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KW-class Industrial Lasers Comprised of Single Emitters

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Outline

- Overview of industrial diode laser systems
- Fiber coupled single emitter packages
- KW approaches
- Demonstrations
- Conclusion

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History - diode laser architectures for industrial applications

Technology Progression

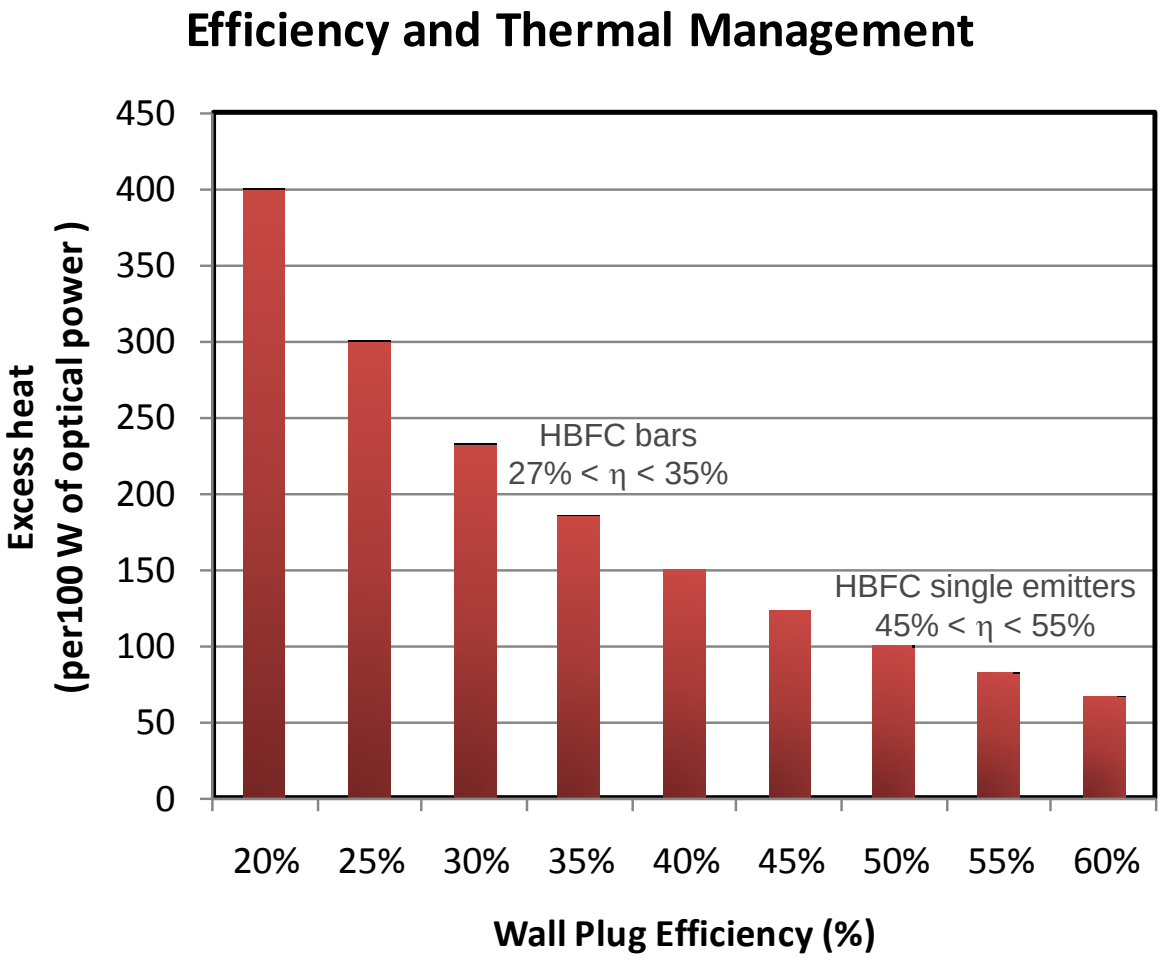
- Future of laser diode systems: efficiency, brightness, and reliability
- Single emitter-based technology
- Efficiency > 50%
- Passively cooled, no microchannel heat sinks

- First significant change in diode laser architecture
- Efficiency > 50%
- Passively cooled , no microchannel heat sinks
- CS bar based

- Direct water cooling required for 30-45% efficient bars
- Standard high power diode lasers
- Actively cooled micro-channel heat sinks
- Bar based laser diodes

1995 2002 2009

Diode laser efficiency in KW systems



Efficiency drives:

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

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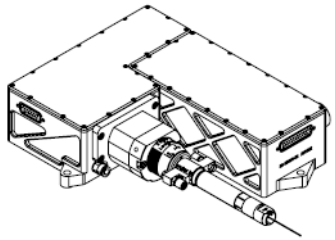
Broad range of industrial building blocks

