Design Considerations with LED Package Primary Optics

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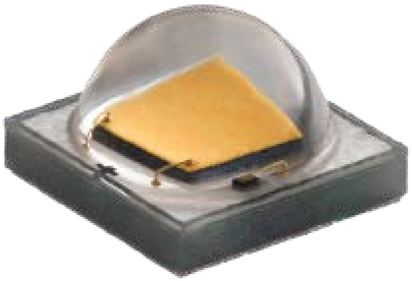
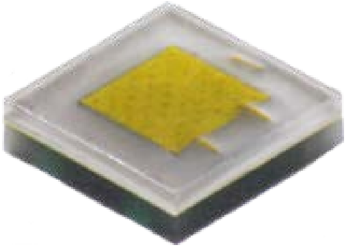
2017 DOE SSL R&D Workshop
2 February 2017

OUTLINE:

1. LED package design concepts – optimizing light extraction from LEDs.
2. Primary Optics: benefits of a “Flat Lens” vs “Spherical Lens”
3. Applications of “Flat Lens” LEDs in designs.

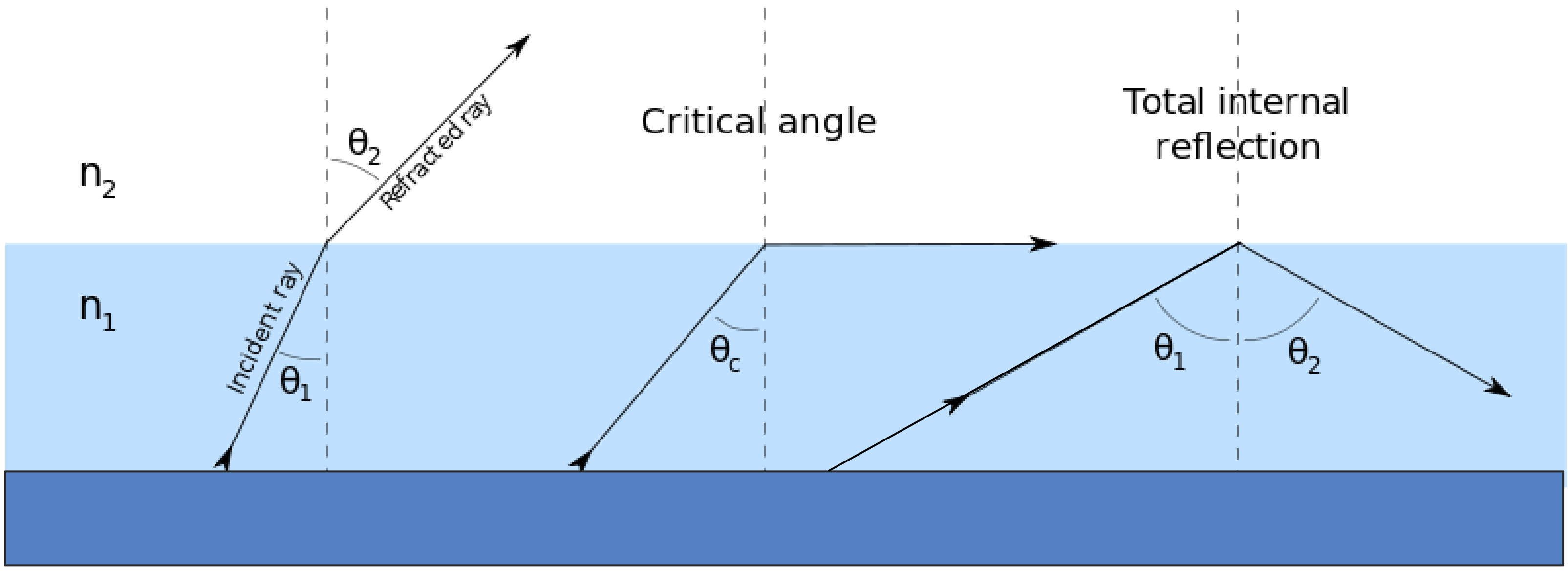




Light extraction of LEDs is governed by Snell's Law.

Snell's Law:

