CREE™

LED Component and System Optics

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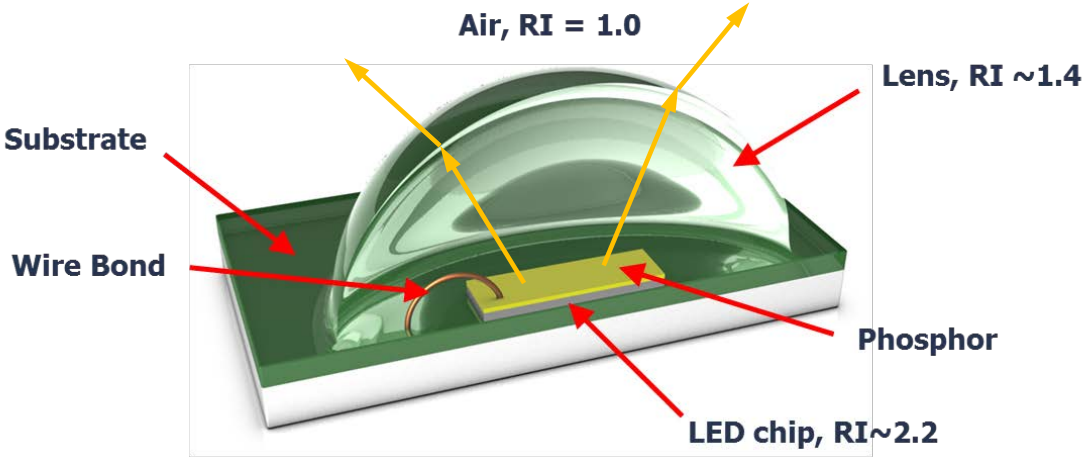
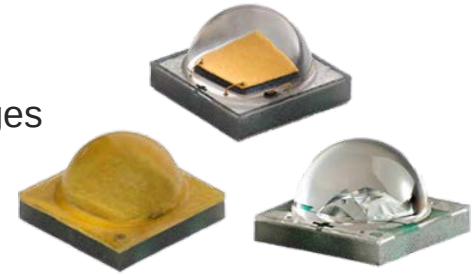
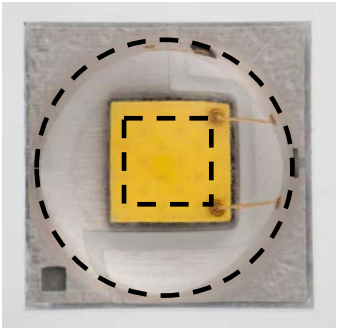
LED Package Optical Design

- **Hemispherical** lenses: maximize first-pass extraction to minimize recycling
  - Recycling (multiple bounces) may lead to significant optical losses
- **Larger source (chip) size** due to magnification may introduce étendue challenges



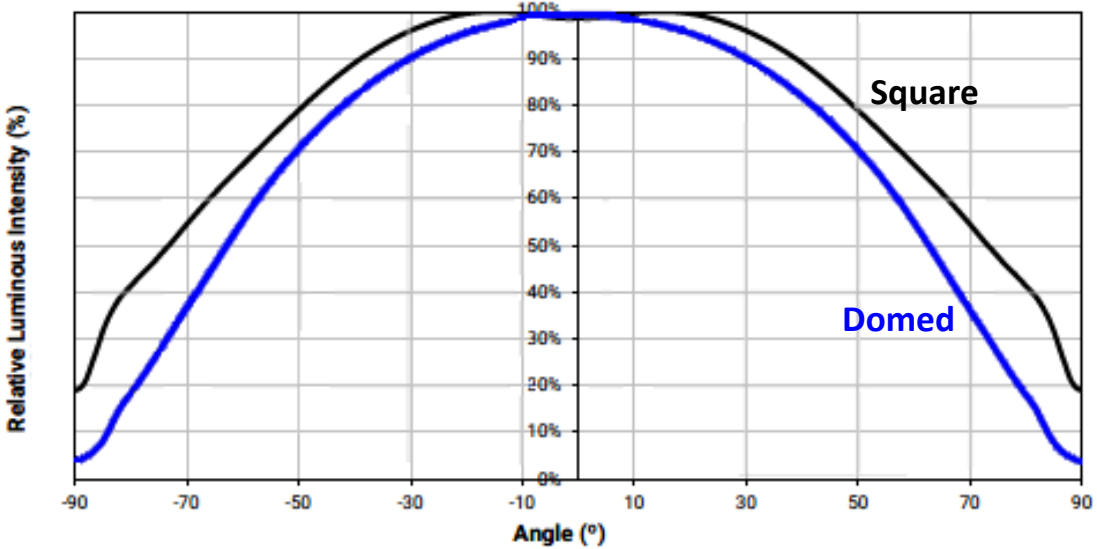




➢ ***Domed packages are optimized for first-pass light extraction… but are they the best choice for <u>all</u> applications?***