75 W, 20 mm-mrad

140 W, 20 mm-mrad

120 W, 10 mm-mrad

500W, 20 mm-mrad



600W, 30 mm-mrad

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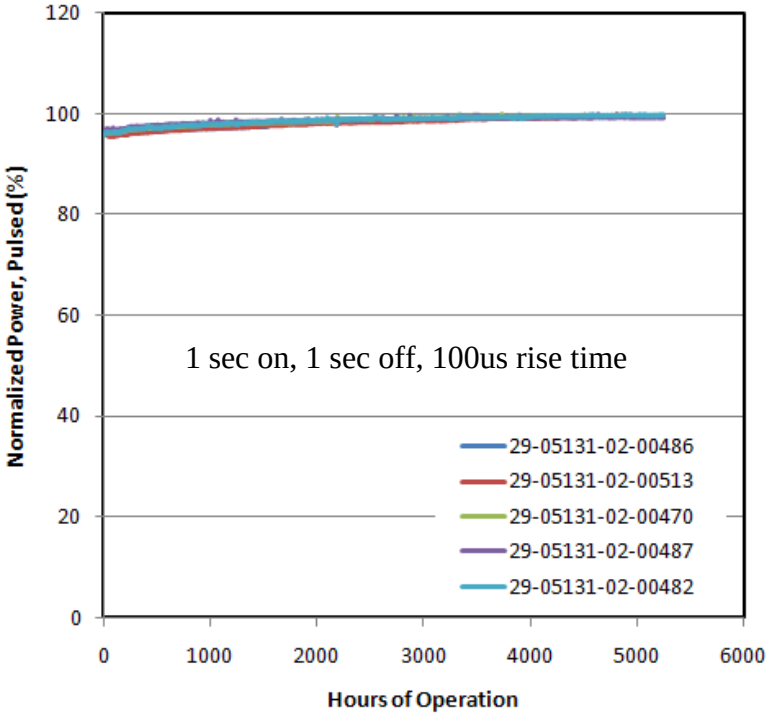
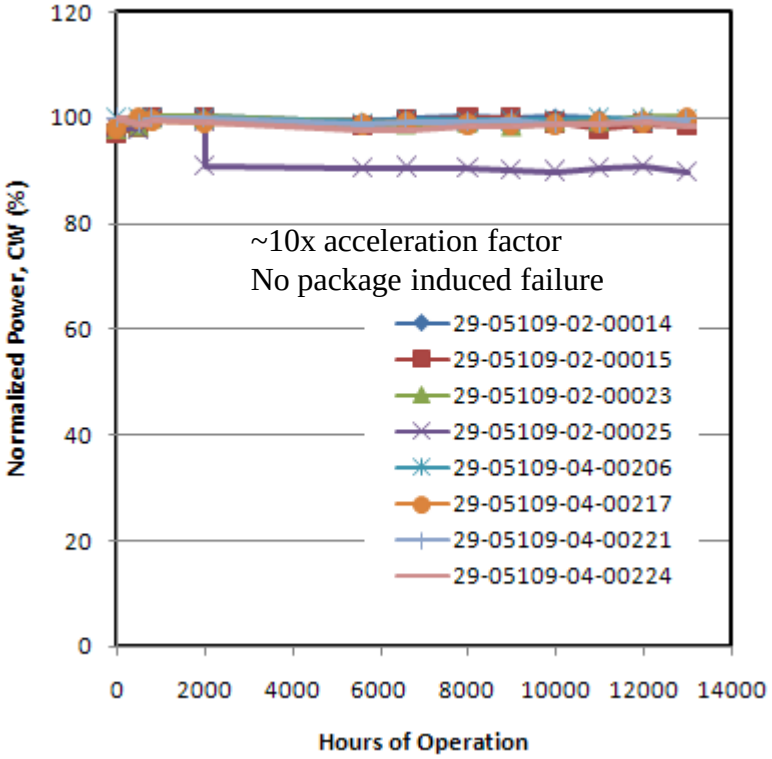
Reliability of single emitter packages

- Series-wired single emitters – soft degradation mode
- Strong reliability under pulsed operation
- High O to O leads to lack of PIF





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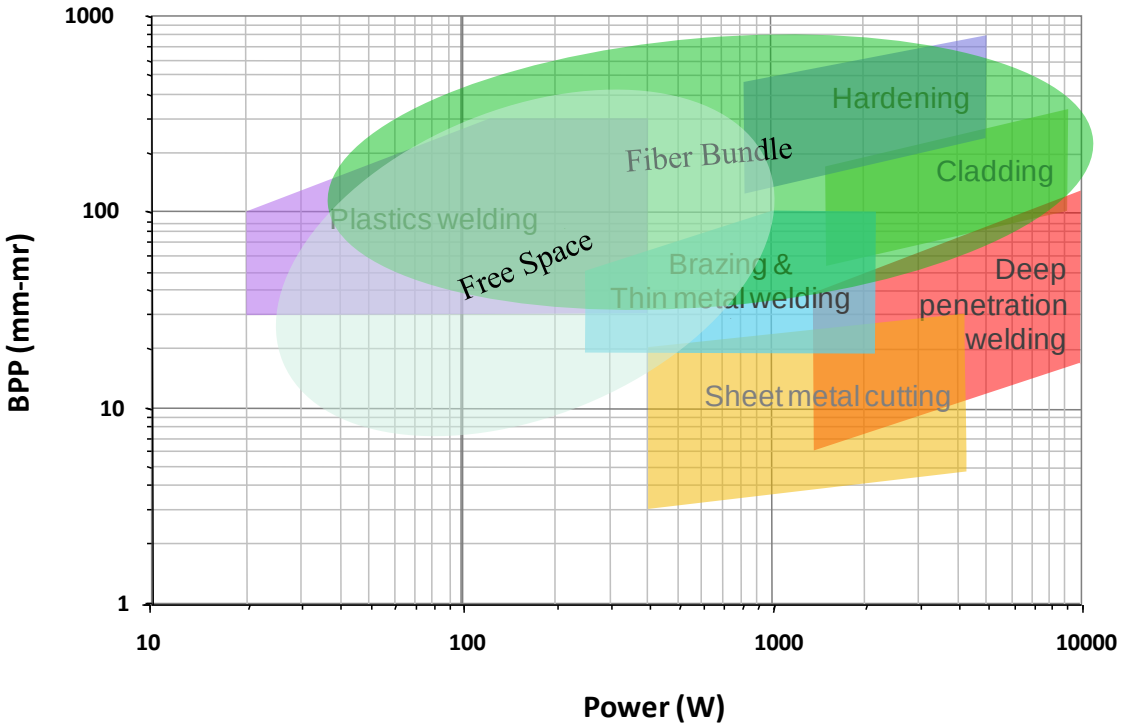
KW-level beam combination methods

Free space beam combination

- Provides optimal BPP preservation from diode to fiber
- Marriage of optics and mechanics
  - Can be space and cost intensive

Fiber Bundle

- Easily scalable
- Few parts – highly reliable design
- Reduced BPP preservation due to cladding and interstitial loss



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Fiber bundle concepts

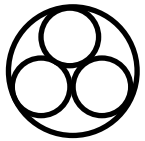
Brightness preservation

- Interstitial and cladding brightness loss

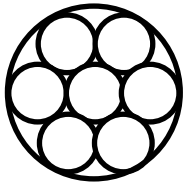
Constant efficiency with scaled output power

