SORAALASER

LASER DIODES FOR NEXT GENERATION LIGHT SOURCES

Providing the brightest, most efficient laser light sources to the world

JAMES W. RARING

GM, VP ENGINEERING

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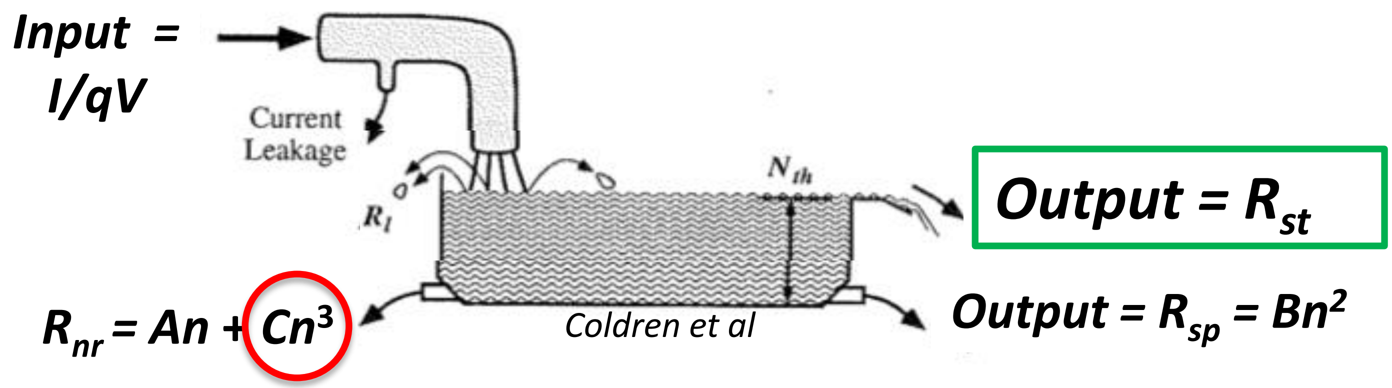
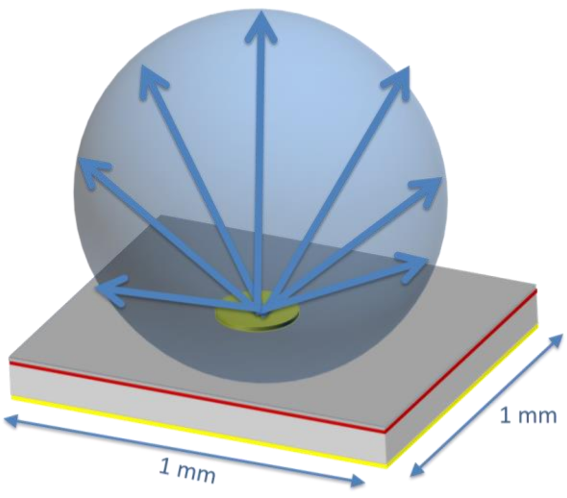
OUTLINE AND KEY MESSAGES

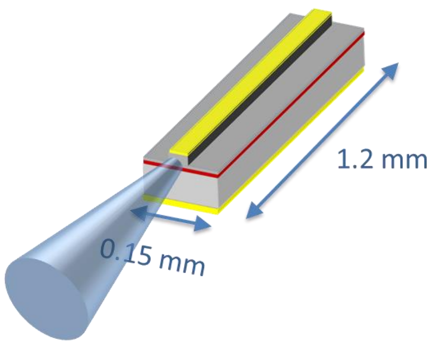
- LDs are solution to droop and offer 10-20X more power per chip area and 10,000X the spatial brightness of LEDs
  - LD + phosphor source can provide superior “delivered” lm/W
- LDs must overcome challenges such as wall plug efficiency to achieve maximum adoption in lighting
  - Evolution of GaAs LDs paved a proven pathway for GaN LDs
- GaN LDs have a bright future