Package Optics for Diffuse Emission

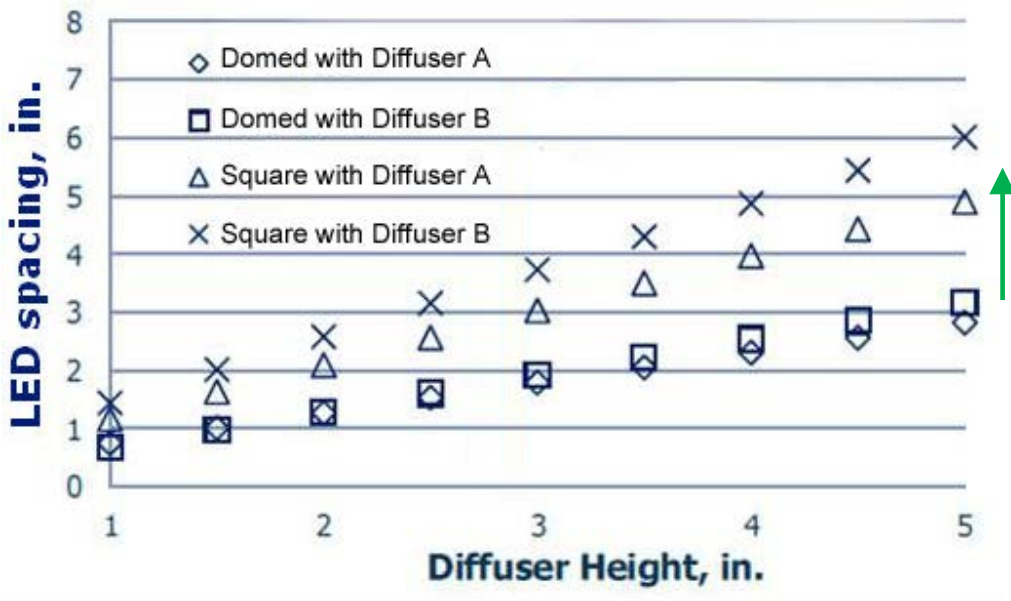
- Cubic or otherwise rectangular lenses **broaden far-field emission over angle**
- **Increased recycling** but little to no optical loss due to high-Q chip, phosphors, and package surfaces



➢ ***Contrary to earlier package designs, it is possible to harness recycling for broader intensity over angle without optical loss.***

Benefits of Broad Emission to System Design

- Well suited to omni-directional and quasi-Lambertian lamps & luminaires
- Broader emission over angle avoids perceptible “pixelation” through diffuser



Wider spacing enabled

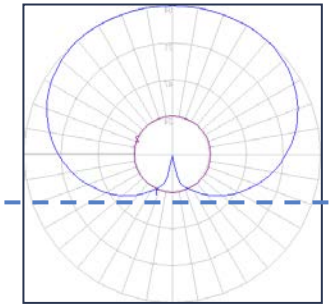
Maximum LED spacing at which pixelation is not perceptible for square vs. domed packages in a direct-view troffer

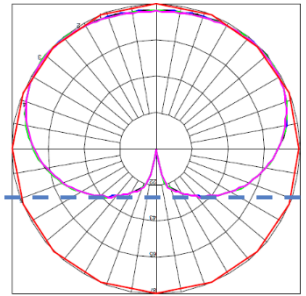
➢ ***Wider package spacing enables cost reduction and/or lower system optical loss via lighter diffusion.***

Bulb Retrofit Example: 810 lm, 2700K E26 Lamp w/ XQ-D

	Original	XQ-D Retrofit
LED Type	5630 Plastic	HP Ceramic
LED Count	27	**16**
Lumens	808 lm	819 lm
Power	10.5 W	9.9 W
Efficacy	78 LPW	**83 LPW**
Emission FWHM	244°	**262°**

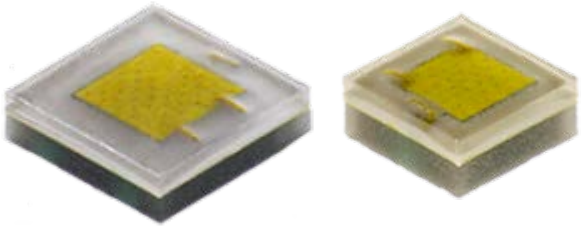
Improved efficacy and emission omni-directionality with no change to the optical system.