Power: 100W
BPP: 10
Efficiency: 50%

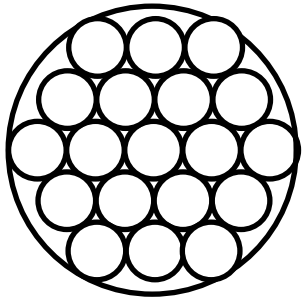
Power: 100W
BPP: 10
Brightness: 100%
Efficiency: 50%



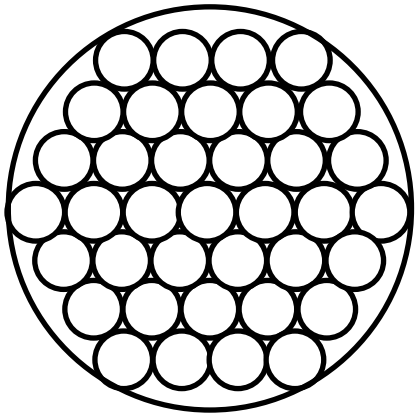
Power: 300W
BPP: 20
Brightness: 60%
Efficiency: 50%



Power: 700W
BPP: 30
Brightness: 68%
Efficiency: 50%



Power: 1900W
BPP: 50
Brightness: 65%
Efficiency: 50%



Power: 3900W
BPP: 70
Brightness: 67%
Efficiency: 50%

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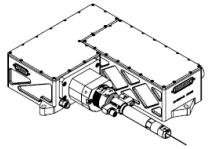
Application space versatility with different building blocks

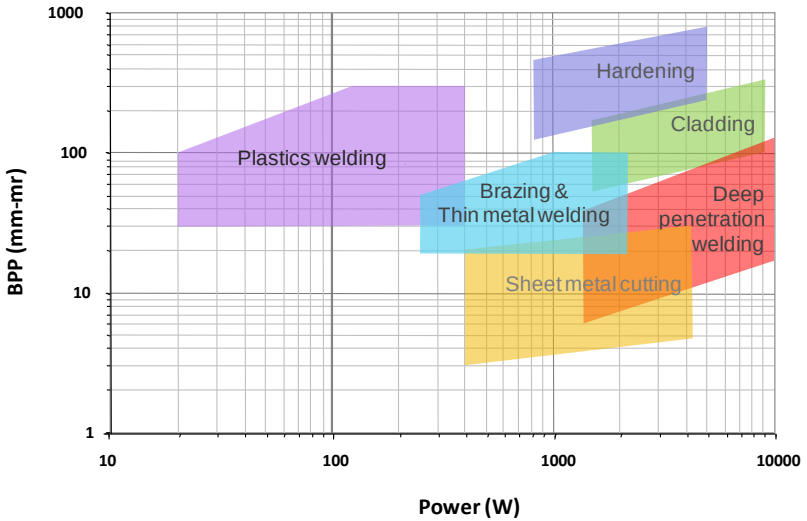


Brightness Preservation for Fiber Bundles												
Number of Elements	P16, 200um, 0.2 NA			P14, 200um, 0.1 NA			P14, 105um, 0.14 NA			P72, 200um, 0.2 NA		
	Power (W)	BPP (mm-mrad)	Brightness (MW/cm2-str)	Power (W)	BPP (mm-mrad)	Brightness (MW/cm2-str)	Power (W)	BPP (mm-mrad)	Brightness (MW/cm2-str)	Power (W)	BPP (mm-mrad)	Brightness (MW/cm2-str)
1	140	20	3.5	110	10	10.1	100	7.5	18.8	500	20	12.7
3	420	42	2.1	330	21	6.1	300	16	10.3	1500	42	7.6
7	980	60	2.4	770	30	6.9	700	22.5	11.5	3500	60	8.7
19	2660	100	2.3	2090	50	6.6	1900	37.5	10.7	9500	100	8.3
39	5460	140	2.4	4290	70	6.8	3900	52.5	11.0	19500	140	8.6

Ultimate flexibility in power and beam quality to optimize for given application

Efficiency remains constant at >= 50%



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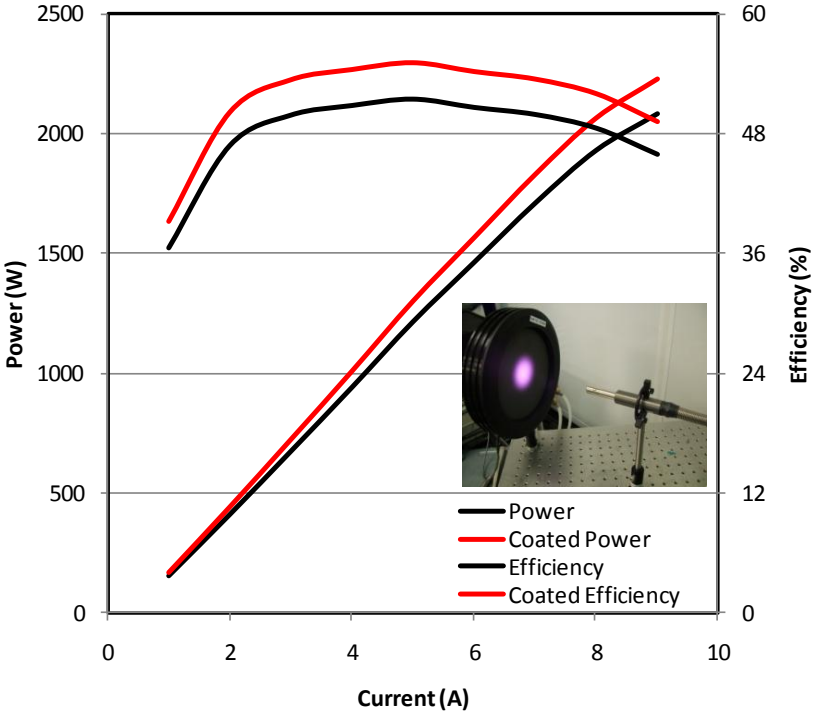
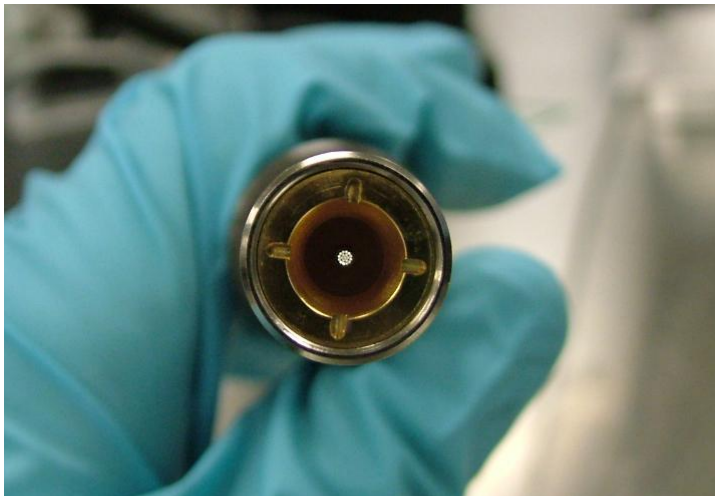
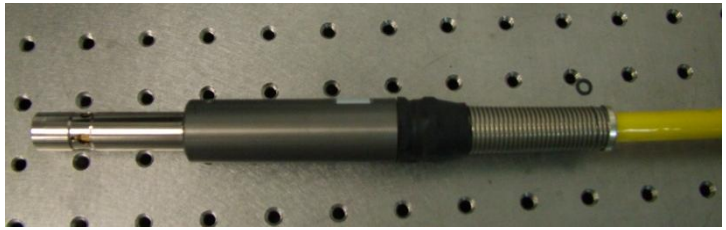
Viability of fiber bundle technology

