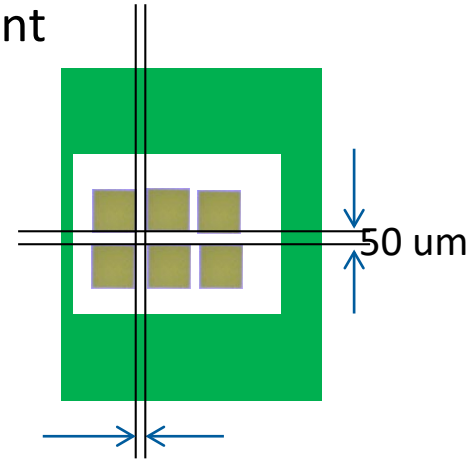




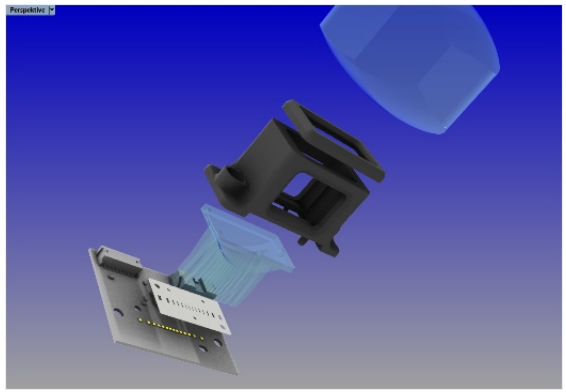
Reducing Optical System Size and Complexity

close die placement

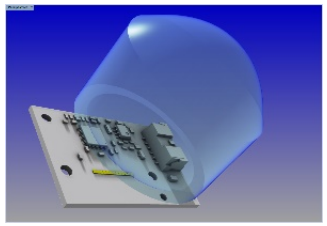




Optical system



Requires pre-collimation



the LED array is directly imaged

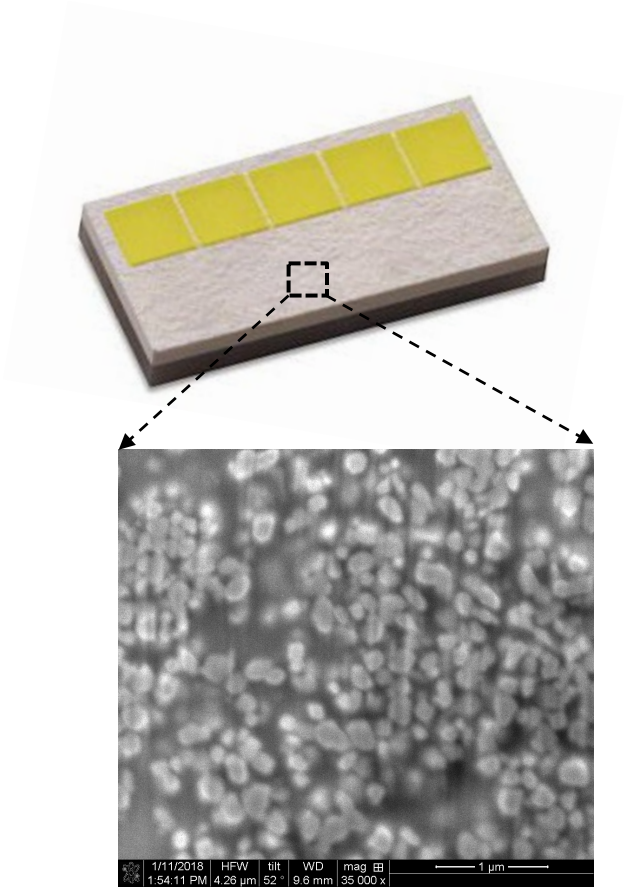
Application Benefits of closely spaced arrays

- Direct imaging
- Eliminate 1º optic
- Color adjustment
- Beam shaping
- Enhanced Resolution
  - > 100 sources