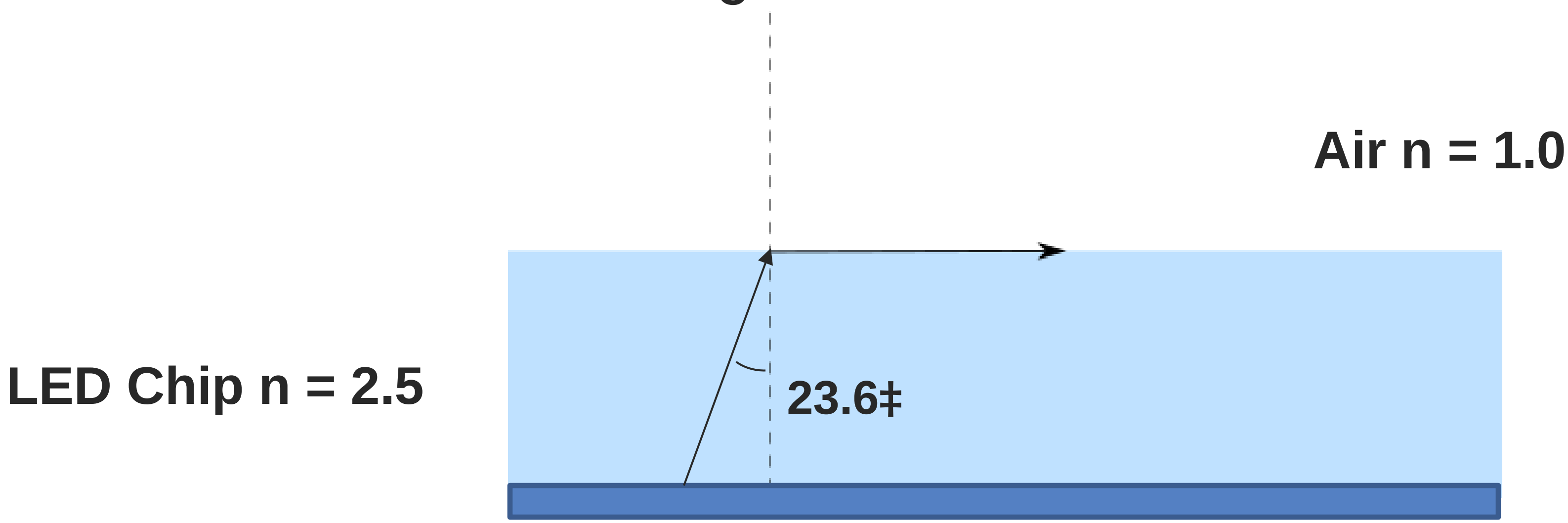
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



Where n = refractive index of material

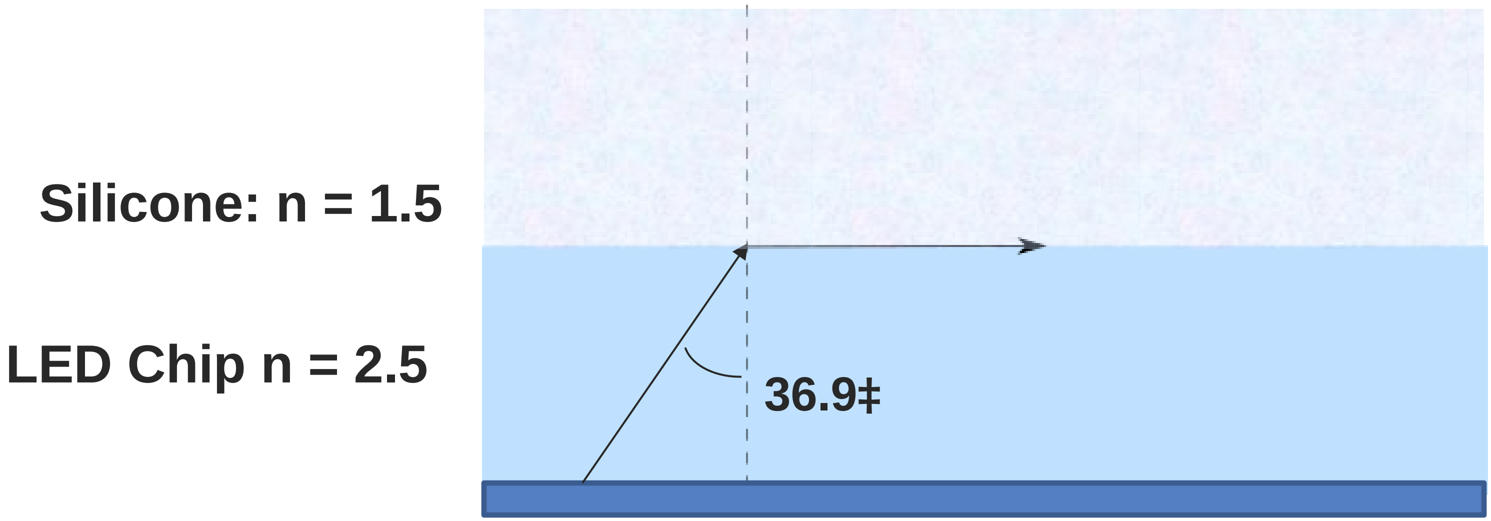
Light Emission into air for InGan LED chips

$$2.5 \sin \Theta_c = 1.0 \sin 90$$
$$\Theta_c = .4$$
$$\Theta_c = 23.6‡$$



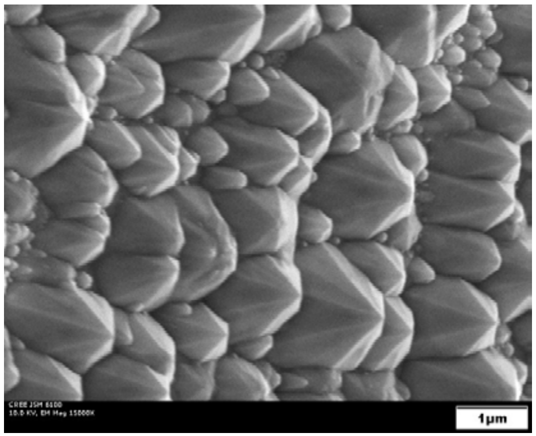
Silicone Encapsulants (n = 1.4 to >1.5) are used as an index matching medium.