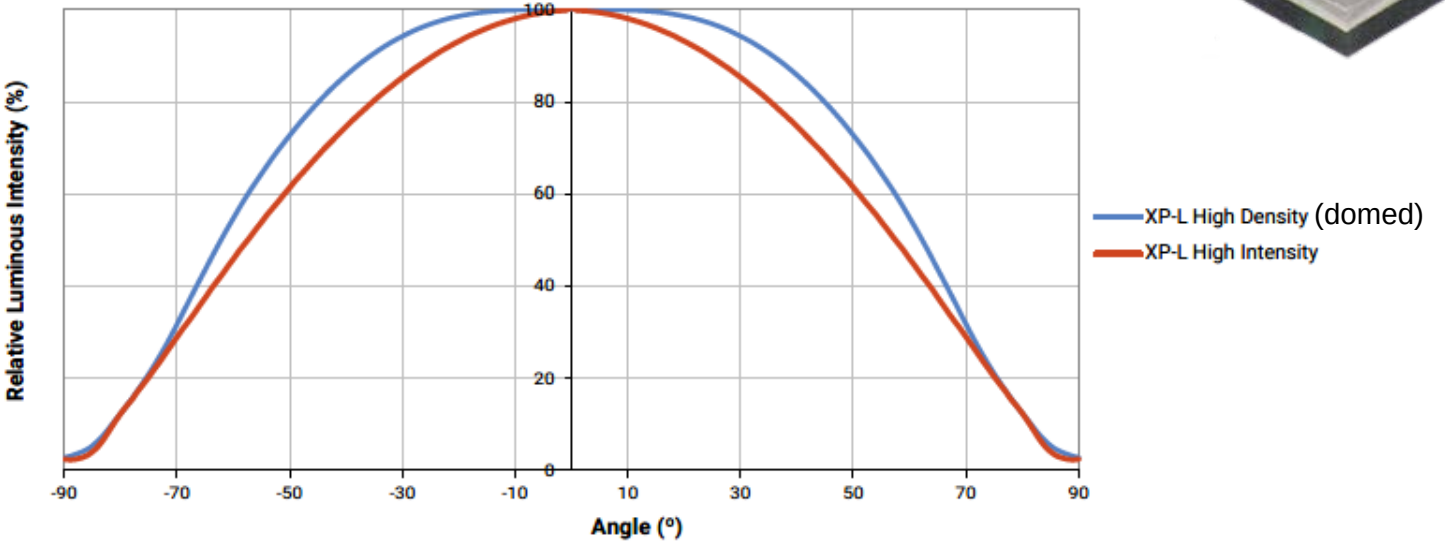




Components for Directional Lamps/Luminaires

- Maximize luminance at a manageable package optical efficiency hit
- Nominal efficacy (lm/W) is lower, but directionality (cd/lm) is higher

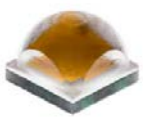


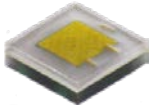


➢ ***Thermal management: high power for high luminance @ high reliability***

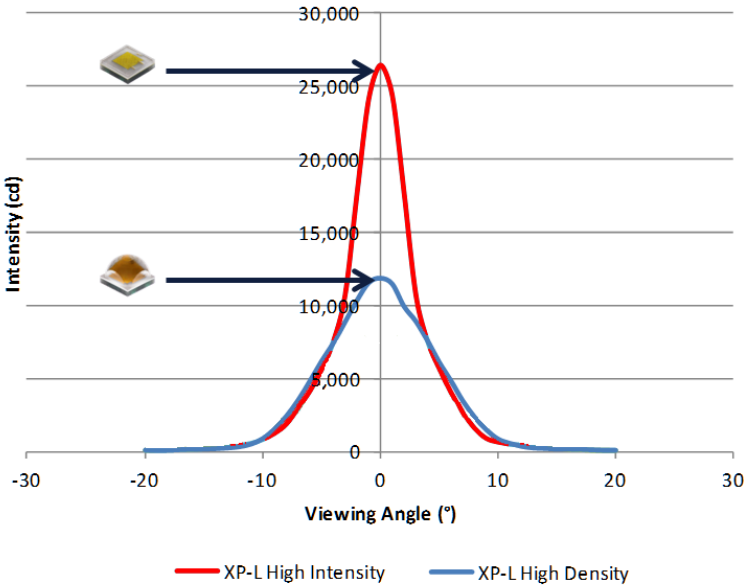
Benefits of Flat-Top Components to System Design

- Directional lamps and luminaires require a high-luminance / “high-punch” source, particularly when size is restricted
- Optics size and cost can often be reduced as source luminance increases