LDs Dominated by Stimulated Emission

Laser Diode

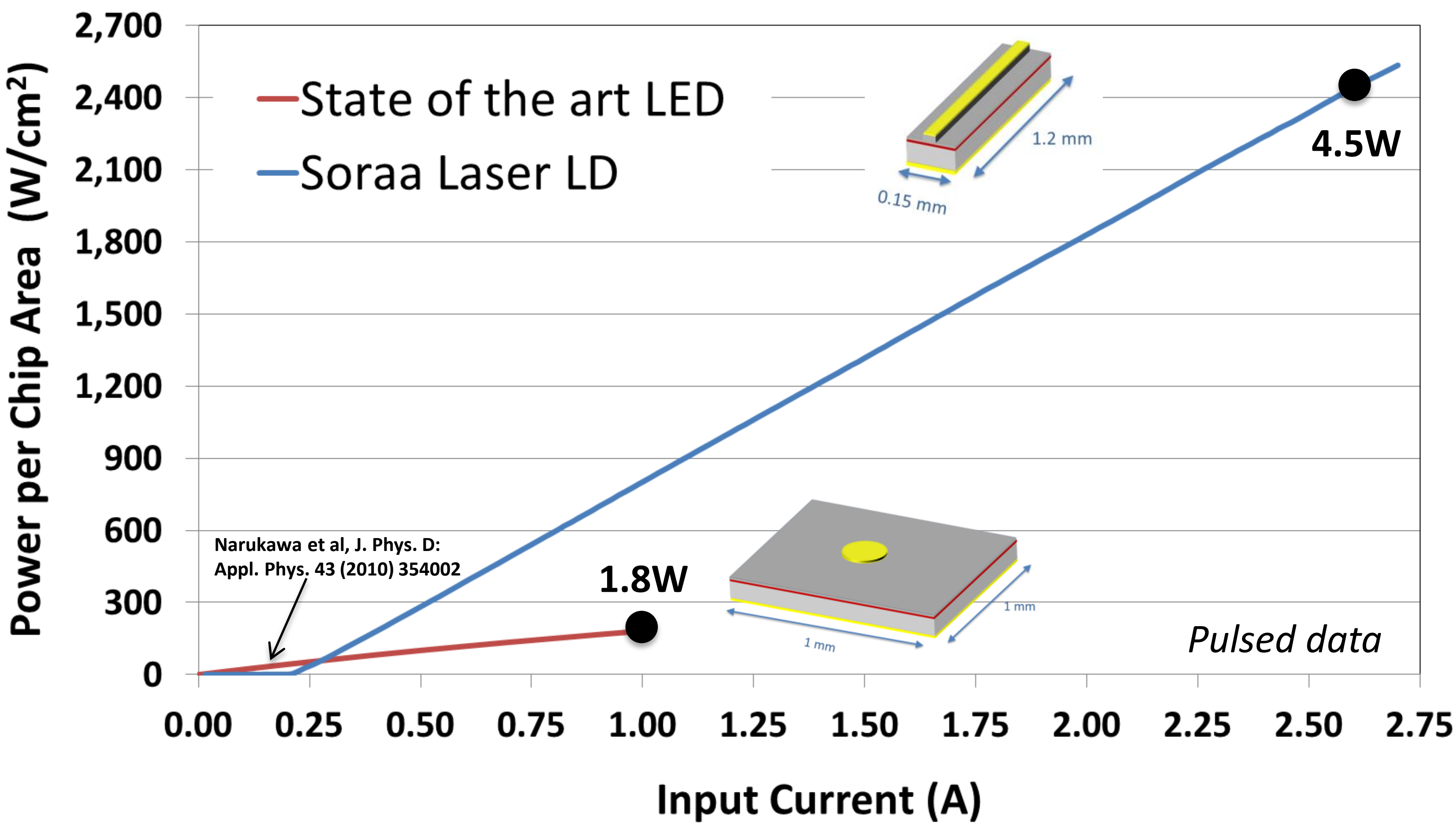






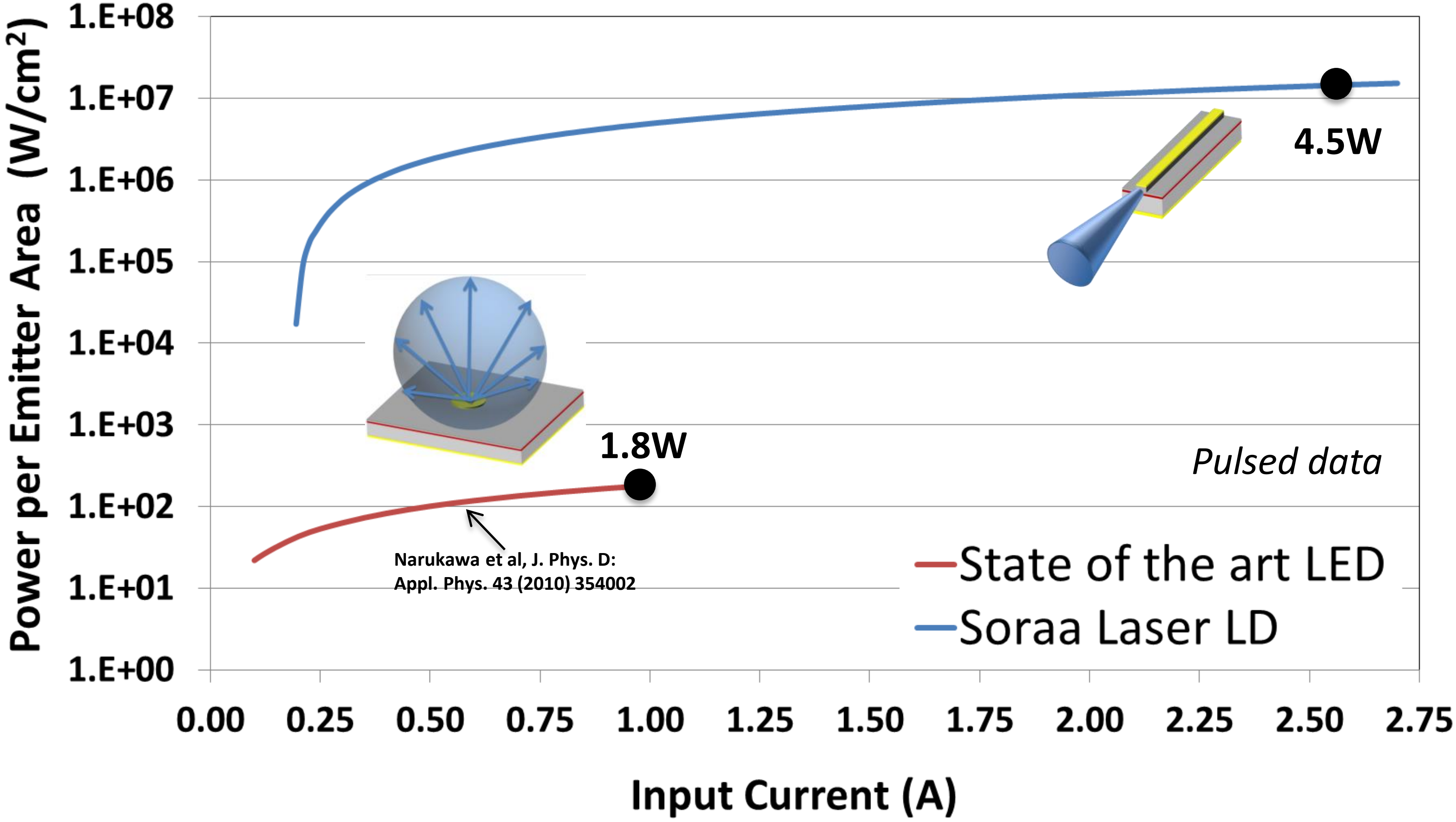
LED VS LD: Power Per Chip Area

Current LDs produce 10-20X more light per chip area



LED VS LD: OUTPUT POWER DENSITY

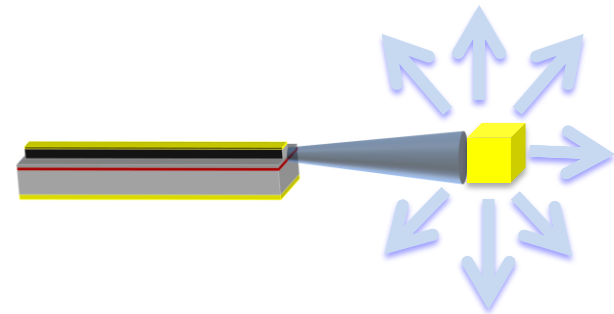
LD aperture 10,000X brighter than LED emitter