$$2.5 \sin \Theta_c = 1.5 \sin 90$$
$$\Theta_c = .6$$
$$\Theta_c = 36.9‡$$

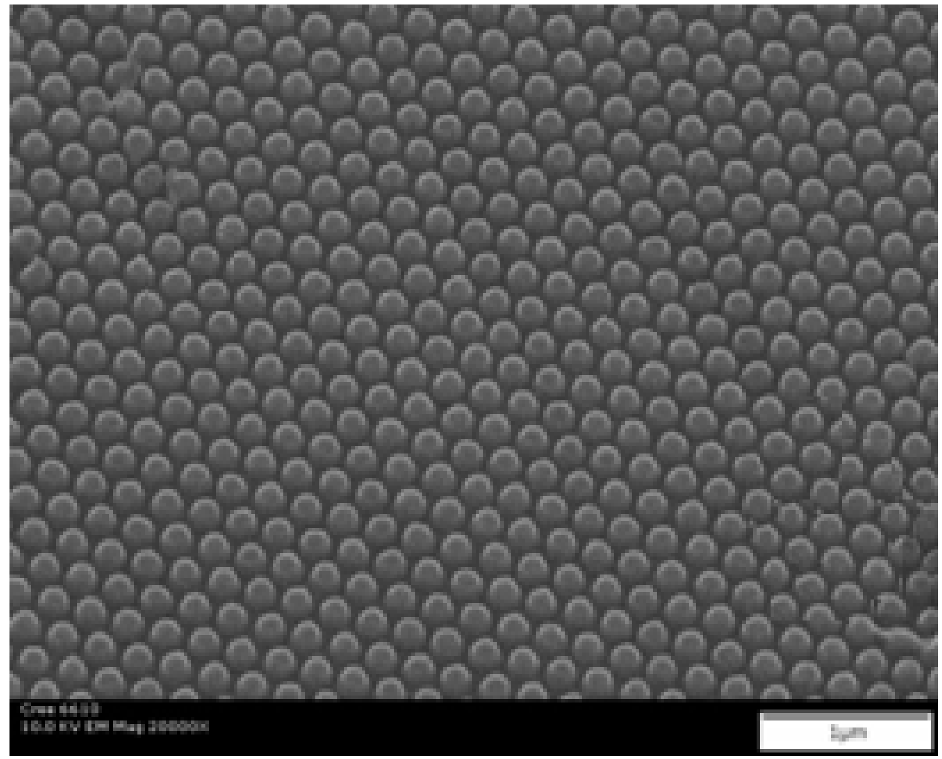


LED Chips are processed to maximize light extraction.