Measured using Carclo 10755R1 TIR optic



	XP-L High Density	XP-L High Intensity
Avg Luminance per Lumen (cd/cm²/lm)	3.2 	7.8 
Optical Source size	1 x	~0.66 x
Package Cost	$	$
Maximum Lumens	1226 lm	1095 lm

➢ ***High luminance has a direct impact on directional lamp size and cost.***

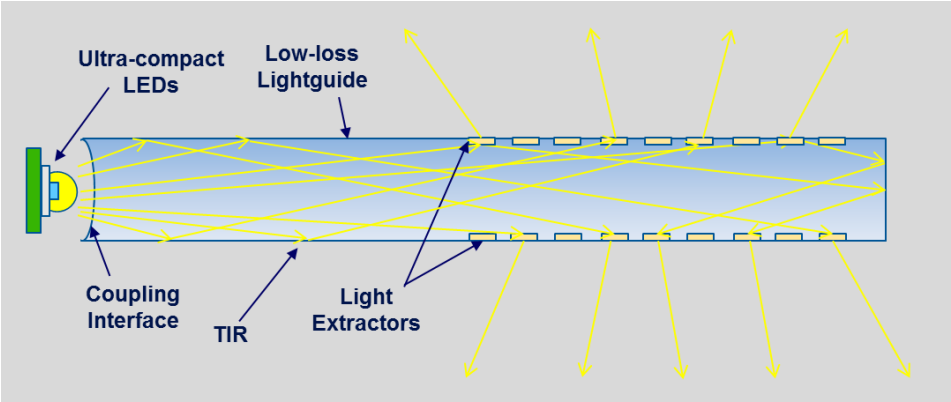
“Nano-Punch” Track Light Concept w/ XP-L High Intensity

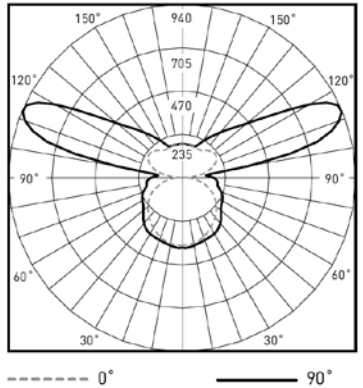
- 83% smaller and lighter than a PAR38
- 9000 cd @ 11° beam FWHM

	Nano-Punch Prototype	Halogen PAR38 Flood
LED	XP-L High Intensity	N/A
CCT	3000K	3000K
CBCP	**9,000 cd @ 11° beam**	2,379 cd @ 12° beam
Initial Lumens	520 lm	1,325 lm
System Power	**8 W**	**71W**
Size	**79mm length 32mm head Ø**	**143mm length 120mm head Ø**
Weight	**0.10 lbs**	**0.70 lbs**

New Optics Designs – Lightguides

- Lightguides require compact LEDs to minimize thickness/volume
  - LED-LG light coupling is a critical factor in optical efficiency





LN4: "asymmetrical to diffuse"
(using ceiling as optical element)

- **Lightguide**: thin for weight, cost reduction, and optical efficiency
- **LEDs**: compact size, high **directionality** (cd/lm) & **luminance** (lm/mm^2) benefit coupling efficiency

Challenges & Opportunities

- Application-specific performance will continue to guide package optics designs & choices:

	Diffuse	Directional	Lightguides
Key Package Characteristics	• Broad emission • Low optical loss due to recycling	• Small source size • High luminance • High power	• Small source size • High luminance
Package Challenges (present and future)	• Low phosphor crosstalk & self absorption • Low chip & package surface absorption	• Thermal management • Phosphor and package reliability (esp. for laser-pumped)	• High package cd/lm at low optical loss • High luminance across all colors
Application Opportunities	• Consistent color over angle among mixed sources (*e.g.* RGBW)	• Increased luminance via efficacy gains • New ultra-compact directional lamp FFs	• Novel, cost effective, & efficient luminaires • Increased application efficiency

Summary

- **LED package optical designs directly benefit luminaire performance and cost.**
- **Future applications will benefit from package-luminaire optics synergy.**

- **Broad/Diffuse**
  - *Challenge*: minimize intra-package optical losses (phosphors, chip/surface absorption)
  - *Opportunity*: optimize luminaire cost and performance by “reducing the burden” on luminaire optics

- **Directional**
  - *Challenge*: ultra-high luminance with high reliability and high color quality
  - *Opportunity*: increased emission directionality and reduced optical source size

- **Lightguide-optimized**
  - *Challenge*: high luminance in ultra-compact packages, across color range
  - *Opportunity*: increased application efficiency in novel luminaire form factors

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