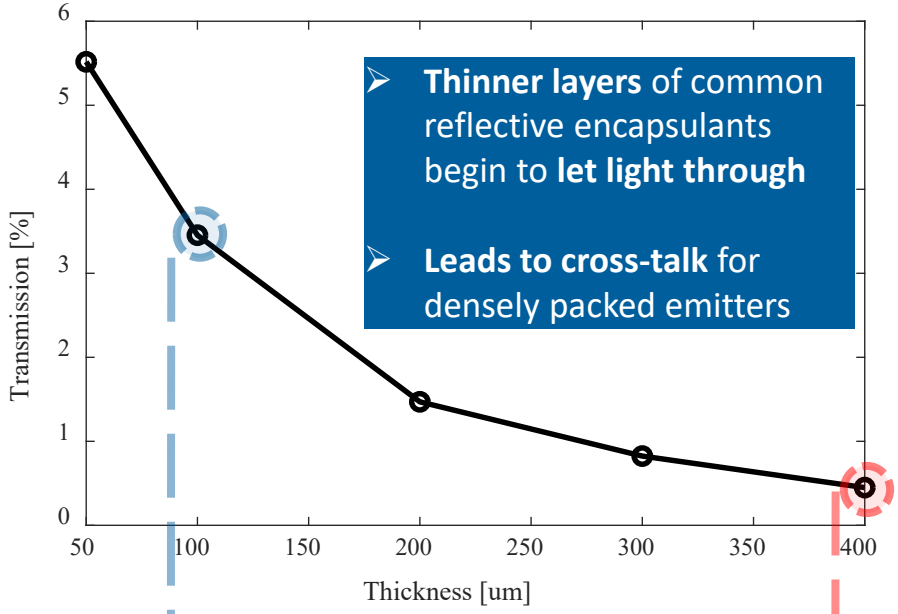
Challenges

- Array customization
- Known good emitters
- Cross-talk
- Heat dissipation

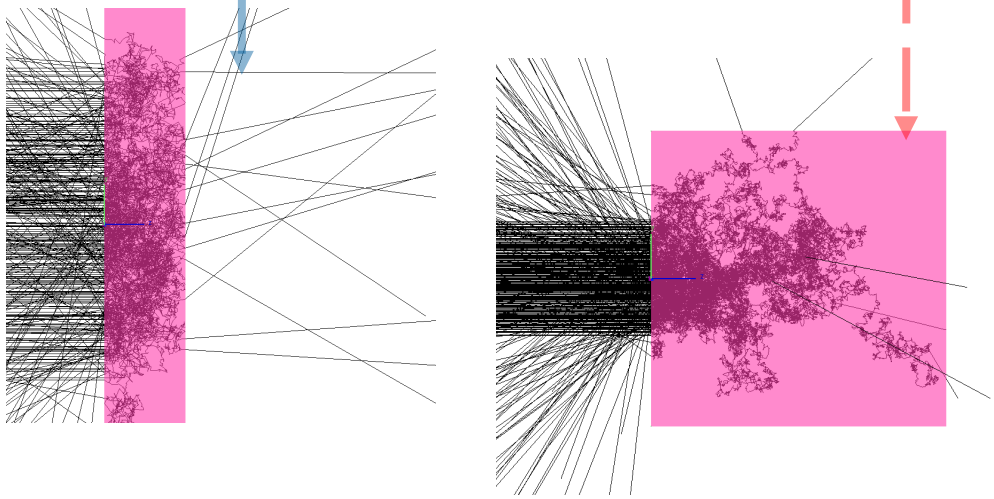
Traditional White Encapsulant Material



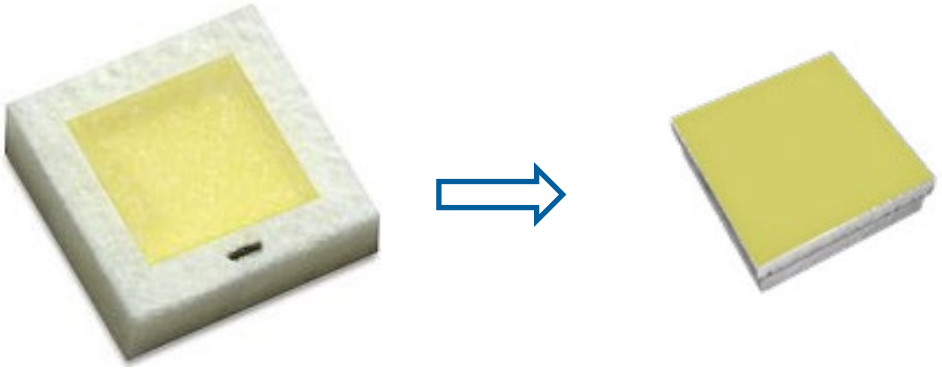
White Encapsulant material composed of scattering nano-particles embedded in organic matrix