- Fiber bundle integrated in robust, industrial-grade package with armor jacketing
- Fiber to fiber coupling module used to homogenize beam
- >2 KW achieved from 100 mm-mrad BPP
- Easily scalable to higher brightness







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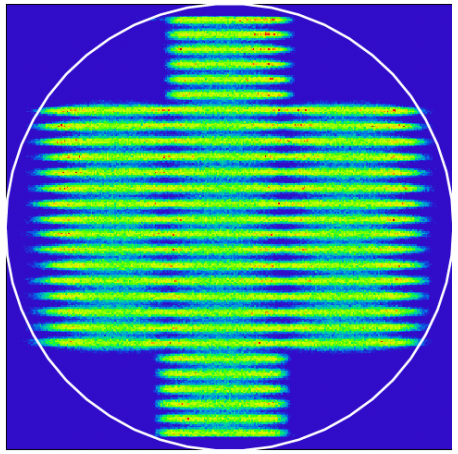
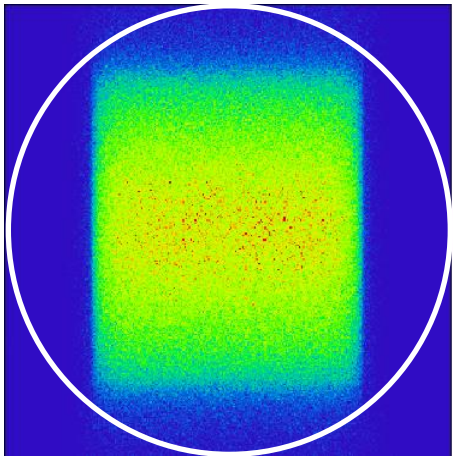
Free space beam combination leads to high brightness sources

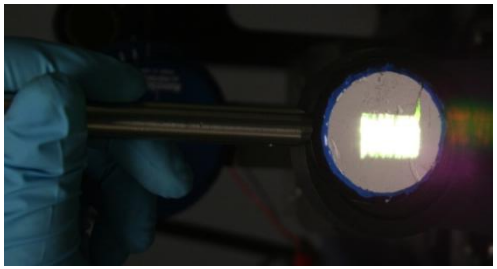
- Optimal beam quality preservation with very little dead space
- Flexibility with use of building blocks
- Excellent preservation of diode brightness and efficiency

