

The logo for nLIGHT, featuring a dark blue rectangular background. The letter 'n' is in a white, italicized serif font, while the letters 'LIGHT' are in a white, bold, sans-serif font.

n LIGHT

High Brightness Fiber Coupled Pump Lasers

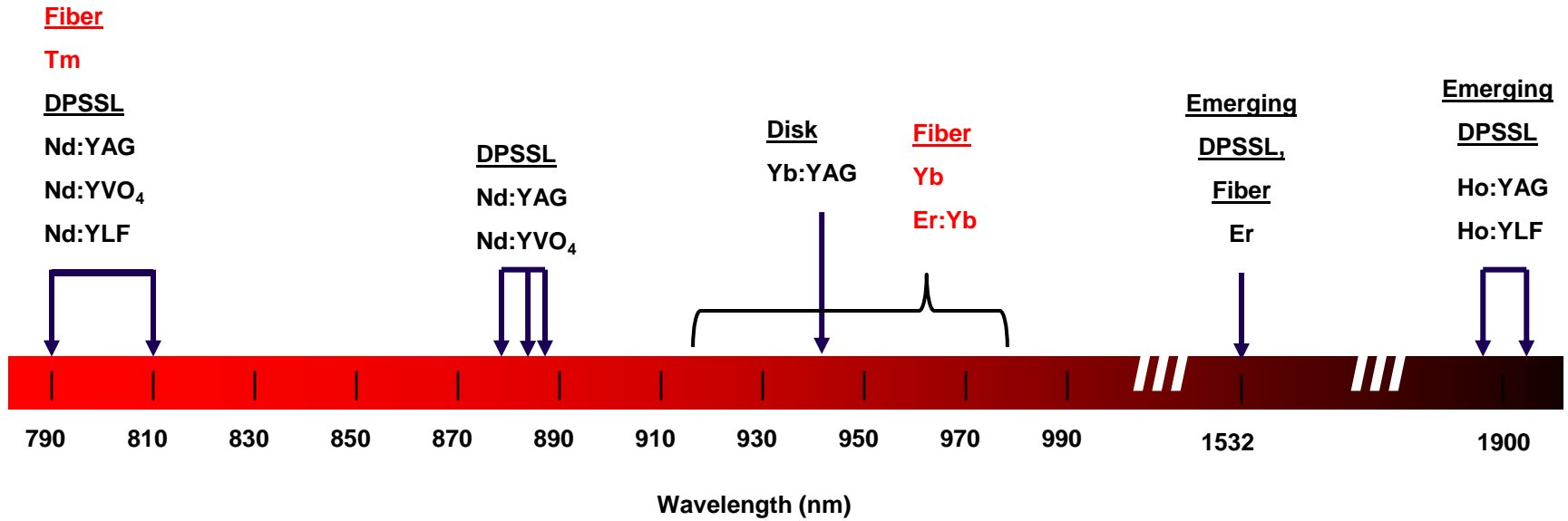
Kirk Price, Scott Karlsen, Paul Leisher, Steve Patterson, and Robert Martinsen

25 January, 2010

Outline

- Pumping applications
 - Role of efficiency in system performance
- nLIGHT fiber coupled single emitters
 - Device and package reliability
- Pump modules
 - 200um modules
 - 100um modules
 - Wavelength stabilized
- Conclusions

Key pumping wavelengths



Pump laser fiber coupled E-O operating efficiency

50%

50-55%

55-60%

25-30%

15%

Alternate Uses



Consumer, Si and Al processing

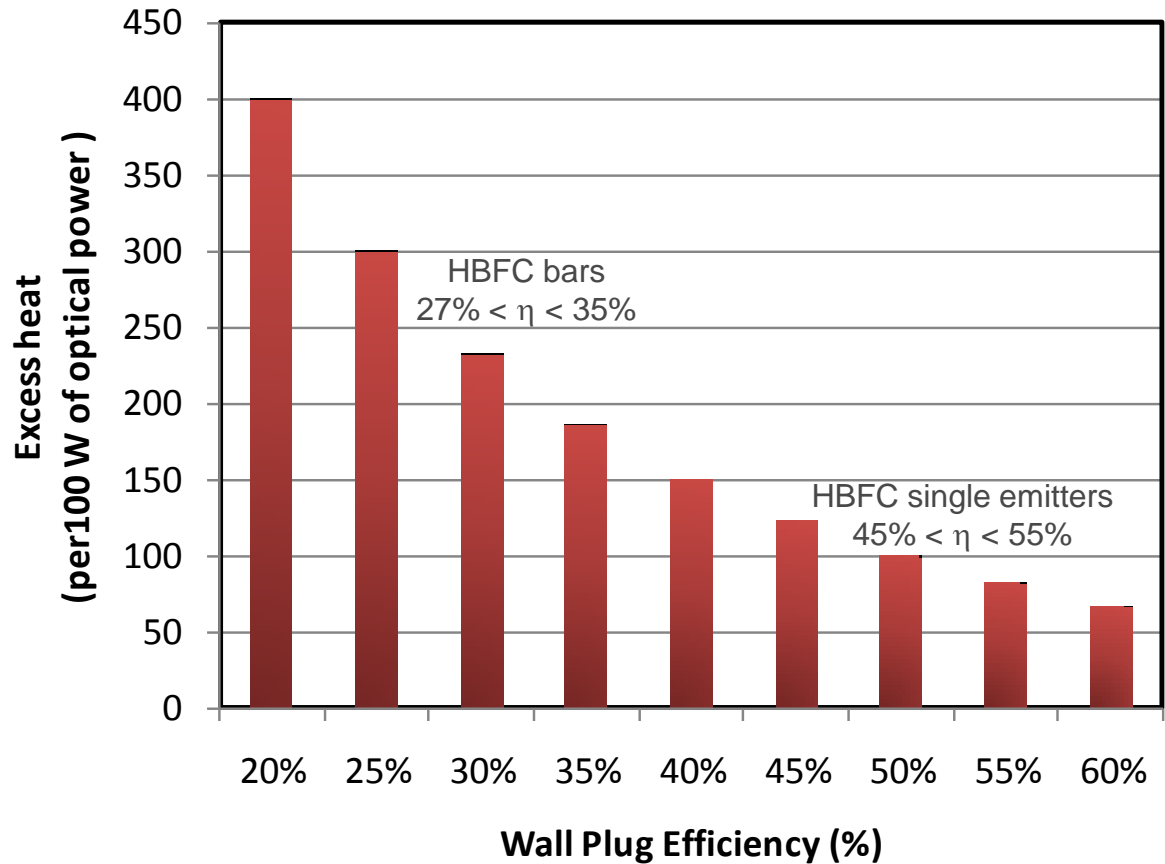


Welding, brazing, hardening, marking



Consumer, Er pumping, Tm pumping, medical

Efficiency and Thermal Management



Reduced waste heat results in:

- Lower \$/W
- Smaller package size
- Simplified cooling
- Reduced OpEx
- Low rates of degradation

Selection of high brightness pump laser diodes

75 W, 20 mm-mrad



140 W, 20 mm-mrad

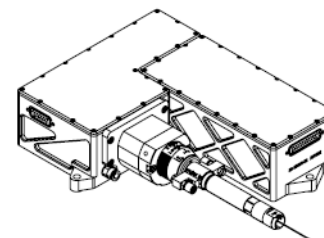


120 W, 10 mm-mrad



500W, 20 mm-mrad

K. Kennedy, "Compact 500W 200um fiber coupled module based on single emitters," Tuesday 2:00, Beam Combining



600W, 30 mm-mrad

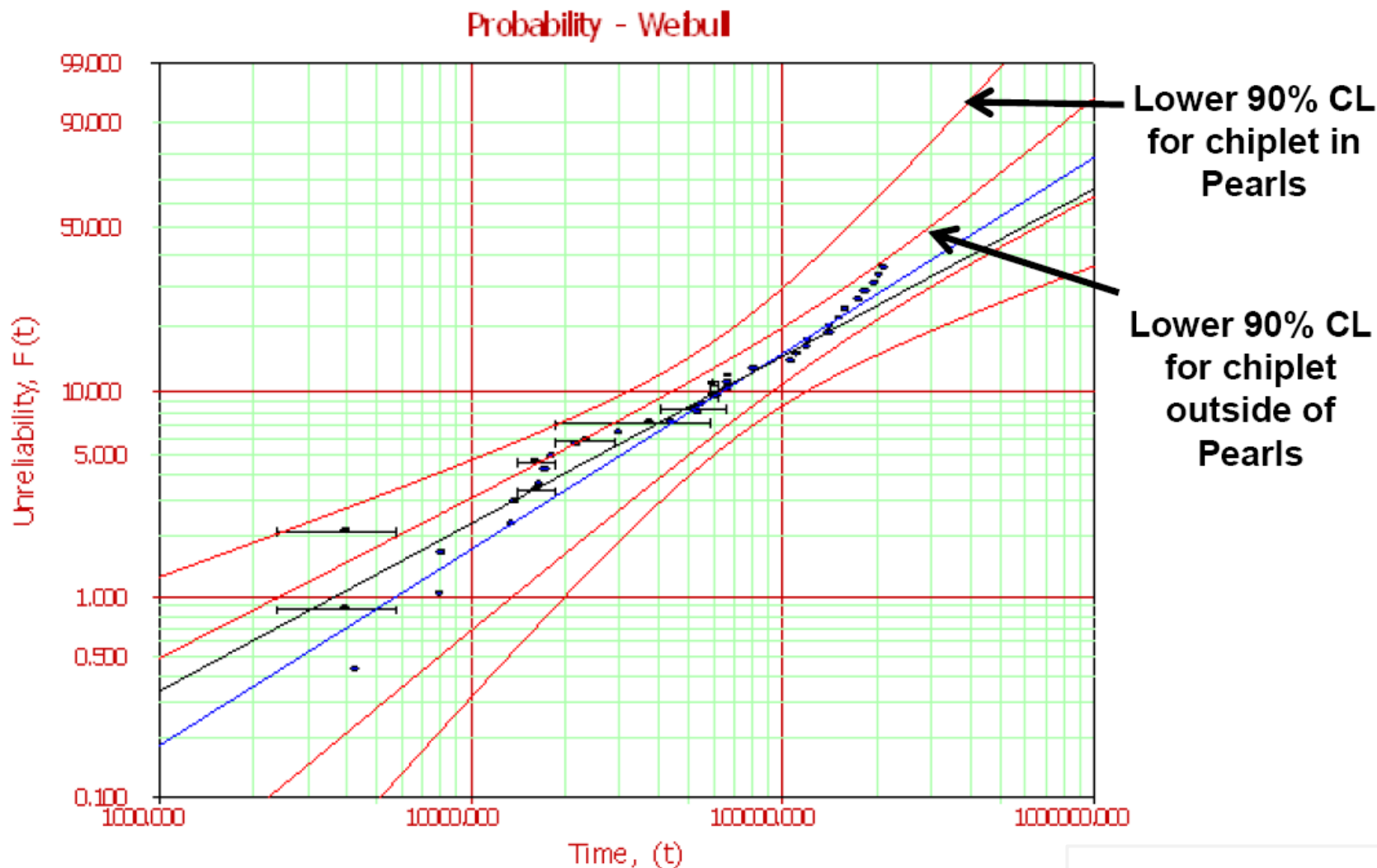
K. Price, "KW-class industrial diode lasers comprised of single emitters" Mon. 2:00, Laser Diode Modules II



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Single emitter reliability with absence of PIF