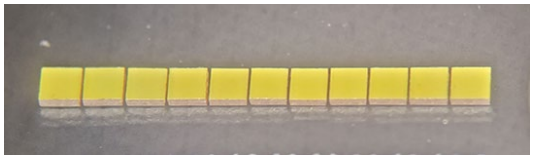
- **Thinner layers** of common reflective encapsulants begin to **let light through**
- **Leads to cross-talk** for densely packed emitters

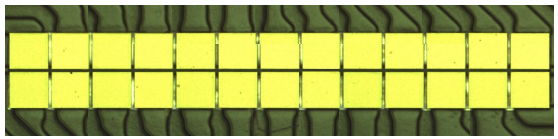


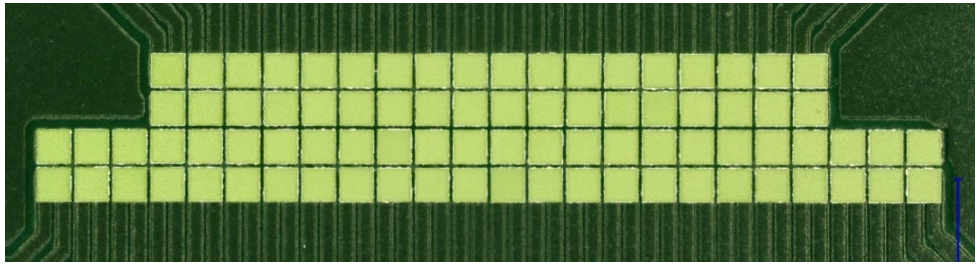
New Packaging Technology based on Thin Film Side Coat



Examples of different array configurations







New packaging technology based on Thin-Film-Side-Coat (TFSC)

- Smallest Package: Light emitting area and package same as chip size
- Improved contrast and crosstalk in arrays
- Known good die for array assembly
- Ease of array layout customization
- ….

Comparison of Optical Cross Talk in Linear Arrays

- TFSC technology enables >5x lower optical cross talk at small die spacing compared to conventional optical side-coat (OSC) technology

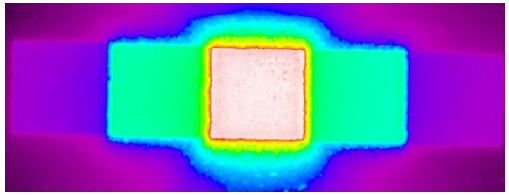
Linear arrays with 0.5mm^2 emitters and 50μm spacing

$$Crosstalk = \frac{L_{80\%\ ON}}{L_{80\%\ OFF}}$$

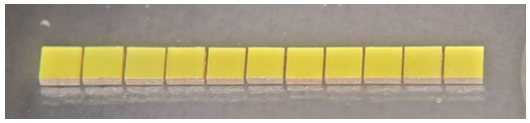
L_v is average luminance over center area of a die with 80% of nominal lateral die dimensions