Example of filling NA space

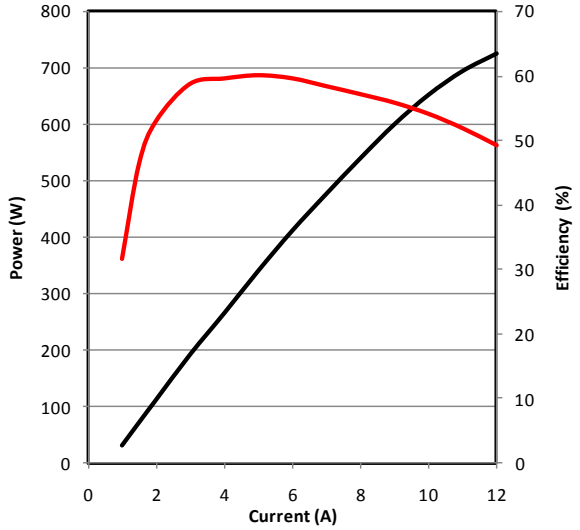


Focused spot on fiber





LI of afocal building block



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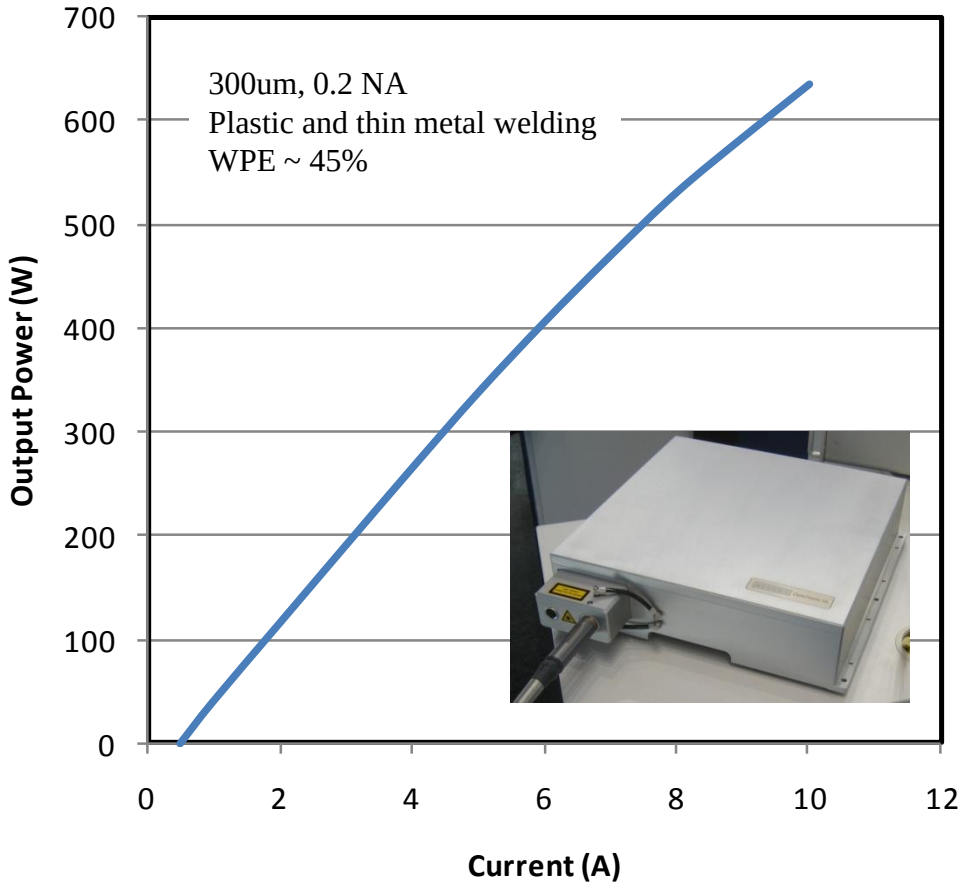
600 W released product and free-space building block

- >500W CW at >45% WPE
- 30 mm-mrad
  - Single wavelength
  - Single polarization
- Industry leading efficiency and reliability
- Modular power scalability
  - Up to 1 kW 1λ to 4 kW 4λ
  - Path to 4 kW 30 mm-mrad with UHB diodes and Pearl modules



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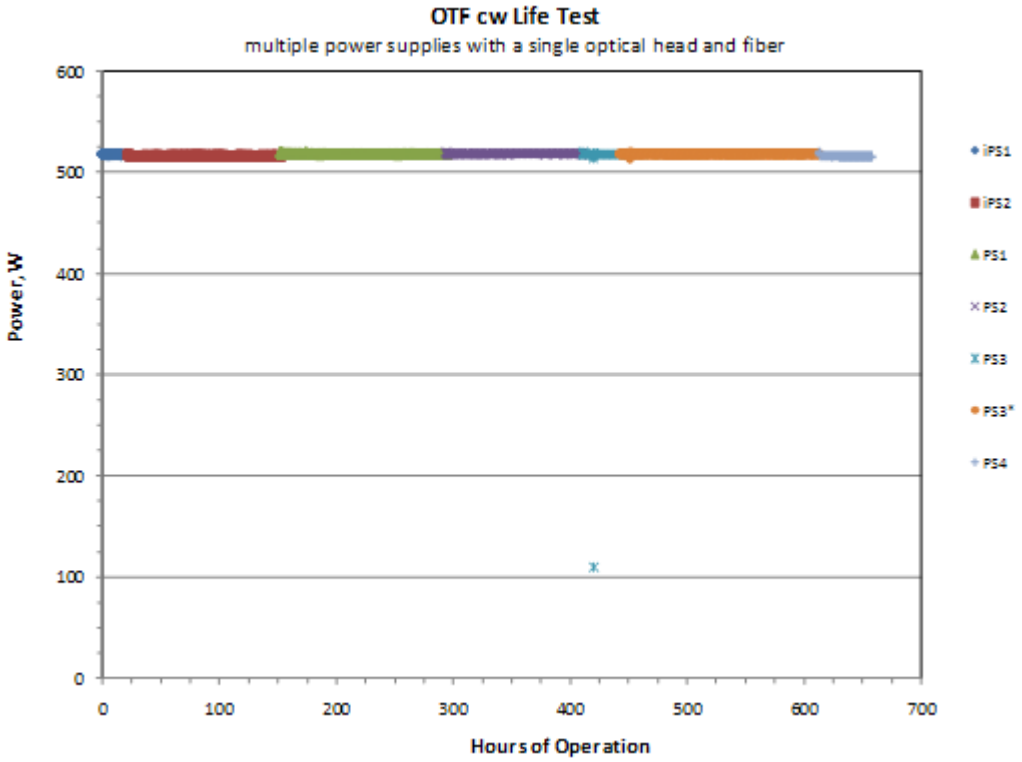
System reliability

- Undergoing TUV testing & CE marking of laser head and power supply
- Designed for use in plastics welding, thin metal welding, and pumping applications
- Industrial features
  - Power monitoring
  - Aiming beam
  - Fiber breakage monitor
  - Control electronics and drivers