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200um pump, 79x – 88x nm

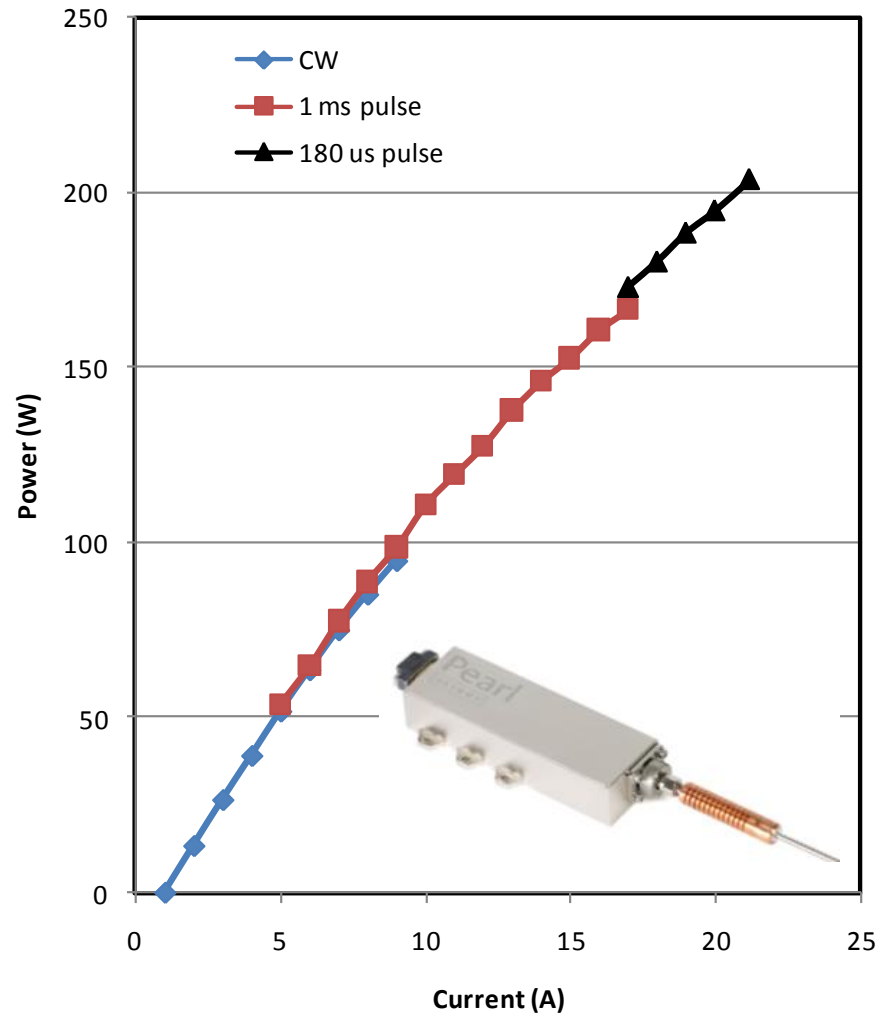
Tm fiber laser and Nd:YAG
pump module

CW and pulsed operation

- 100W, CW
- 200W, pulsed

NA ~ 0.14

2 nm FWHM spectral line



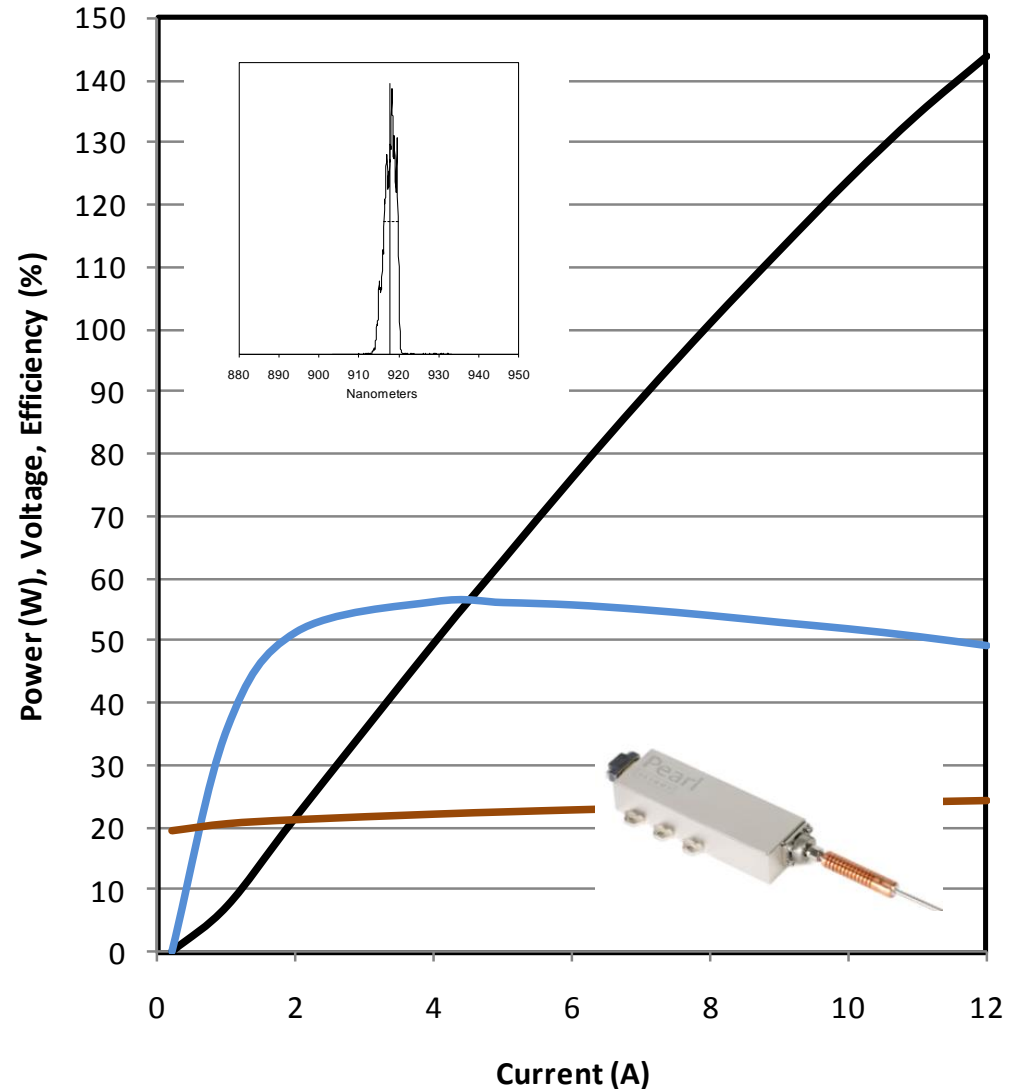
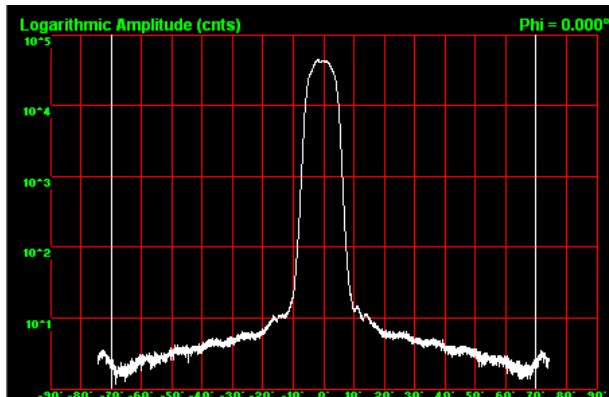
High brightness fiber laser pumps, 9xx nm

