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LASER DIODE + PHOSPHOR [LDP] FOR HIGHLY DIRECTIONAL SOLID STATE LIGHTING

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Outline and Key Messages

LDP solves the LED luminance challenge

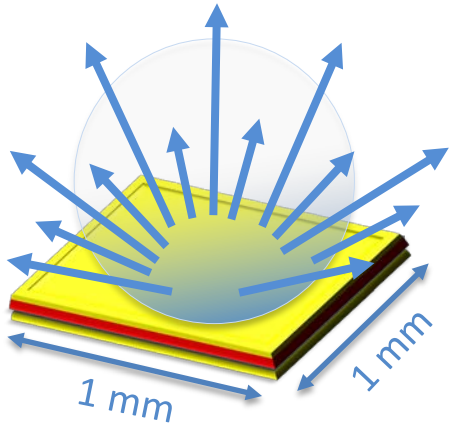
- **>10X the range and delivered lm/W**
- **Enables novel luminaire designs**
- **Superior dynamic illumination**

LDP technology will evolve and mature

- **LD toward LED wall plug efficiency**
- **The challenge of color quality**
- **Perspectives on cost**

SSL Sources; LDP for High Luminance

LED



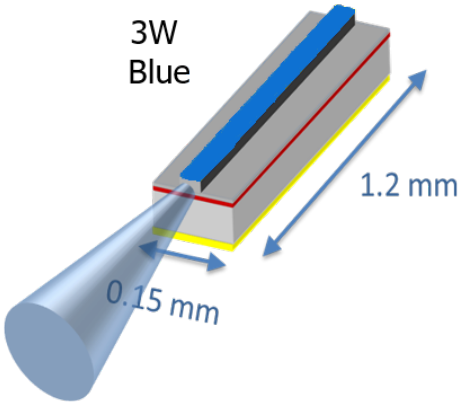
Low Luminance

- Efficiency droop - Auger
- Limited by physics
- Low Jop and flux/area

Safe

- Incoherent, Lambertian

Direct laser diode



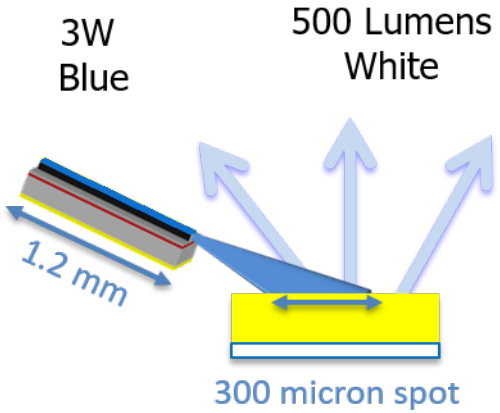
High Luminance

- Stimulated emission
- >10,000X flux/emit area
- 20X flux/chip area

Not Safe

- Coherent, Collimated

LD Phosphor (LDP)