LD + Phosphor for Illumination

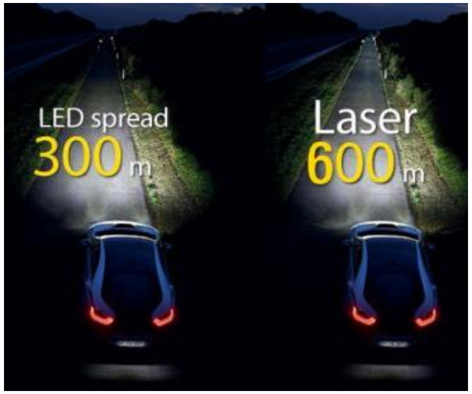
- **Low etendue + high brightness make LDs ideal excitation source**

LD + Phosphor
3W in <100µm Ø spot on phosphor
>380 W/mm²



LDs >300X brighter than LED: Superior for directional applications

Even with ½ the WPE, LDs can provide higher delivered lm/W

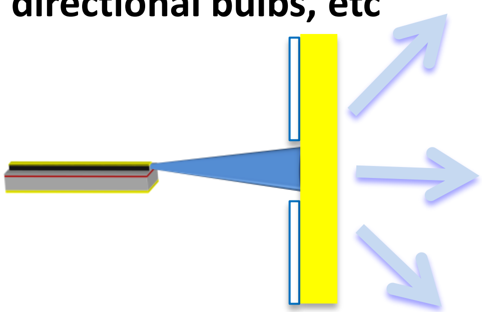


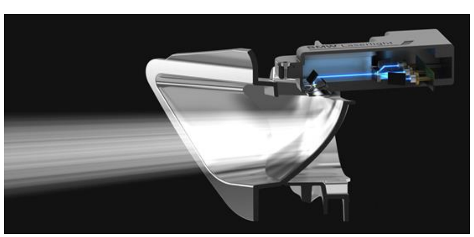
LD + Phosphor Configurations

- Phosphor technology for high power density LD excitation exists today
  - **Ceramic and single-crystal YAG:CE demonstrate low thermal quenching, high IQE, and robust lifetimes at >200C**
- Infinite number of LD + phosphor configurations; Opportunity