120W, 200um, <0.10 NA

<2% cladding light

35 dB 1um isolation

Pumping and direct diode applications

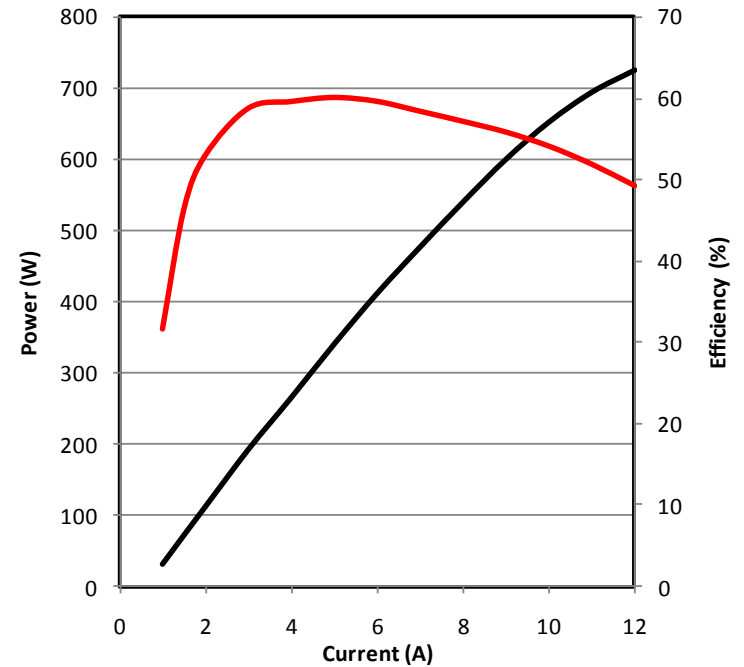


Compact, high power packages

Optimal beam quality preservation
while maintaining high efficiency

Rated at ~500 W at product release

Compact footprint with 72 emitters
– BPP of 20 mm-mrad



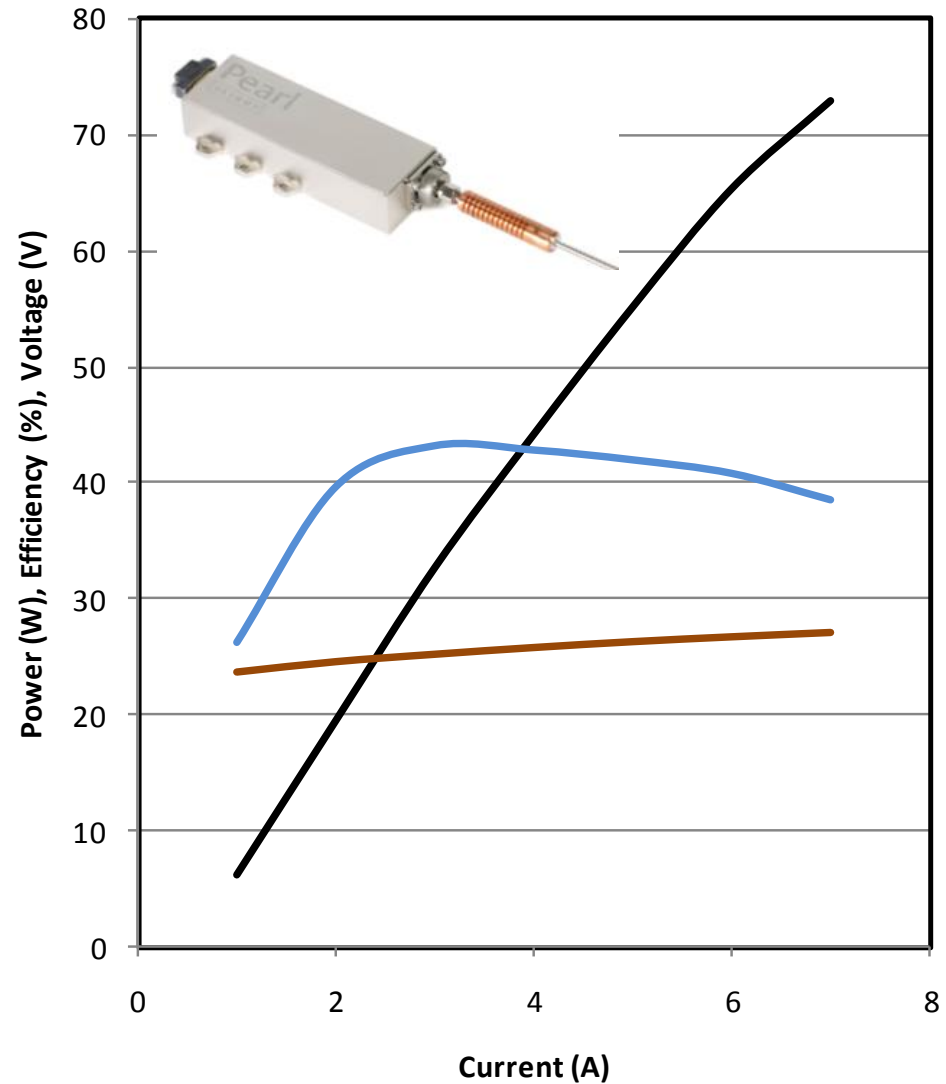
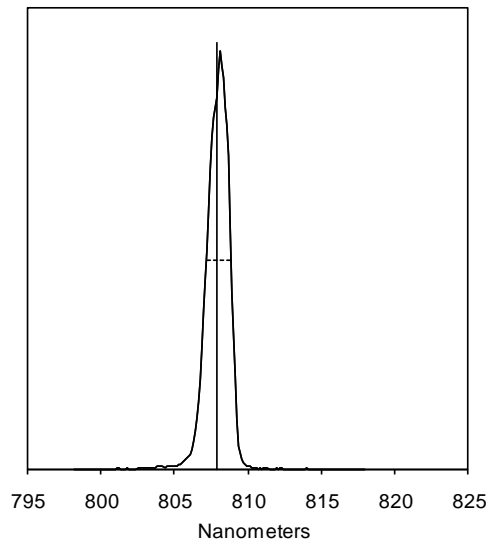
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70W, 105um, 0.14 NA at 79x-80x nm