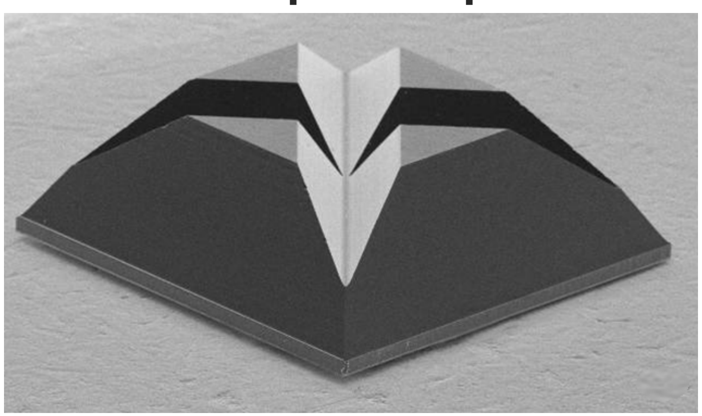
Roughened Surface



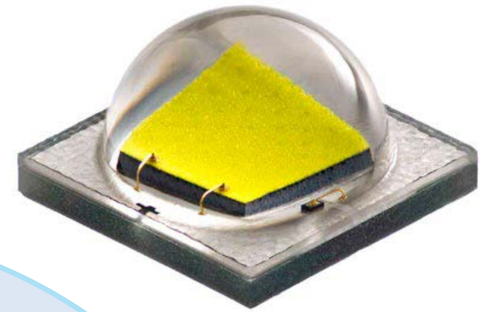
Micro Lens Patterning



Shaped Chip



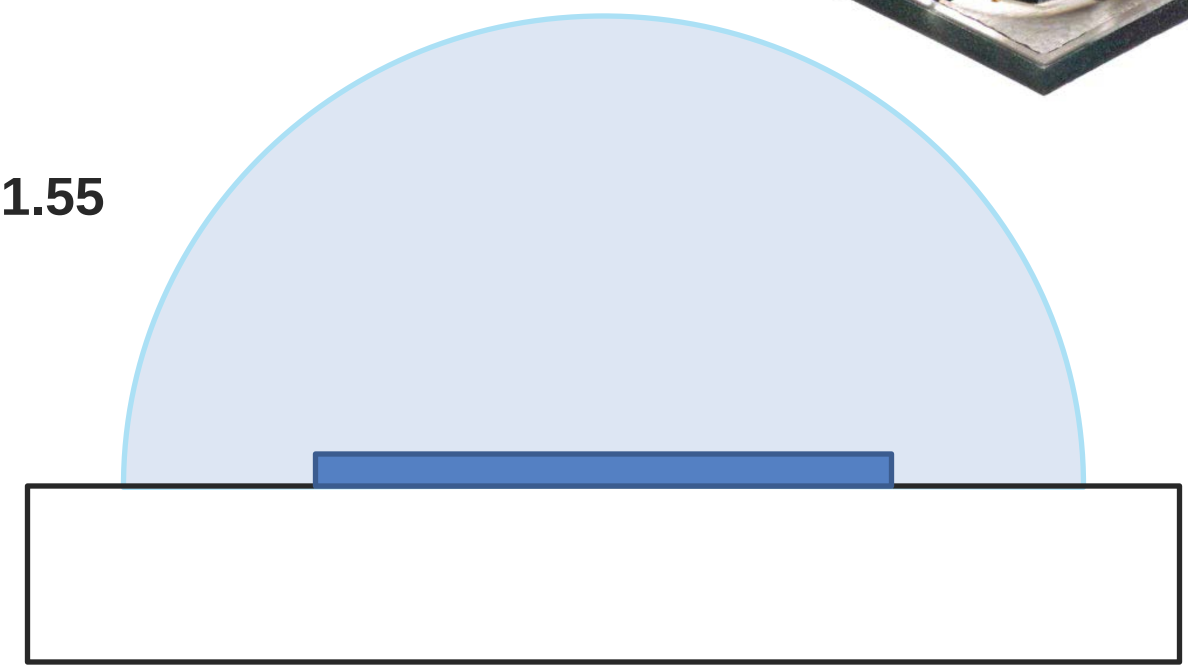
Silicone is molded in a spherical dome above LED chip. (Increases light output by ≥10%)



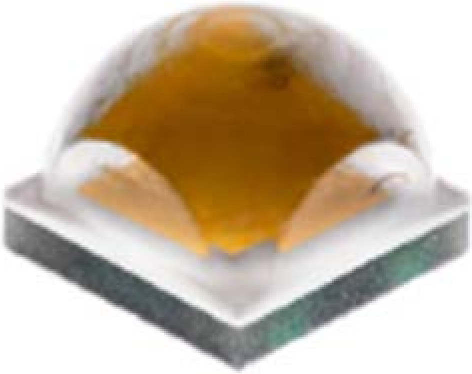
Air n = 1.0

Silicone: n = 1.4 to 1.55

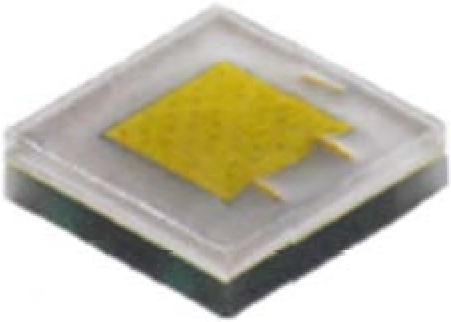
LED Chip n = 2.5



Spherical Lens vs Flat Lens Packages

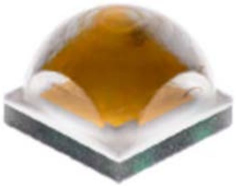


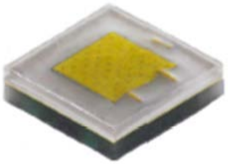
XP-L "High Density" LED



XP-L "High Intensity" LED

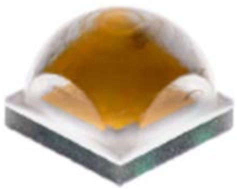
LED Package Comparison



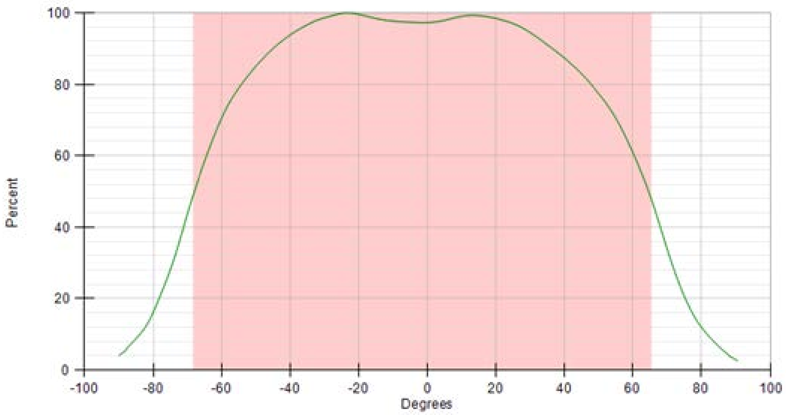


	High Density (Domed)	High Intensity (Flat)
Footprint	3.5mm X 3.5mm	3.5mm X 3.5mm
Package Height	2.7mm	1.0mm
Max Current	3A	3A
LF @ 1A	450 lumens	405 lumens
Efficacy @ 500lm	145 lpw	132 lpw
Intensity: Cd @ 1A	100%	188%