Transmission

e.g. spotlights, headlights, directional bulbs, etc

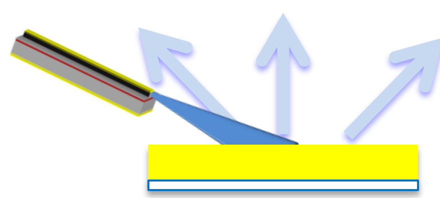




BMW I8; motorauthority.com

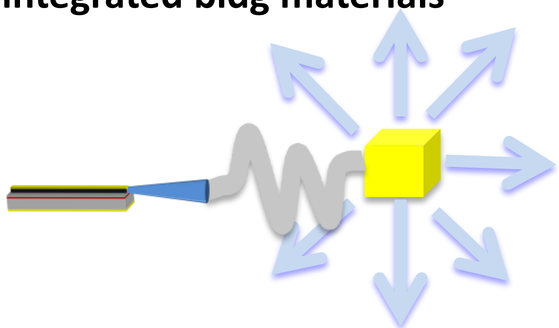
Reflection

e.g. spotlights, headlights, directional bulbs, etc



Remote: T or R

e.g. street, bridge, tunnel light; integrated bldg materials



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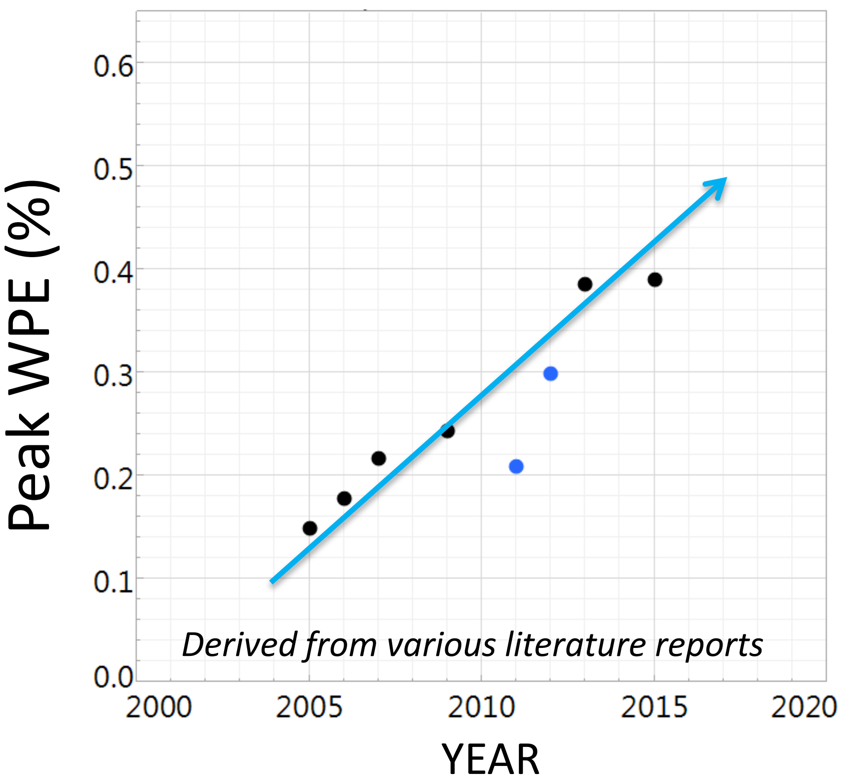
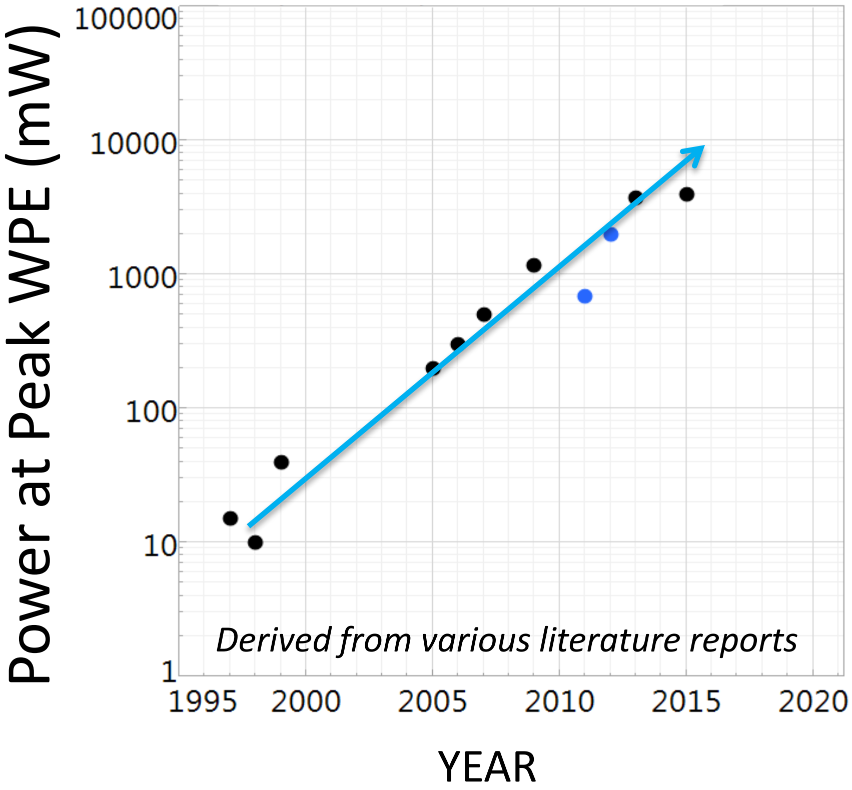
LD WPE @ ~40% w/ Rapid Progress