Tm fiber laser pump –
enabling KW power scaling

Brilliance = 13 MW/cm²-str



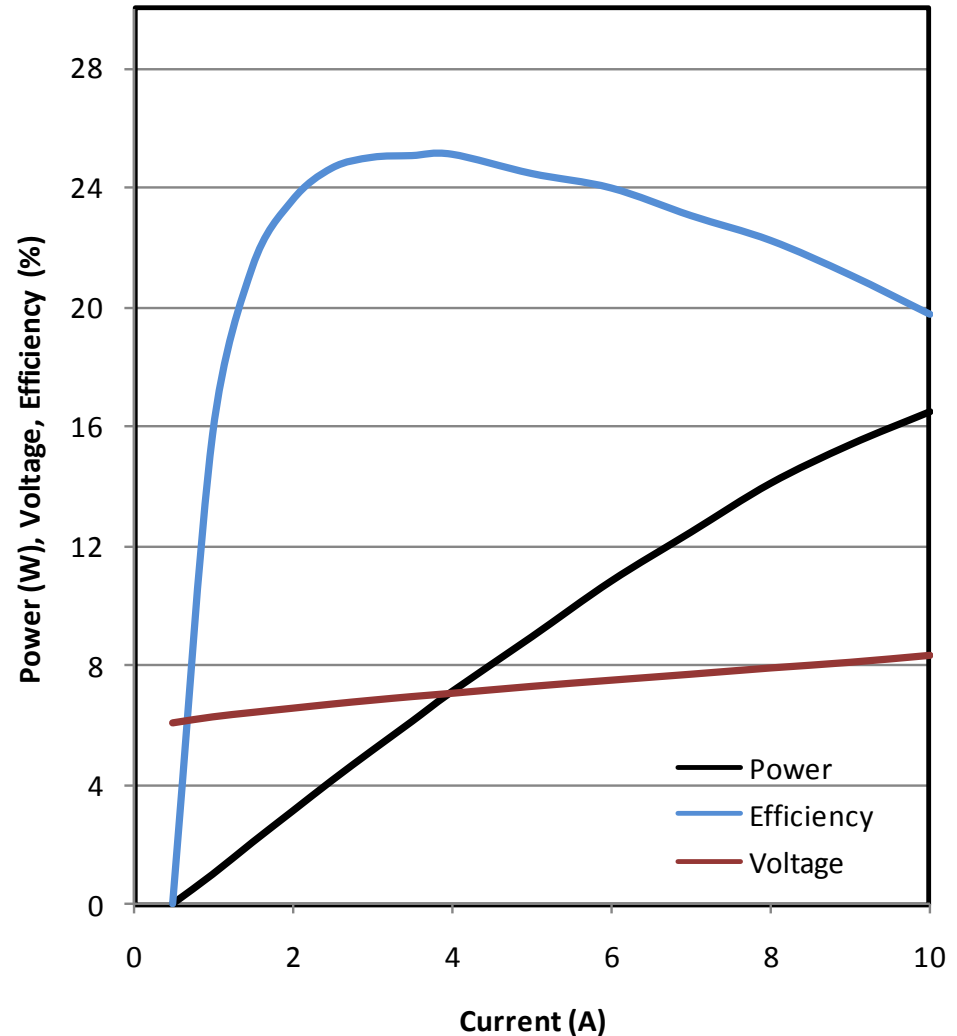
100um, 0.14 NA, 15xx nm

Power up to 15 W (single polarization)