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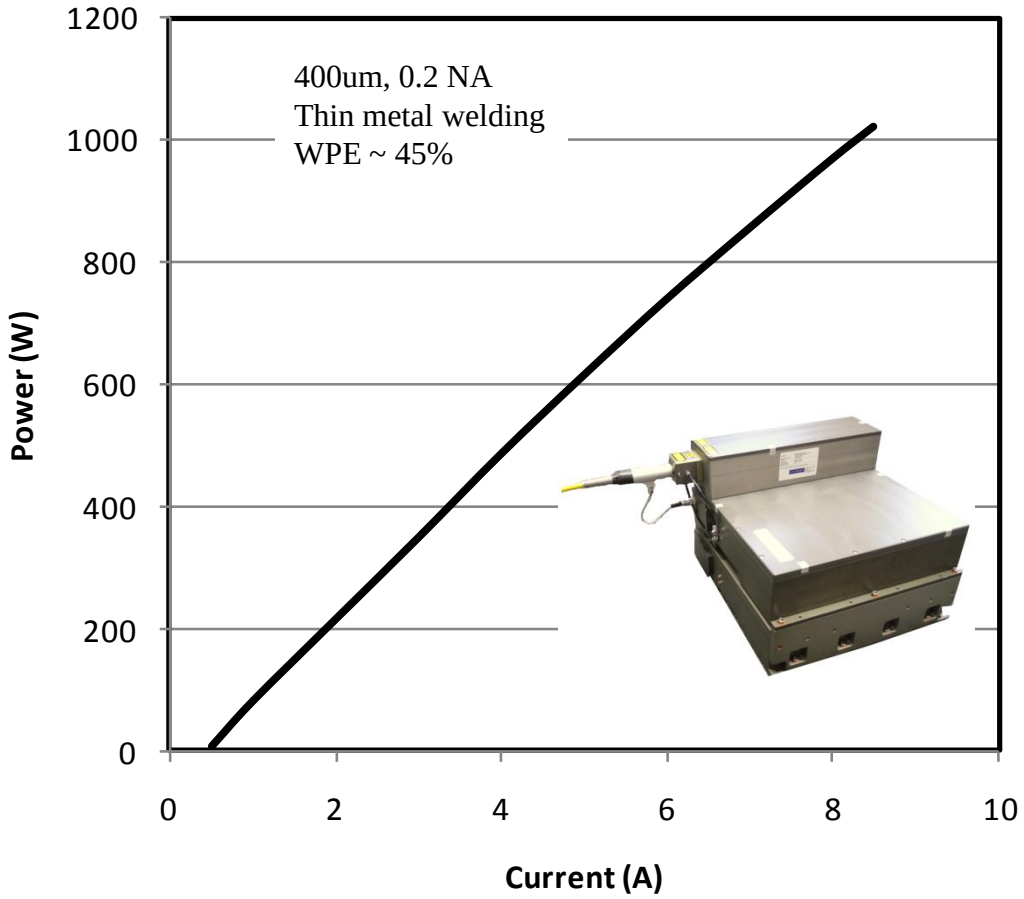
Free-space single emitter-based KW demonstration

- Polarization or wavelength multiplexing to achieve 1 KW
- Stacking of two 500W modules
- Excellent preservation of beam quality, brightness, and efficiency
- Multiple systems deployed in an industrial manufacturing environment



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Conclusions

- nLIGHT is actively pursuing direct diode lasers for industrial applications
- Requirements for high brightness and high power systems
  - Free-space optics have optimal brightness
  - Fiber bundles provide easy power scalability
- Both approaches demonstrated to power levels in the KW range

Thank you for your attention

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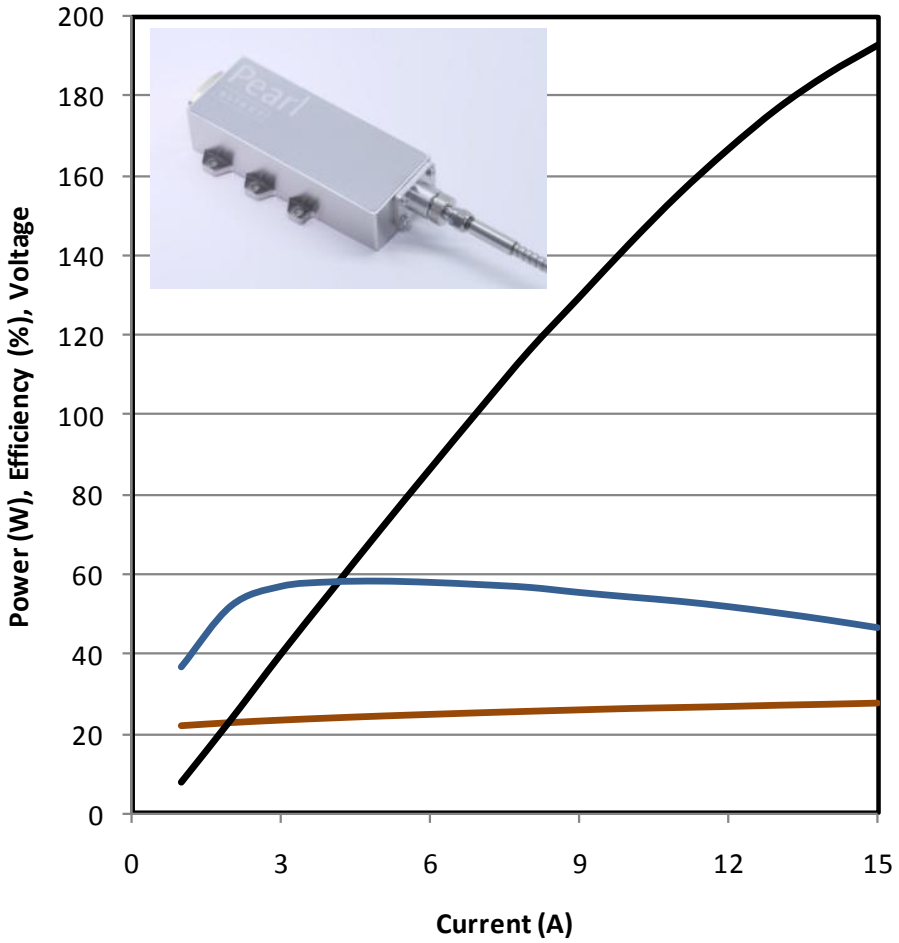
200um fiber laser pumps, 9xx nm

- > 50% WPE at 160 W output power
- Small form factor
- Brilliance = 4.3 MW/cm^2-str
- Available from 910 to 980 nm
- 3.5 nm spectral width typical
- No fused fiber combiners