High Luminance

- >3W in controlled spot
- 100X LED w/ 300um Ø
- 900X LED w/ 100um Ø

Safe

- Incoherent, Lambertian

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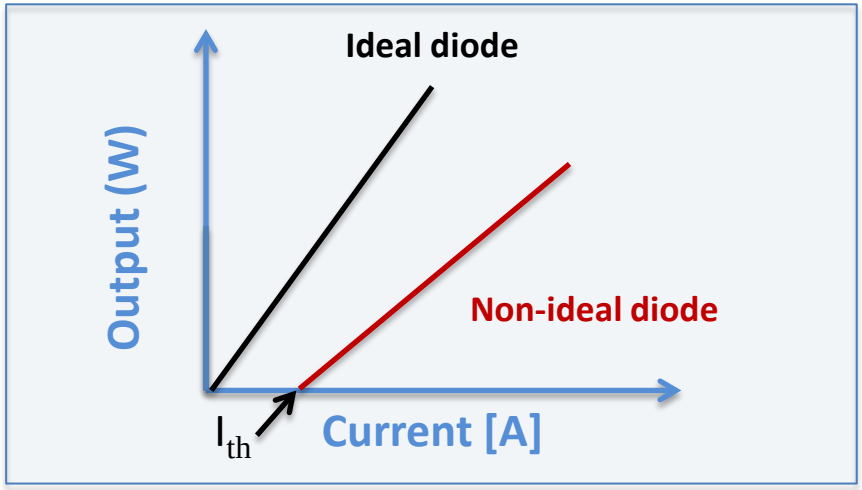
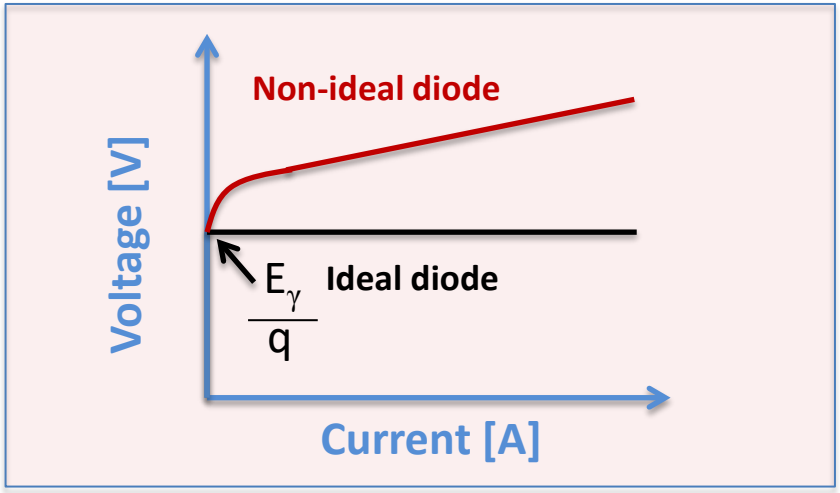
Toward LED WPE in Blue LDs

Today's blue LEDs demonstrate ~2X the WPE of blue LDs

- 70-80% for LED versus 35-40% for LD
- LEDs rarely operated at peak WPE

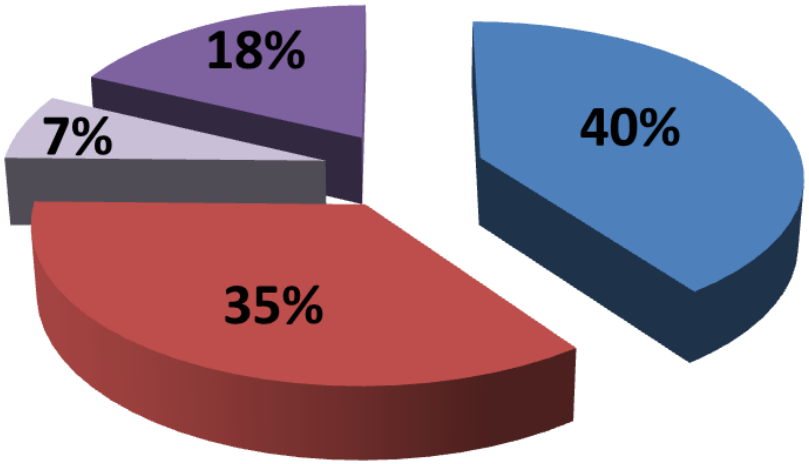
$$WPE = EQE \left(\frac{h\,v}{q\,V}\right)$$



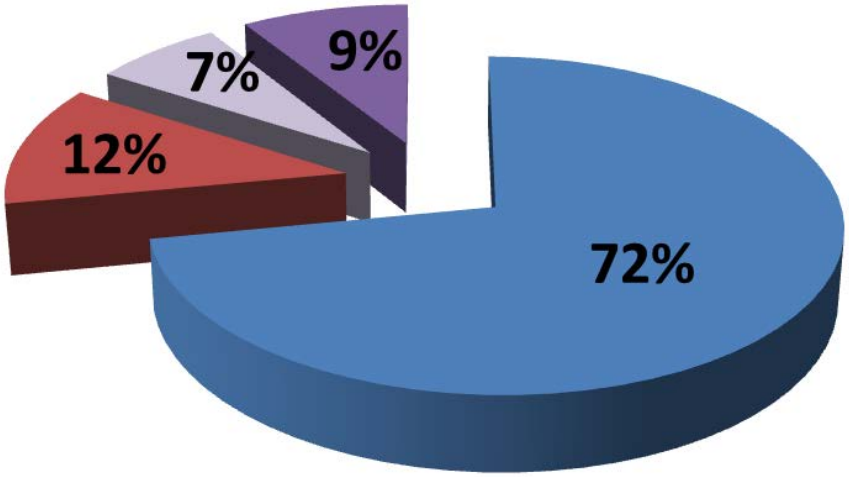


PROOF POINT; GAAS LDS DELIVER LED WPE

4W/40% WPE GaN blue LD;