Demonstration of Er fiber laser pumping

>30 W of optical power possible with polarization multiplexing

Brilliance = 3.5 MW/cm²-str



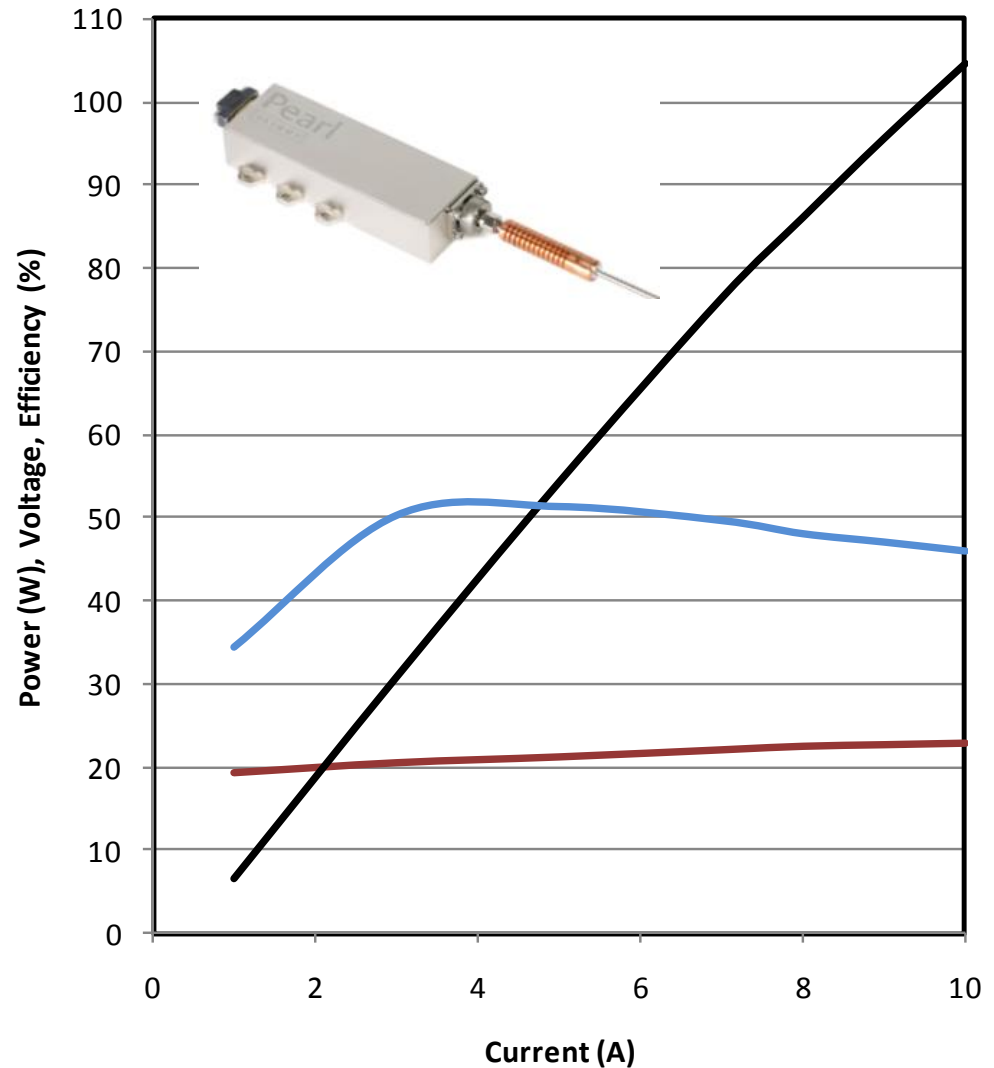
Ultra-high brilliance fiber laser pump

100W, 105um, 0.15 NA

Brilliance = 20 MW/cm²-str

<2% cladding light

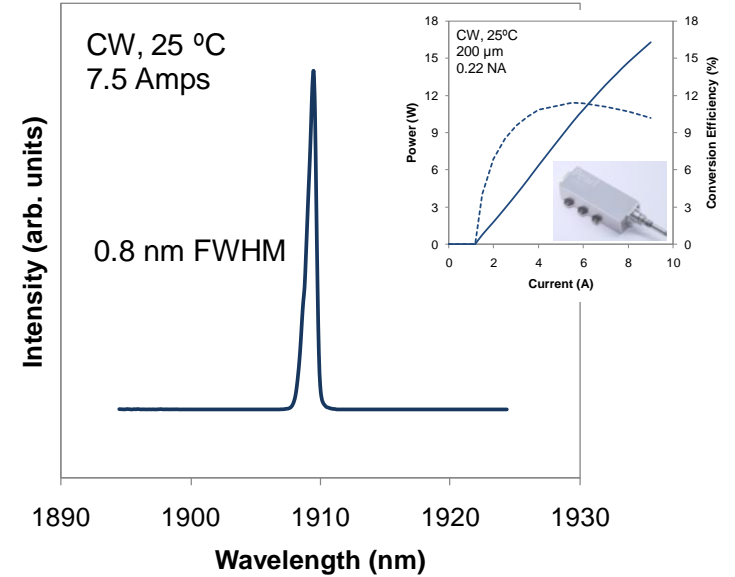
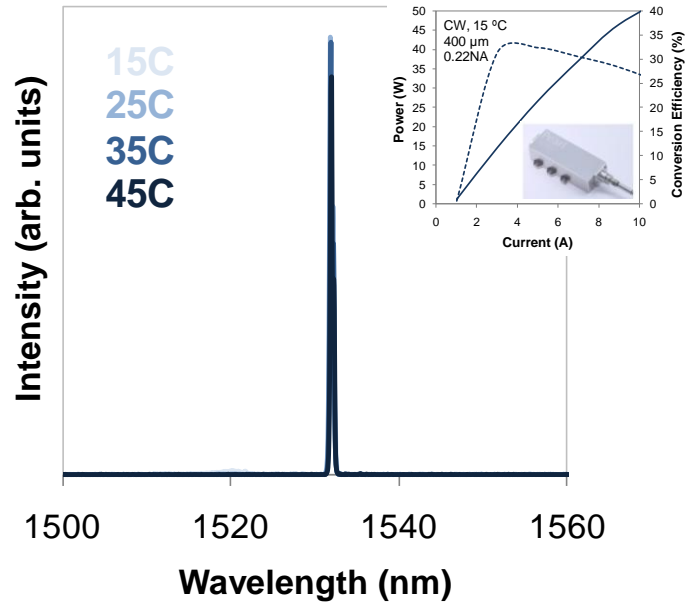
>45% E to O efficiency



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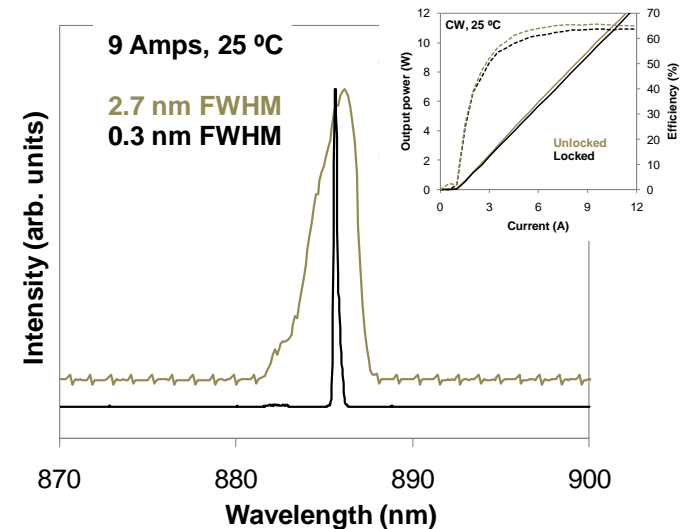
Wavelength stabilization available across the spectrum



Spectral locking developed across the spectrum

Little to no power/efficiency penalty

Highest efficiency wavelength locked devices



Conclusions

▪ **Developments in high brightness packages**

- Efficiency is driving key metrics of performance, reliability, and operating cost
- SE-based architectures recognized as best path for high brilliance systems
- Reliability of packaged devices and single emitters show no statistical difference

▪ **Pumping developments**

- SE pumps offer highest reliability and high brightness packages
- Brilliant packages demonstrated from 79x to 15xx nm
- Extremely compact designs realized at powers >500 W
- Near-zero power penalty demonstrated for spectral stabilization