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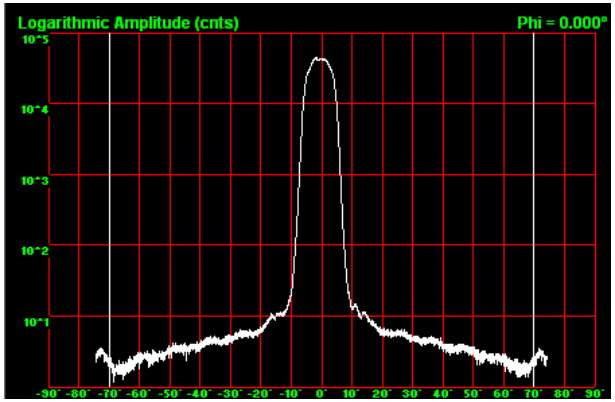
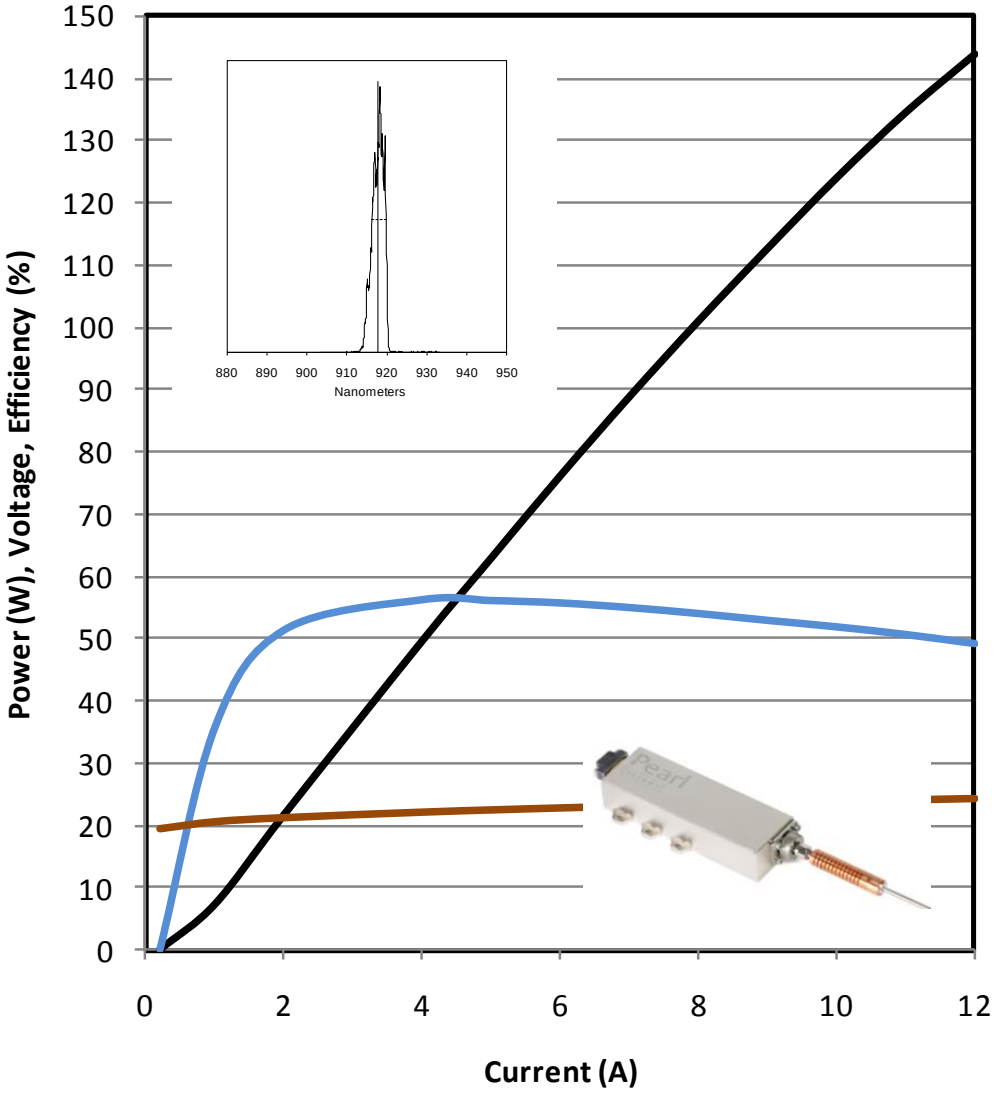
Low NA fiber laser pump source, 200um, 0.1 NA

- 120W, 200um, 0.10 NA
- Brilliance = 14 MW/cm^2-str
- Excellent direct diode source
- <2% cladding light
- 35 dB 1um isolation
- Enabled novel pump coupling architectures