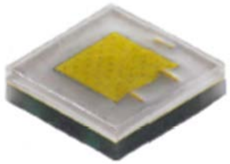
Far Field Patterns



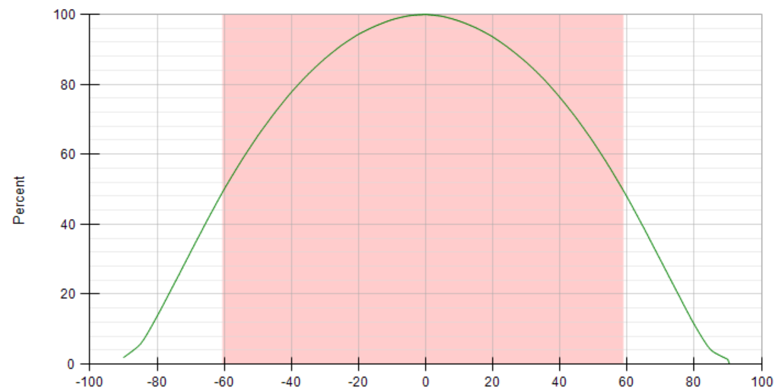
High Density (Domed)



Beam Angle 135˚

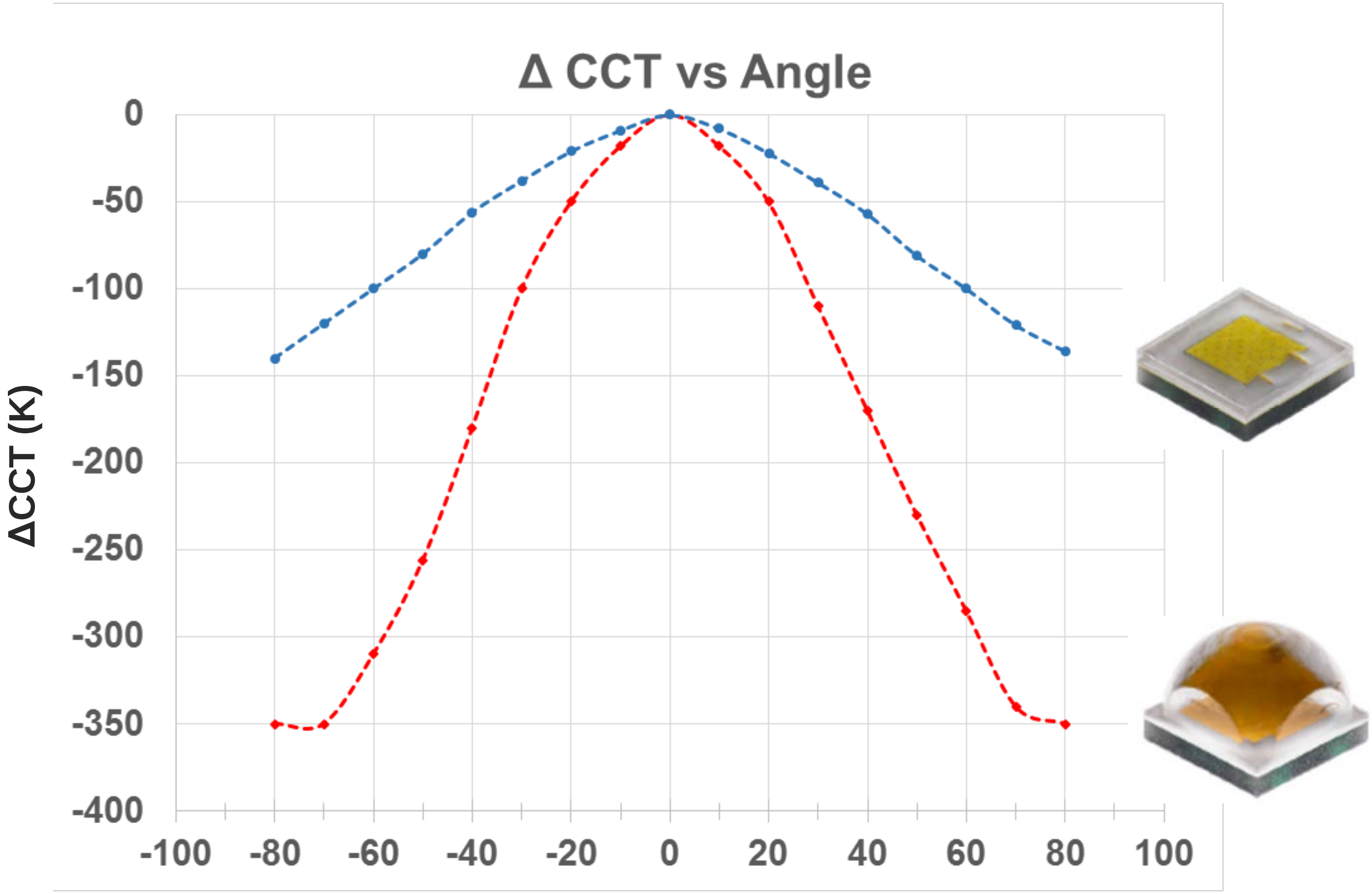


High Intensity (Flat)