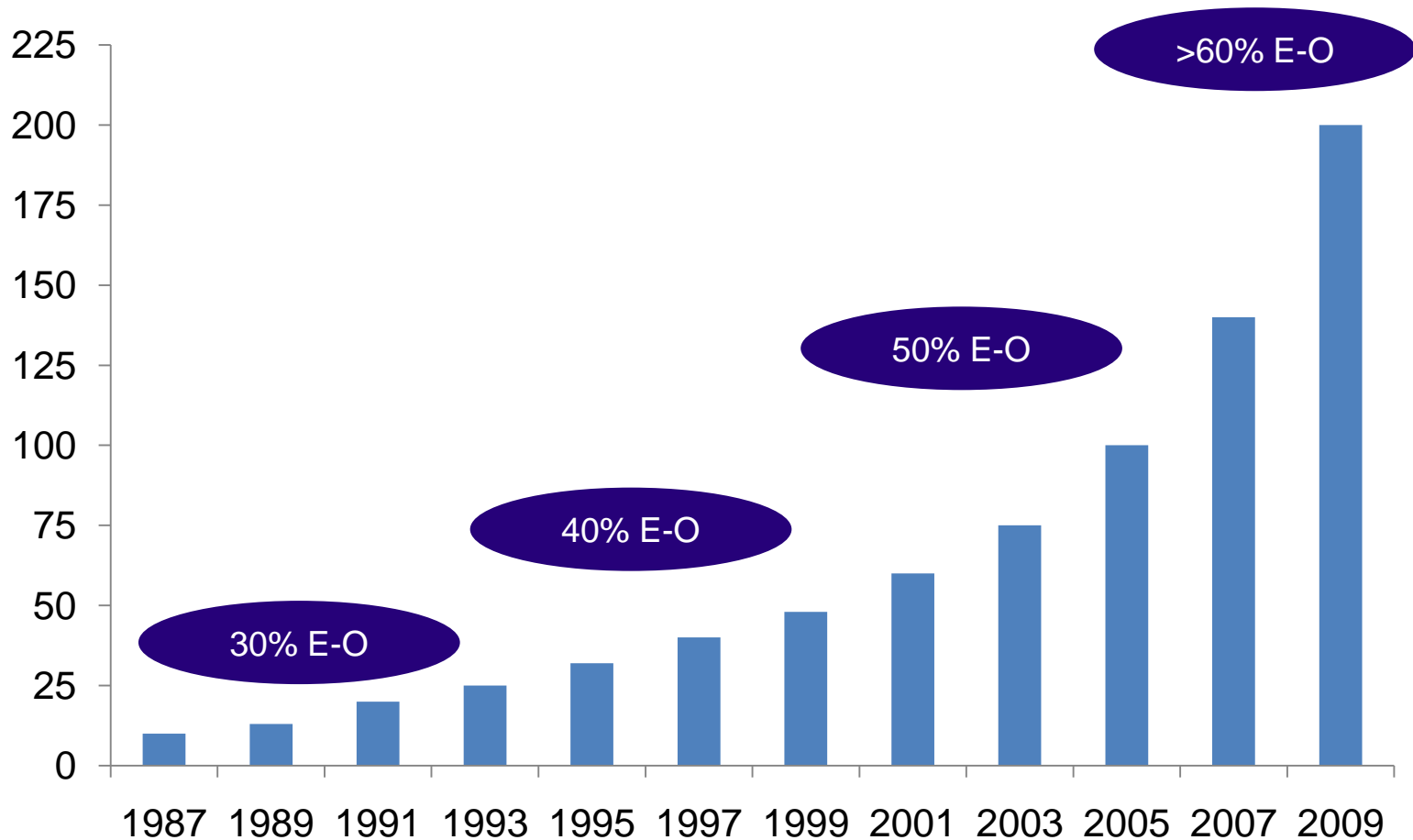
Thank you for your attention

Kirk Price
Product Development Manager
nLIGHT Corporation
kirk.price@nlight.net

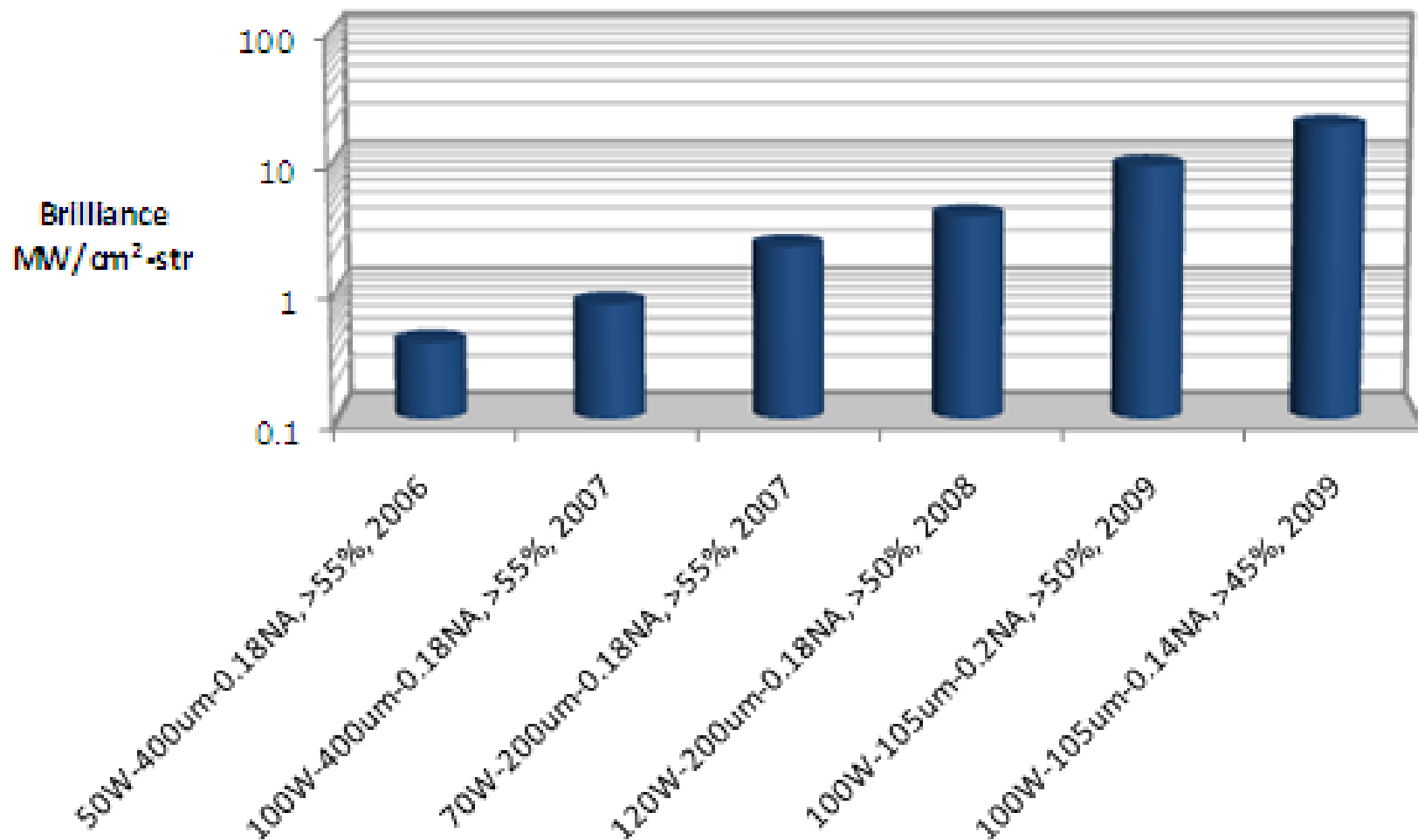
Performance driven by continued efficiency improvements