4W/72% WPE GaAs 940nm LD;



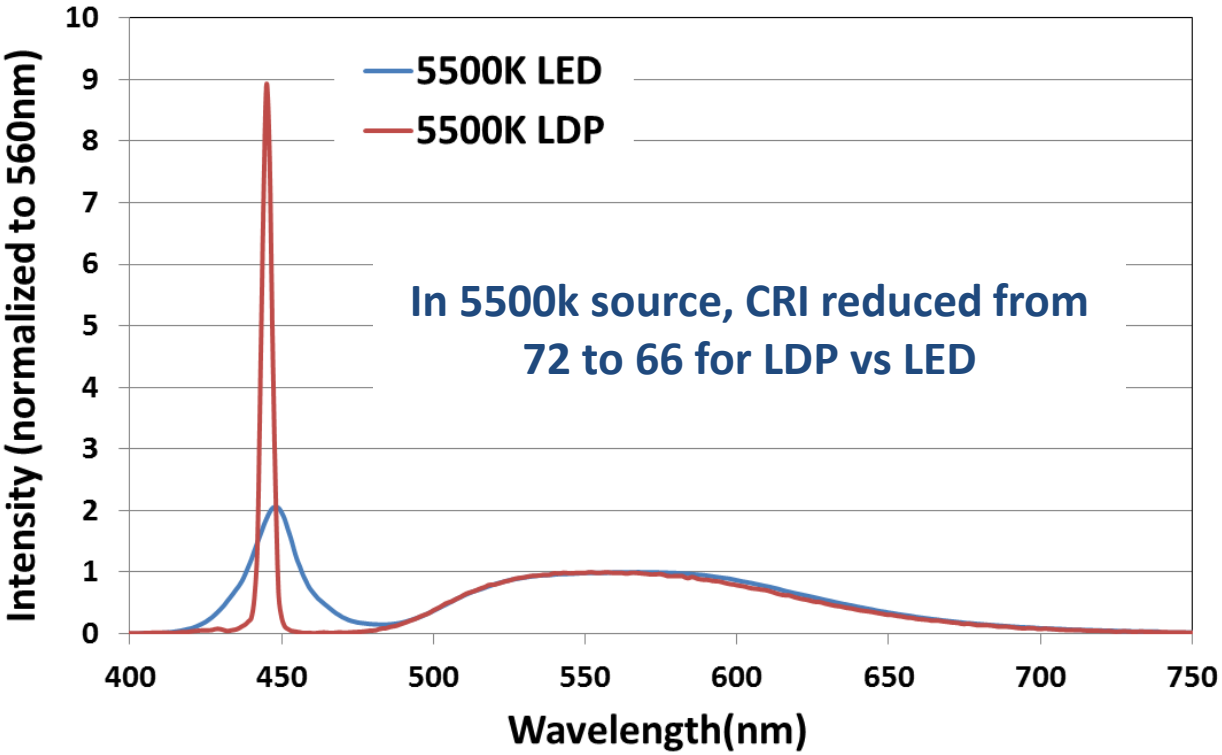
nLIGHT; Crump et al, 2005

- Useful Output
- Voltage Defect
- Threshold
- Slope Defect

LD	GaN	GaAs
WPE (%)	35 - 40	70 - 80
V_D (V)	>1.5	0.15
η_{inj} (%)	>80	>95
α_i (cm^{-1})	1.0 - 2.0	0.3 - 0.5