Conventional side-coat

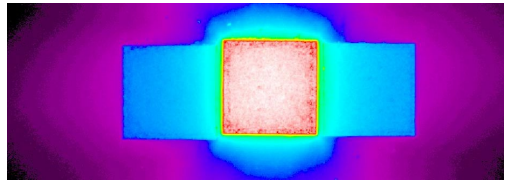
Crosstalk ~40



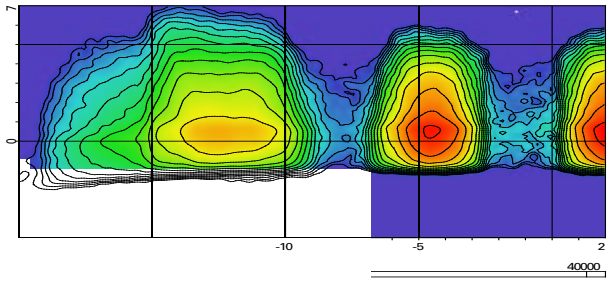
TFSC

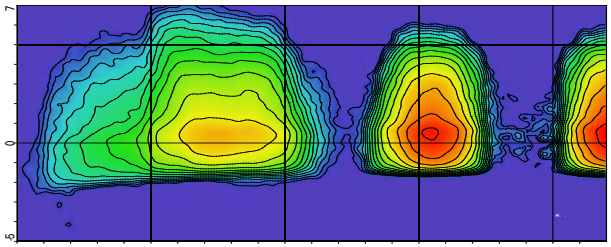


Crosstalk ~200



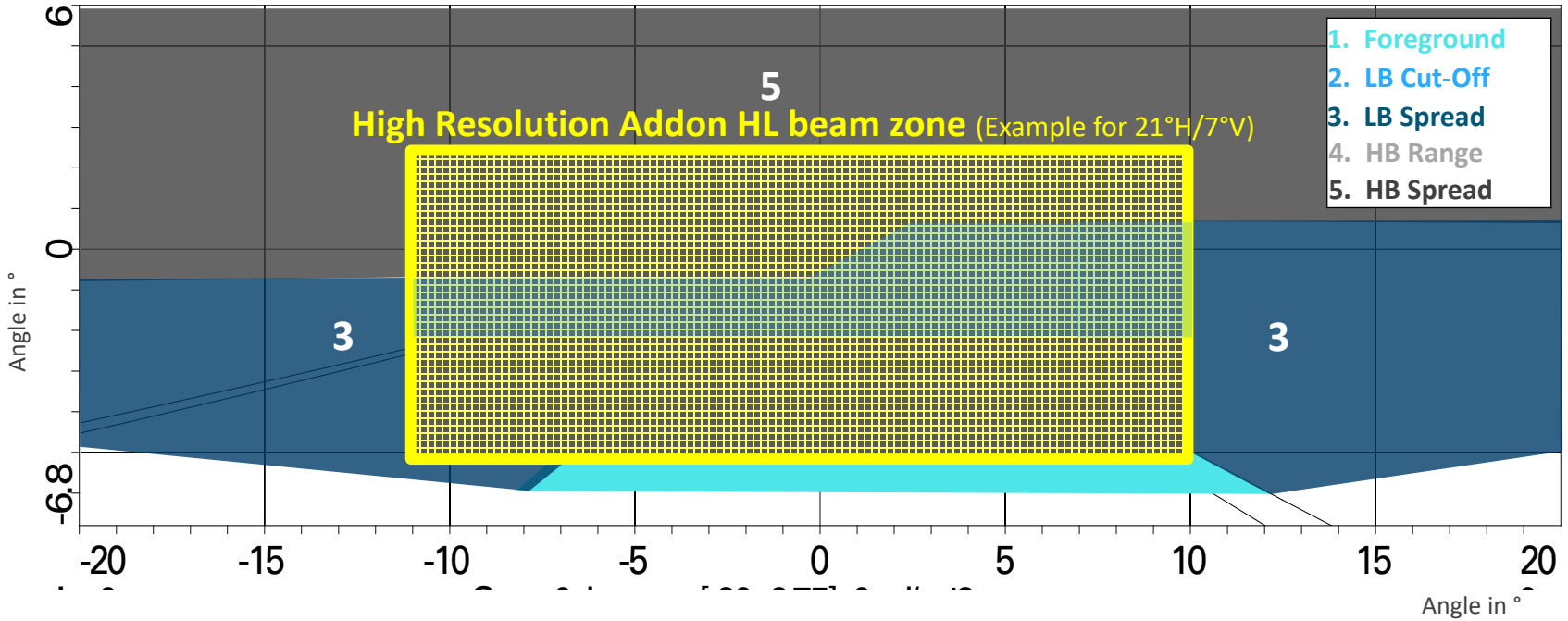
- TFSC solution demonstrates superior contrast in 1D ADB system:
  - TFSC System: Intensity < 250cd everywhere in the “off” pixel
  - OSC “Fill” System : Intensity > 400cd in some spots within the gap