High Power Semiconductor Laser History

Watts / cm bar



Evolution of nLIGHT fiber coupled diode modules



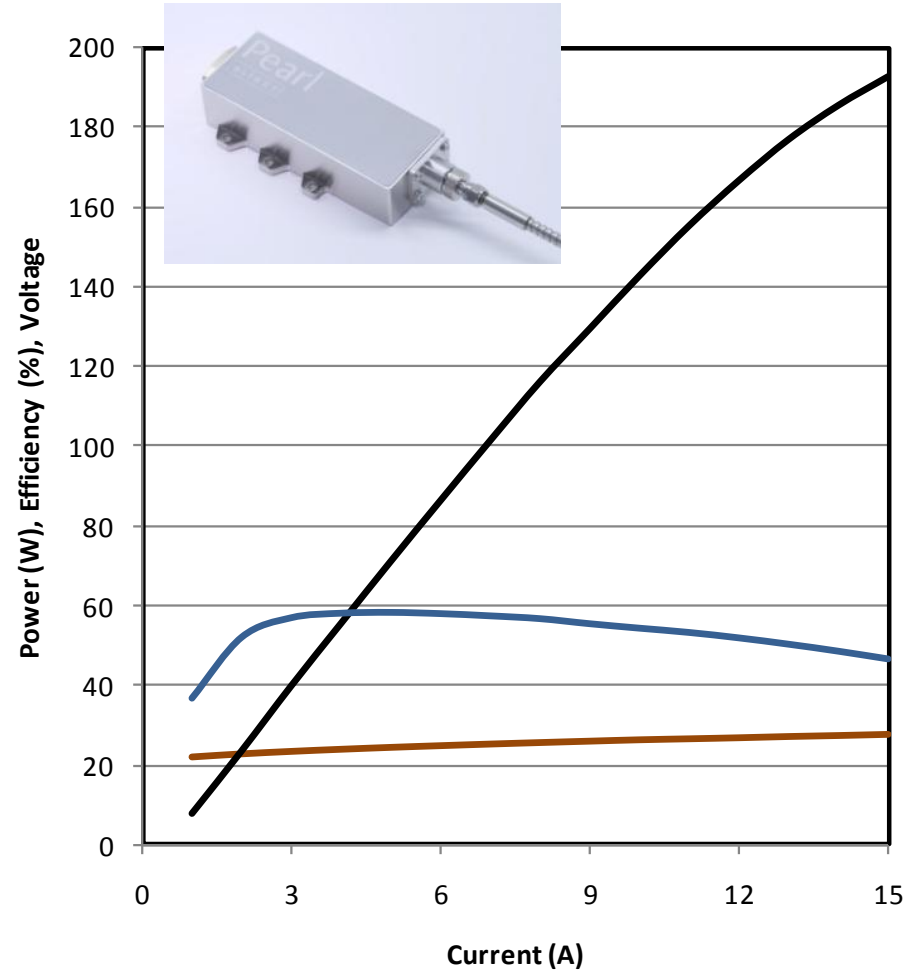
200um pump module, 0.18 NA, 9xx nm

> 50% WPE at 160 W output power

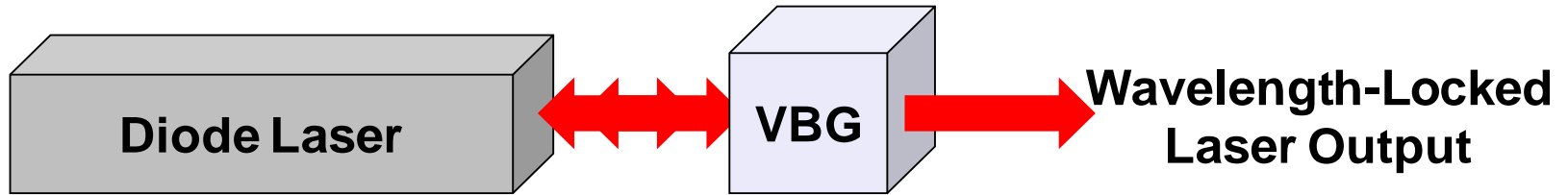
Small form factor

3.5 nm spectral width typical

No fused fiber combiners

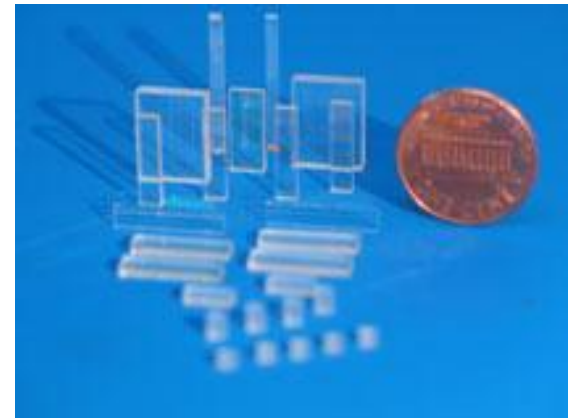


Wavelength Locking: External volumetric gratings



Motivation for *external* VBG locking:

- Optimize epi design for high brightness, efficiency
- Narrower spectral linewidth possible
- Most cost-effective method to wavelength stabilize devices



<http://www.ondaxinc.com>

Technology enables temperature stabilization and line narrowing