Color Quality Challenge

Development required for high CRI and low CCT LDP sources



1. Narrow blue linewidth

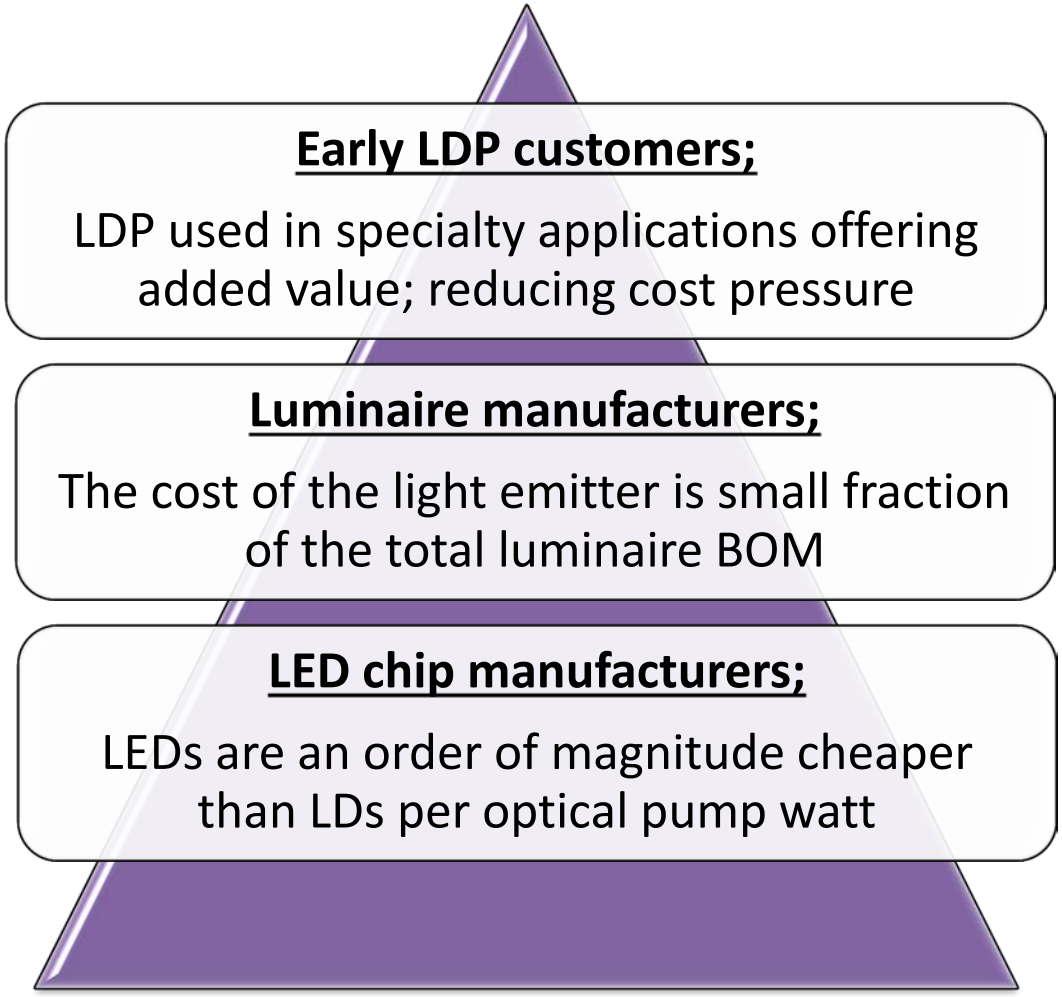
- Multiple LDs or SLEDS
- Phosphors beyond YAG
- Violet pump

2. Phosphor compatibility

- Phosphors beyond YAG
- Novel architectures

Opportunity for improved color quality with phosphor development and novel LDP architectures

LDP Cost Perspectives



Early LDP customers;

LDP used in specialty applications offering added value; reducing cost pressure

LDP can deliver >10X the range and 10X lm/W in directional apps + superior dynamic illumination

Luminaire manufacturers;

The cost of the light emitter is small fraction of the total luminaire BOM

LDP has the opportunity to reduce luminaire costs by simplifying the system [ie size, optics, etc]

LED chip manufacturers;

LEDs are an order of magnitude cheaper than LDs per optical pump watt

LDs produce 20X more power per area; With volumes, yields, and substrate scaling LDs can compete

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THANK YOU