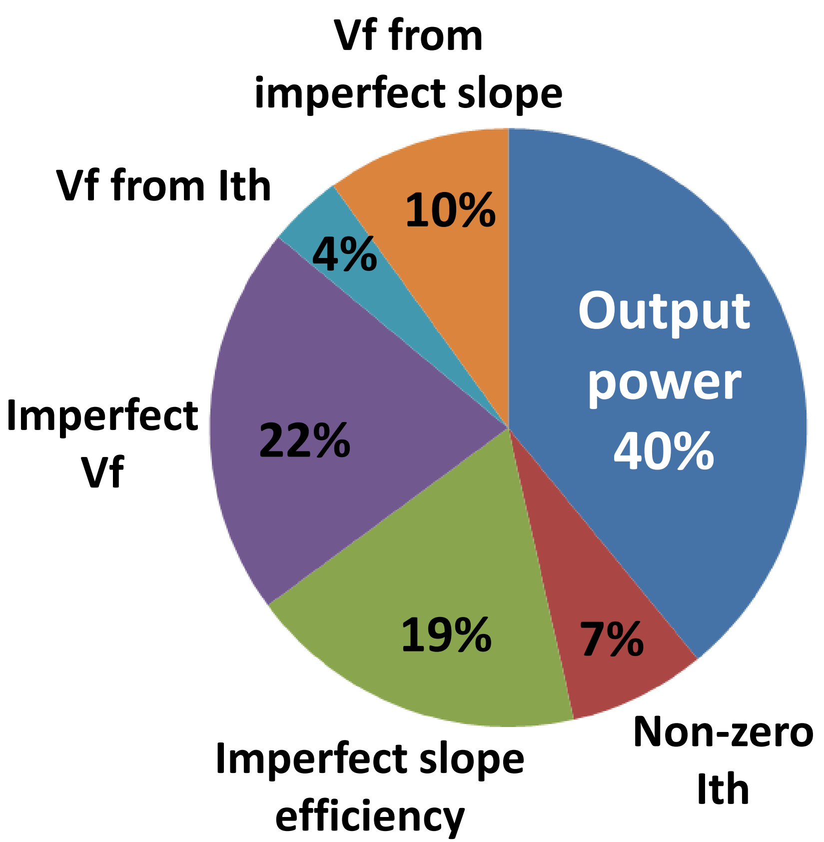




- Blue LD WPE increased from 15% in 2005 to ~40% in 2015
- P @ max WPE increased from 10mW in 1997 to 4W in 2015

BLUE LD POWER CONSUMPTION PARETO

Example 4W/40% WPE Blue LD;



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

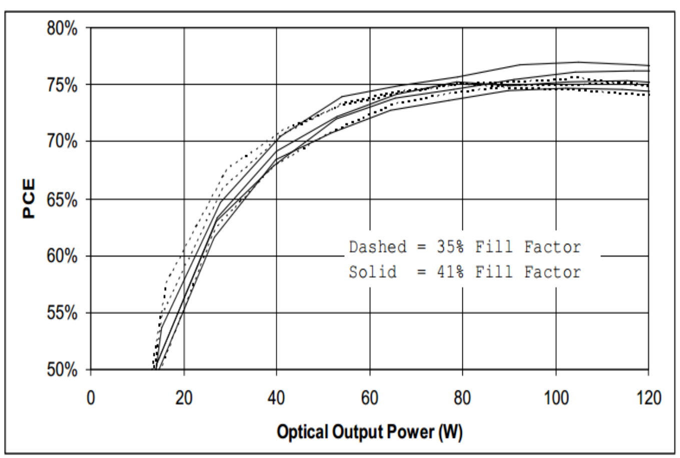
$$\eta_{inj}\quad \frac{a_m}{a_m + a_i}\quad \frac{(I - I_{th})}{I}$$