High Resolution beam requirement for Digital Headlighting

Headlighting beam zones



Key specification requirements

- Total Flux
- Maximum Intensity
- Contrast
- Resolution

Specification to Address High Resolution Digital Beam

Source: Driving Vision News

ADB:

- Imax >70000 cd

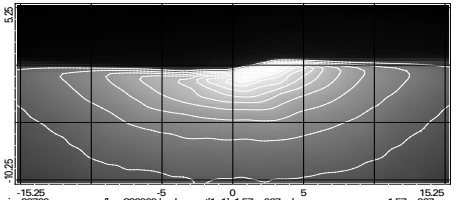
Field of View:

- H:>+/-10.5°
- V:+3°/-4°

Source: Gommelblog.it

Lane marking resolution:

- <7.5 cm in 50 m => 0.085°

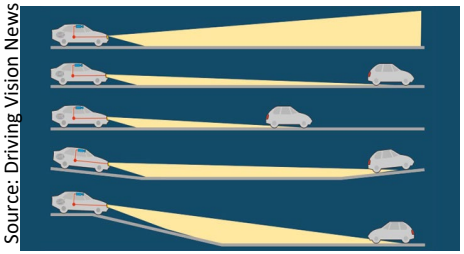


Contrast LB:

- 1:250 within 0.5°

Contrast ADB:

- 1:200 within 0.2°



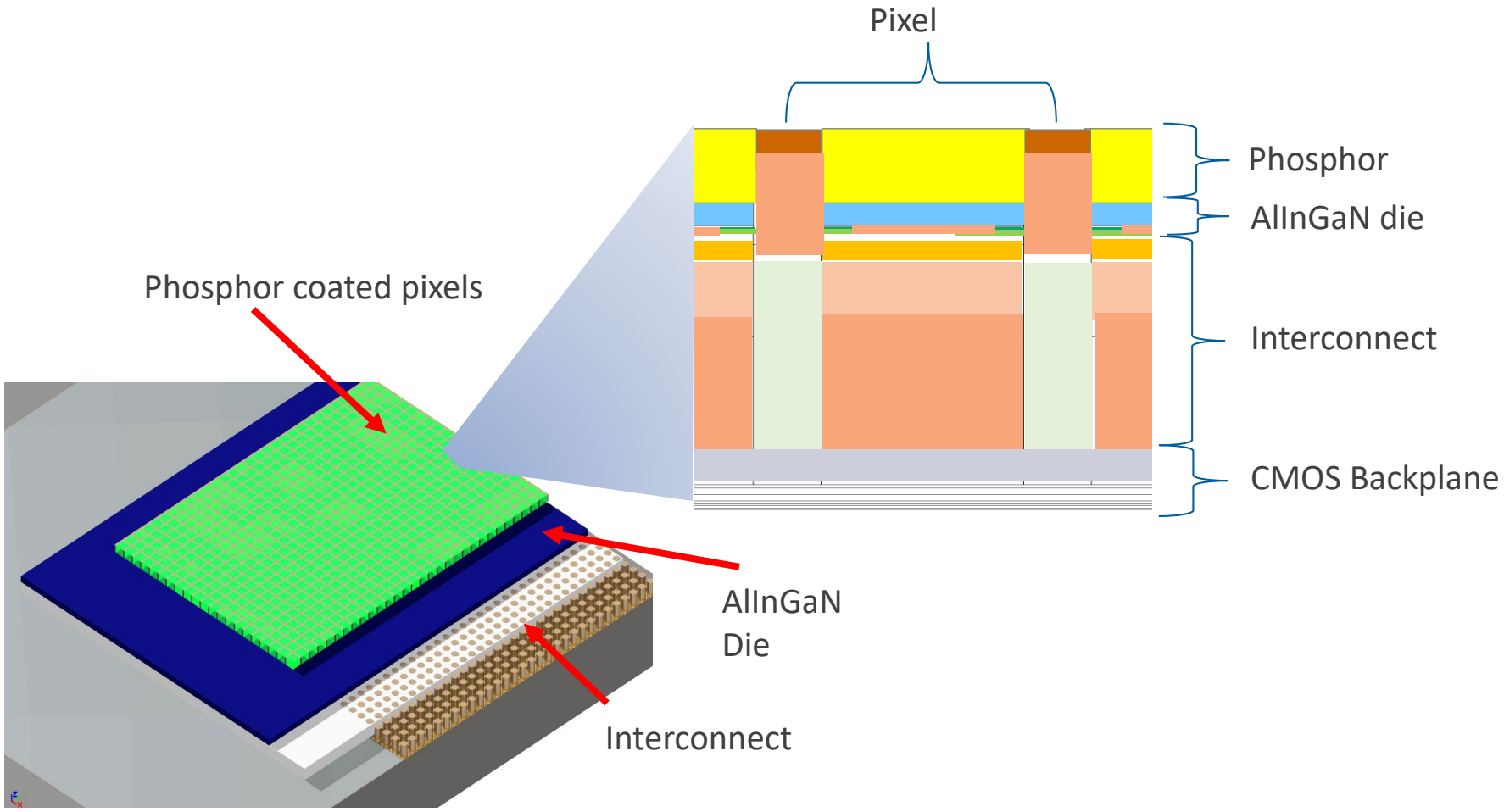
Source: Driving Vision News

Leveling resolution:

- <12 m in 75 m => 0.085°

Specification	Configuration 1	Configuration 2
Full Beam Width [°]	21	21
Full Beam Heigth [°]	7	7
Solid andle [sr]	0.045	0.045
I_{max} [cd]	70000	70000
Installed Flux w/o losses [lm]	3115	3115
Installed Flux inc. Opt. Losses [lm]	9440	9440
Angular resolution	0.085	0.1
Number of Pixel	20346	14700
Flux / Pixel	0.46	0.64
Luminance of source [MNit]	93	65
Pixel Size [mm]	0.040	0.056
Totel Chip Size [mm²]	32	46
Minimal Lens Diameter [mm]	38	46

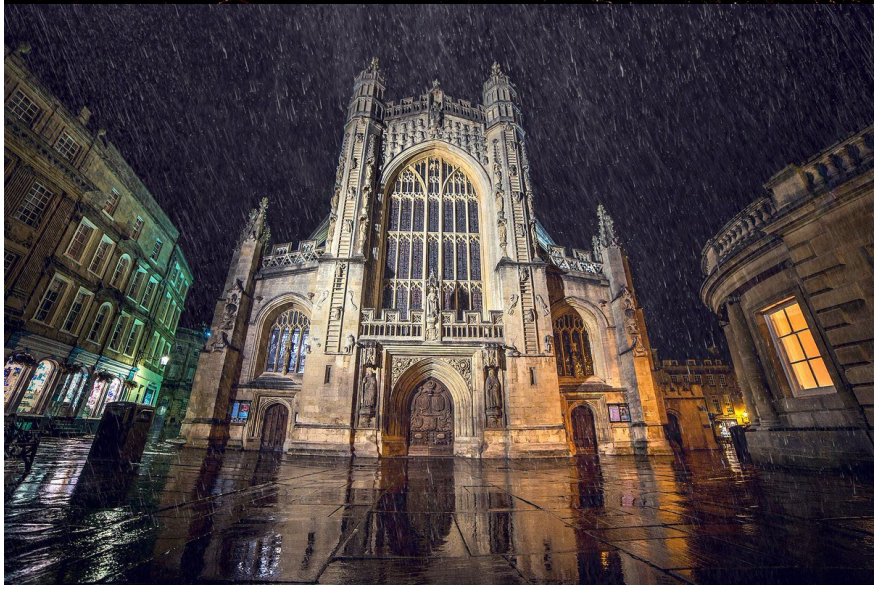
Automotive μLED Array Architecture



Challenges for Automotive uLED Array Development

- Design compromise between
  - Pixel size vs light output/efficiency
  - Optical contrast vs light output/efficiency
  - Pixel count and resolution vs chip size and pixel size
- Addressing multiple aspect ratio 1:3 and 1:4
- Thermal management (High Beam mode would require 50W – 60W out of a 30 -40 mm^2 light emitting area)
- Extremely high yield (5N = 99.999%).
- Defect reduction efforts to support large die (~50 mm^2).
- Defect control must take place to avoid dead pixels, affecting cleanroom and contamination control strategies throughout manufacturing operations.