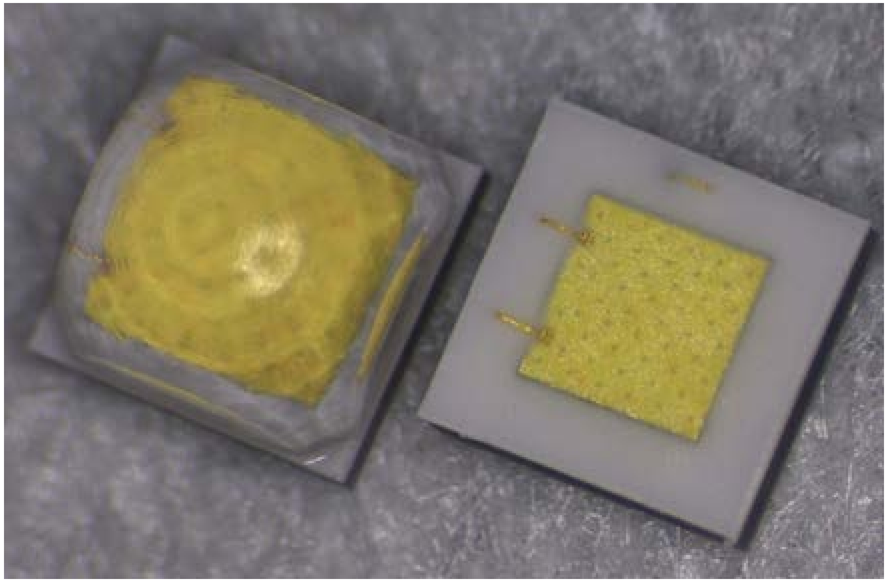


Beam Angle 115˚

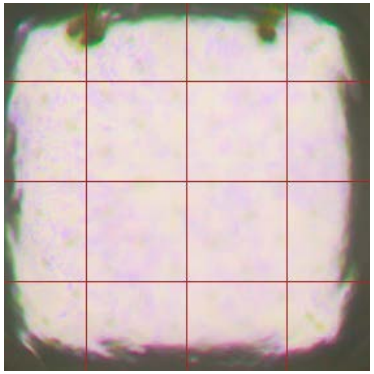
Color over Angle



Optical Source Size

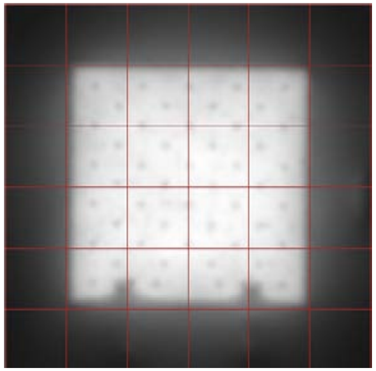


XP-L



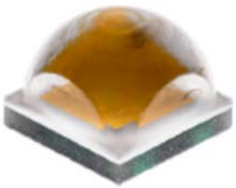
(1.5X)

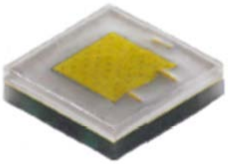
XPL-HI

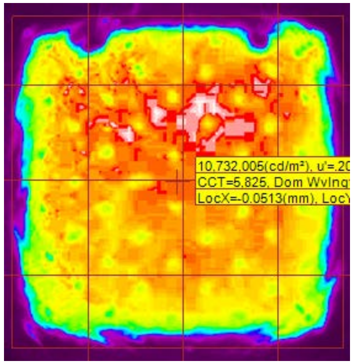


(1.0X)