LD	GaN	GaAs
WPE (%)	35 - 40	75 - 80
η_{inj} (%)	>80	>95
α_i (cm^{-1})	1.0 - 3.0	0.3 - 0.5
ħv/qV (V)	>1.5	0.15

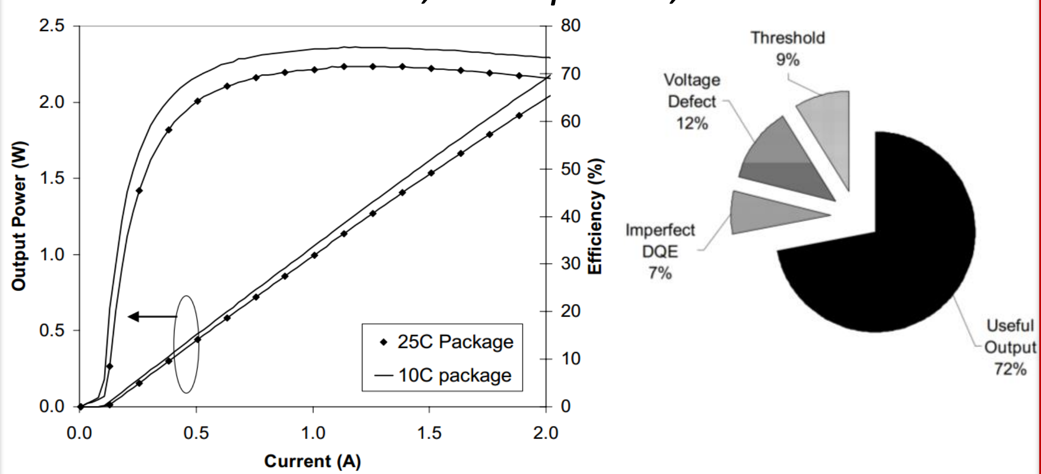
SHEDS: A Model to Drive GaN LD WPE

- In 2003 DoD launched SHEDS (super-high-efficiency diode sources)
  - **Featured 8 partners; JDSU, nLight, Alphalight, several universities etc**
- Program goal to drive GaAs 9xx nm LDs from 45-50% to 80% WPE
  - **Motivated by interest to improve the efficiency of diode-pumped solid-state lasers**
- SHEDS was huge success driving WPE 75-85% by program end;
  - **<u>In <1 year achieved 65% WPE, by program end in 2006, ~75% WPE at RT and 85% at -50C</u>**

JDSU; Peters et al, 2005



nLIGHT; Crump et al, 2005



ADDITIONAL CONSIDERATIONS

SORAA LASER

Cost

Volume driven; LD fab yield, substrate costs, etc

GaAs LD pathway mapped to <$0.03/W in studies

Lifetime/Reliability

Low defect densities and optimized process

Wide stripe, specialized facet coating technology

Thermal Management

Current 4W LD has >400X waste power density of 1W LED

P-side down bond, thermal materials, remote light

Eye Safety Concerns

Laser + phosphor; Design for safety will be key element

Laser based projectors already in wide-spread use

SUMMARY: LDs HAVE BRIGHT FUTURE

LDs offer inherent benefits over LEDs; Next Gen light sources

- LDs are Droop-Free at >100x current density
- LDs are 10,000x brighter and can yield 10-20x more power from epi area
- LD sources already provide superior “delivered lm/W” in directional apps

LD adoption will grow with tech maturity and Next Gen lighting

- GaAs LDs paved a proven pathway towards performance and cost for GaN LDs
- SHEDs as example of a program to drive GaN LDs to GaN LED efficiencies
- Benefits of LDs will become further attractive in Next Gen lighting

Thank you for your attention