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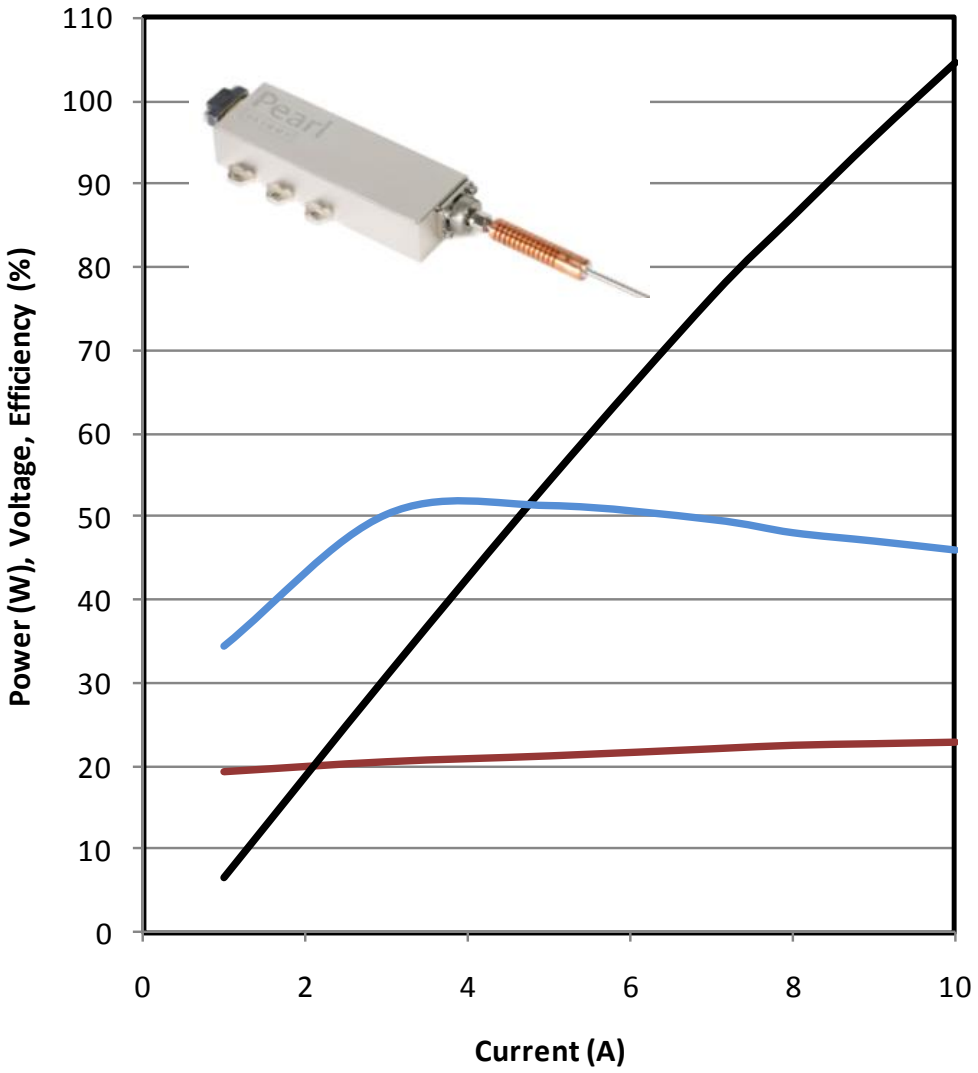
Ultra-high brilliance fiber laser pump

- 100W, 100um, 0.14 NA
- Brilliance = 20 MW/cm^2-str
- <2% cladding light
- >45% E to O efficiency
- Compact footprint: 140x50x22 mm
- Also available in100um format:
  - 14xx nm
  - 15xx nm



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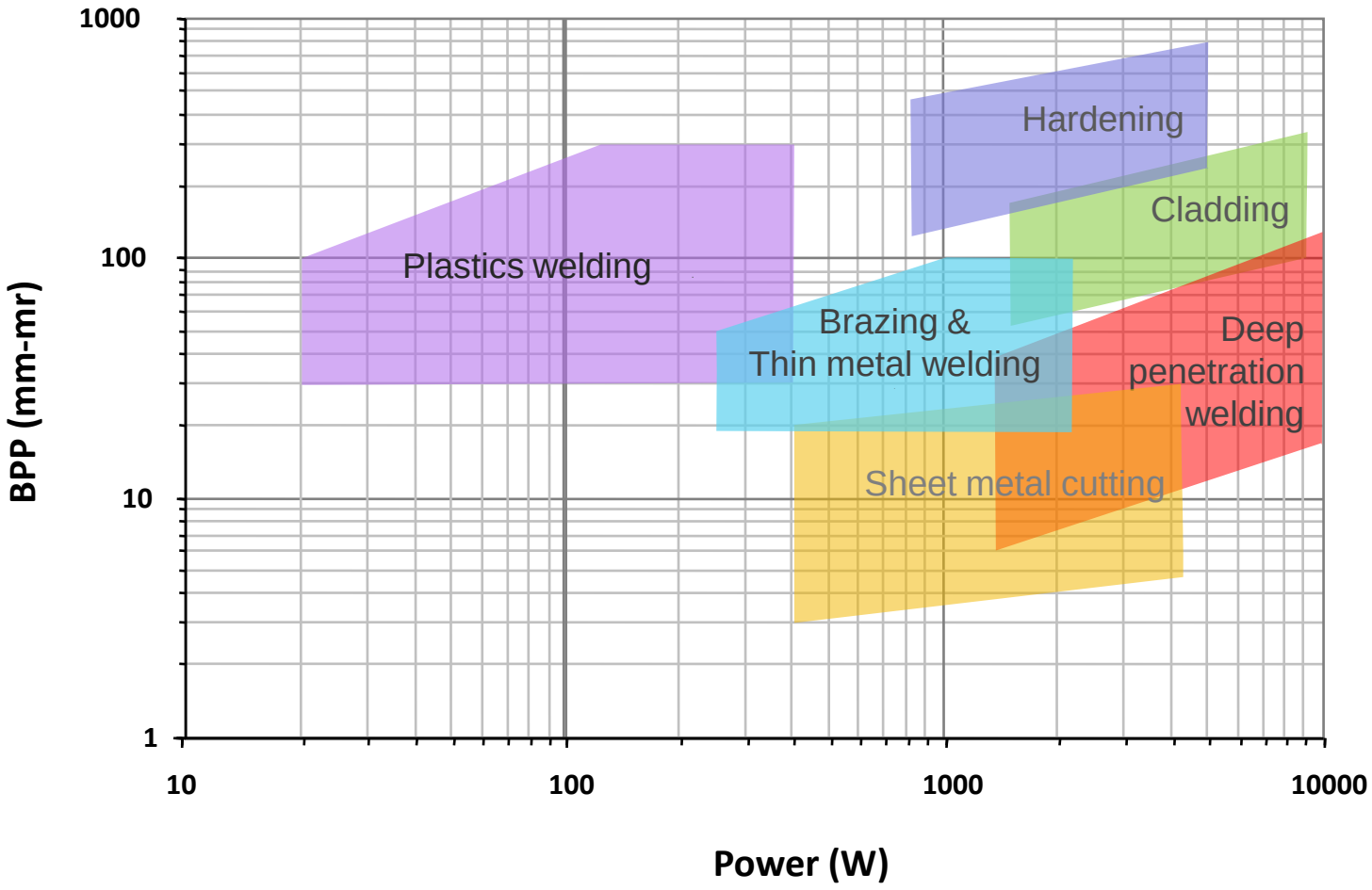
Industrial laser application space



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Summary slide from Ling's reliability talk

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