Functional Light in General Illumination



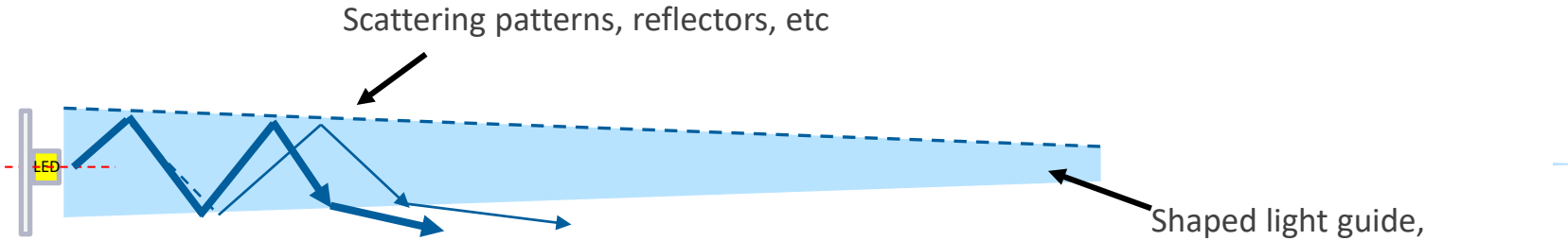
- Nice aesthetics

But…..

- How functional is the light?
- And what about the glare?

……much better!

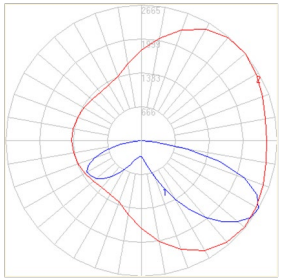
Light Guide Plate Technology



- Emitted light is distributed across a large area
- Light distribution is controlled

Reduced Glare

Custom designed light distribution



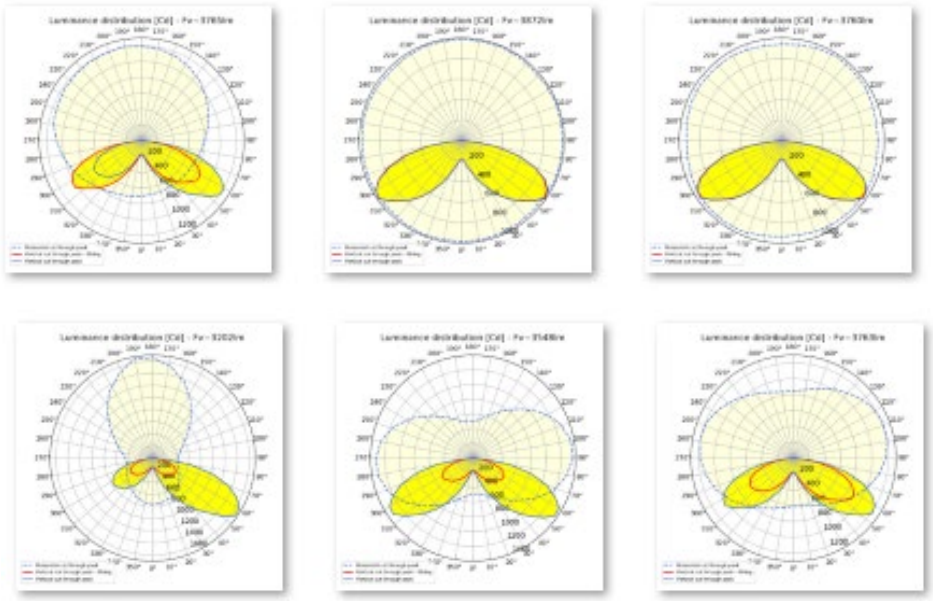
Measured

A Variety of Light Distributions Possible

Dynamically Controlled Light Distribution

- Light engine can be divided into zones
- Each zone having optical elements to radiate light in certain direction and across lightguide surface

- Static or dynamic, low glare controllable radiation patterns can be produced



Summary

- Lighting is moving to higher levels of functionality and technology integration
- In automotive forward lighting, new technologies advance miniaturization and greater functionality of compact ADB sources.
- In general lighting, light-source technology can be further paired with electronic and optical systems to extend the dynamic capability of the source.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