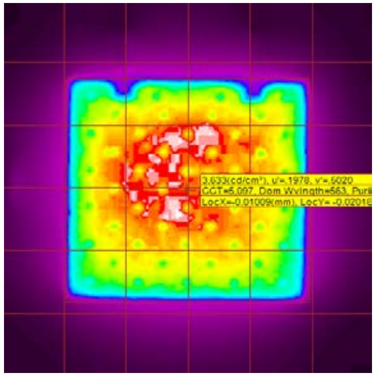
Average Surface Luminance per Lumen





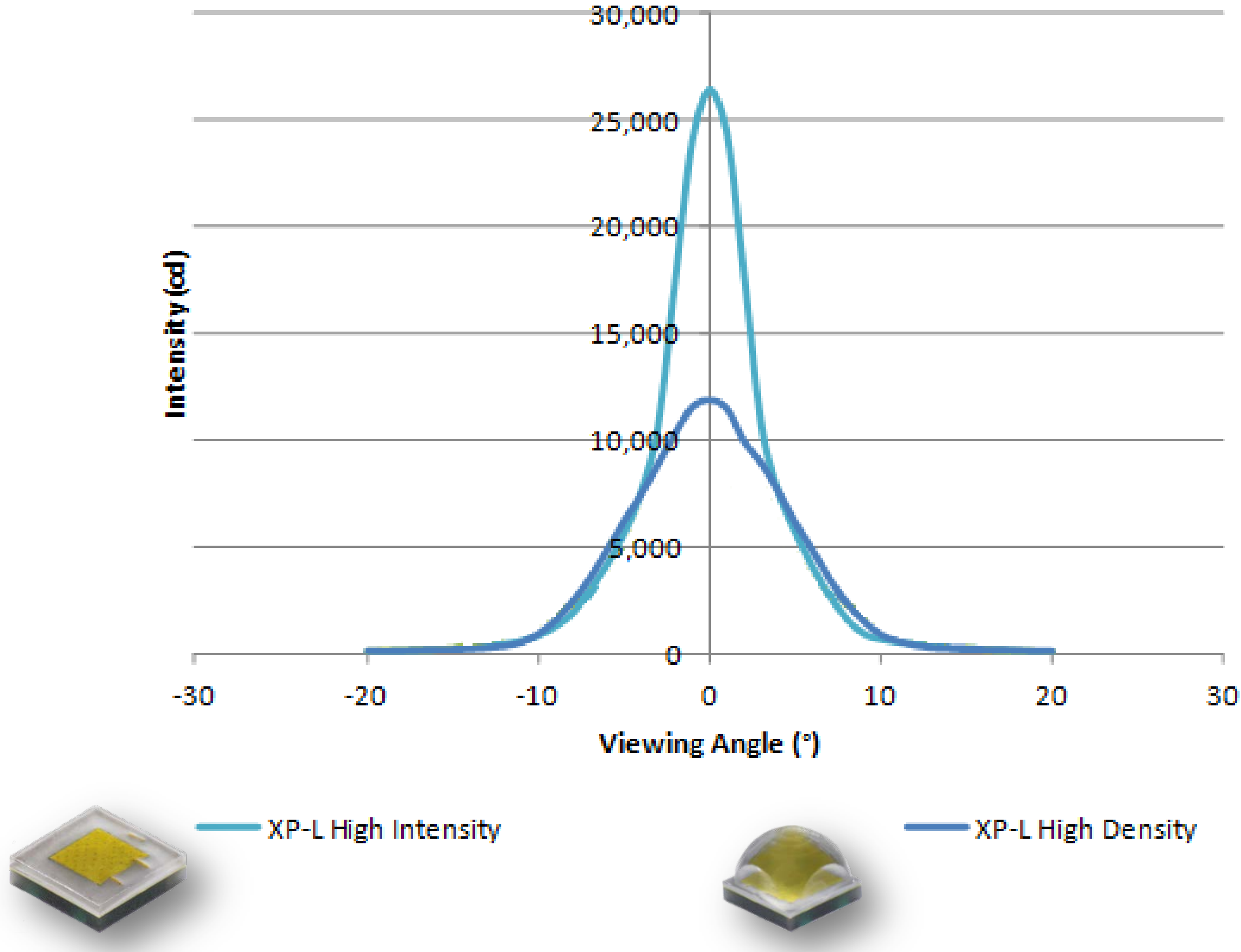


$3.2\ cd/cm^2/lumen$

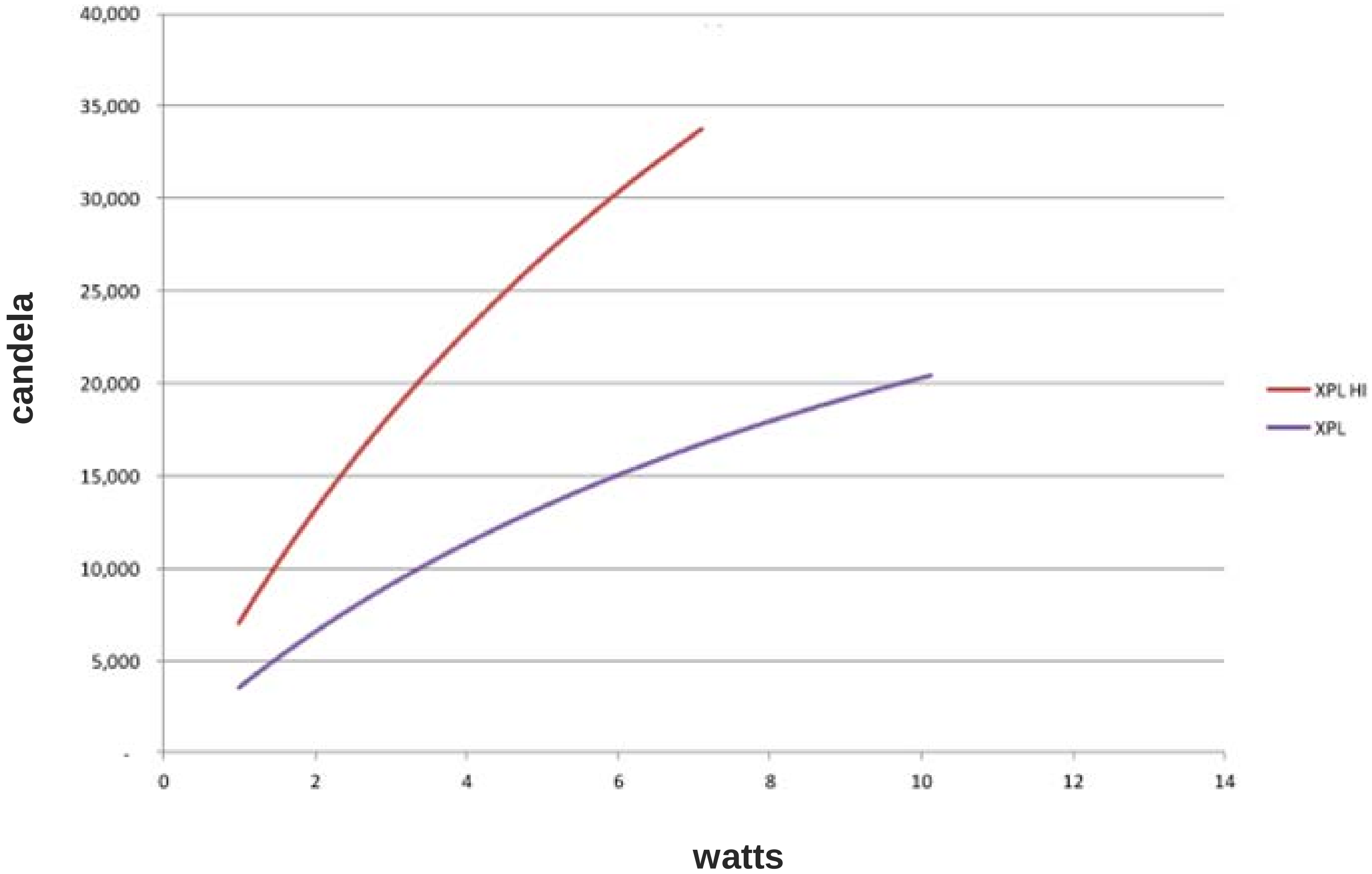


$7.8\ cd/cm^2/lumen$

Measured using Carclo 10755R1 TIR optic



Cd/W for Spherical Lens vs Flat Lens XPL LED

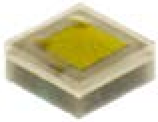


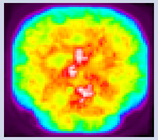
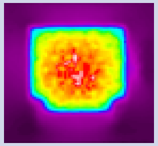
Nano-Punch Track Light Concept – *XP-L High Intensity*

- 83% smaller and lighter than a PAR38
- Only 8W of system power
- 9000 cd

	Nano-Punch Prototype	Halogen PAR38 Flood
LED	XP-L High Intensity	N/A
CCT / CRI	3000K / 82 CRI	3000K / 98 CRI
CBCP	**9,000 cd @ 11° beam**	2,379 cd
Tsp	98° C	---
Initial Lumens	520 lm	1,325 lm
System Power	8 W	71W
Size	79mm (length) 32mm (head) 31mm (body)	
Weight	.10 lbs	.70 lbs

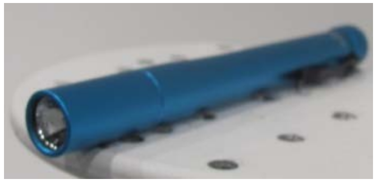
XQ-E 1.6mm X 1.6mm

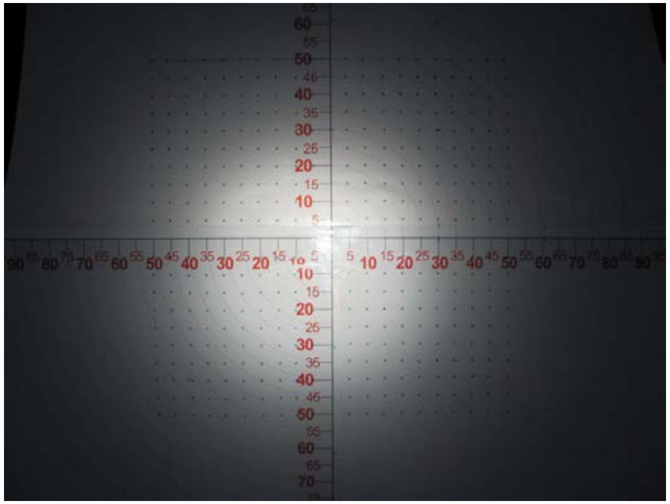


	XQ-E HD	XQ-E HI
Avg Surface Luminance per Lumen (cd/cm^2/lumen)	 16	 27
Optical Source Size	2X	~1X

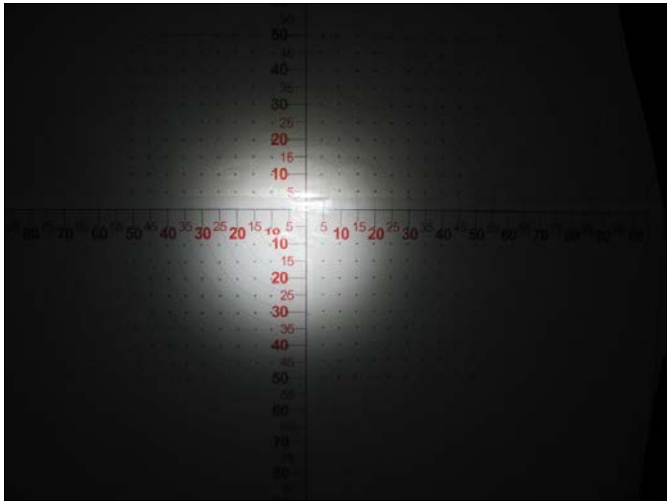
Lens		XQ-E HD	XQ-E HI
Carclo 10003 Lens (20 x10 mm) 	Beam Angle	7.5°	5.5°
	Field Angle	15°	11.3°
	Cd/lm	35	64

Small Diameter (15mm) AAA Flashlight Retrofit (XQ-E)





Domed Lens
173 lumens
281 lx @ 2m



Flat Lens
159 lumens
643 lx @ 2m

Lighting Applications

~~Non-Directional~~

Directional

~~Downlight~~

~~Linear~~

Outdoor/High Bay

Portable

OUTLINE:

1. LED package design concepts – optimizing light extraction from LEDs.
2. Primary Optics: benefits of a "Flat Lens" vs "Spherical Lens"
3. Applications of "Flat Lens" LEDs in designs.

Is Candela/Watt an appropriate metric of a products efficacy for certain applications?

Thank You!

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