

n LIGHT

Diode Laser Efficiency Increases, Enables > 400-W Peak Power from 1-cm Bars, Shows Clear Path to Peak Powers in Excess of 1-kW

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- *Work to improve \$/W through increased power per bar is supported by **AFRL** under contract number: FA9451-04-D-0354*





- **nLight Overview**
- **Survey of peak bar performance across wavelength**
- **Projected path to increased power**
- **Experimental progress**
 - Includes update on high efficiency devices
- **Cryogenic Results**
- **Conclusions**

nLight Overview

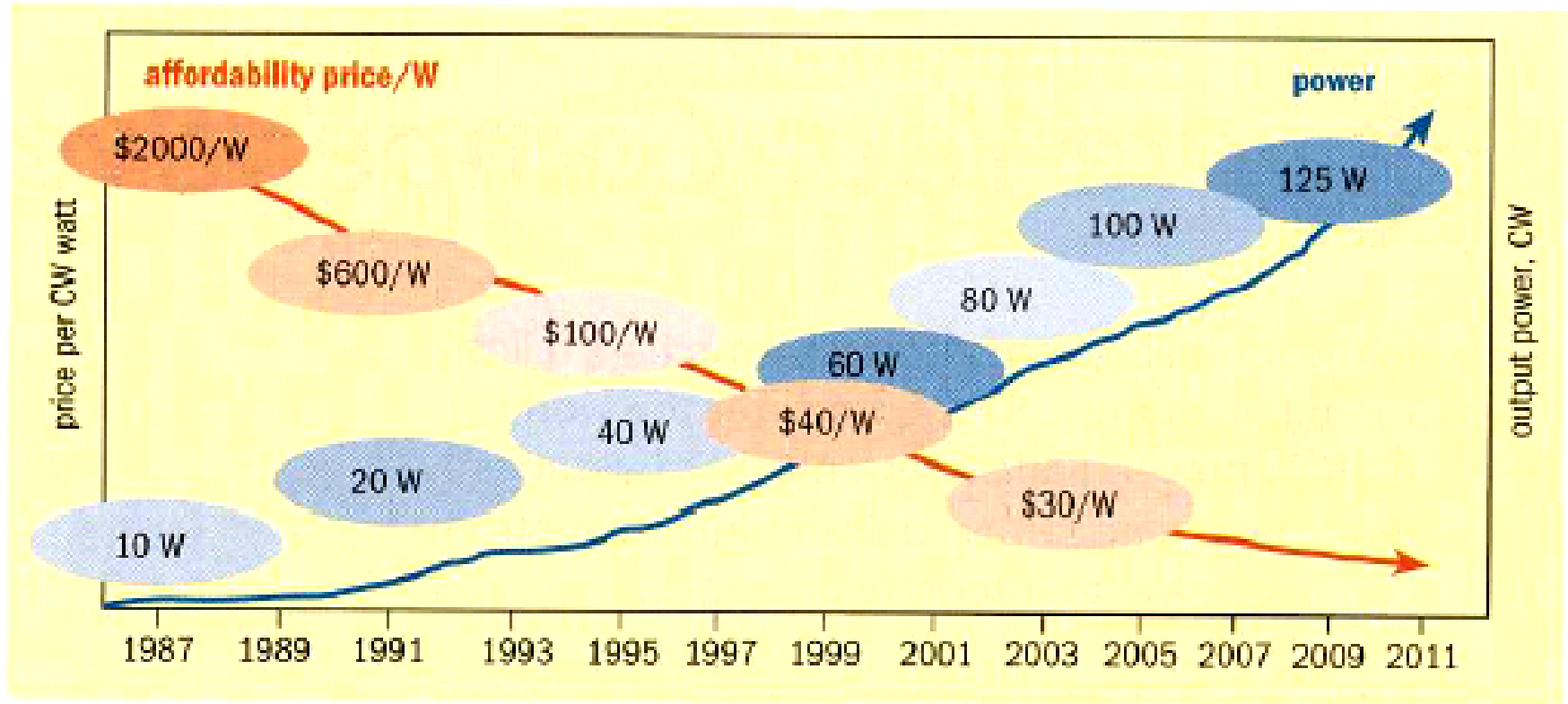


- **History**
 - Founded in 2000
 - Over 100 employees
- **Technology**
 - High power laser diodes from 630 to 1900 nm
 - Broad range of packages
- **Production**
 - 60,000 sq ft vertically integrated manufacturing facility
 - Complete capabilities with MOCVD through packaging

nLight's products range from several Watts to several tens of kW

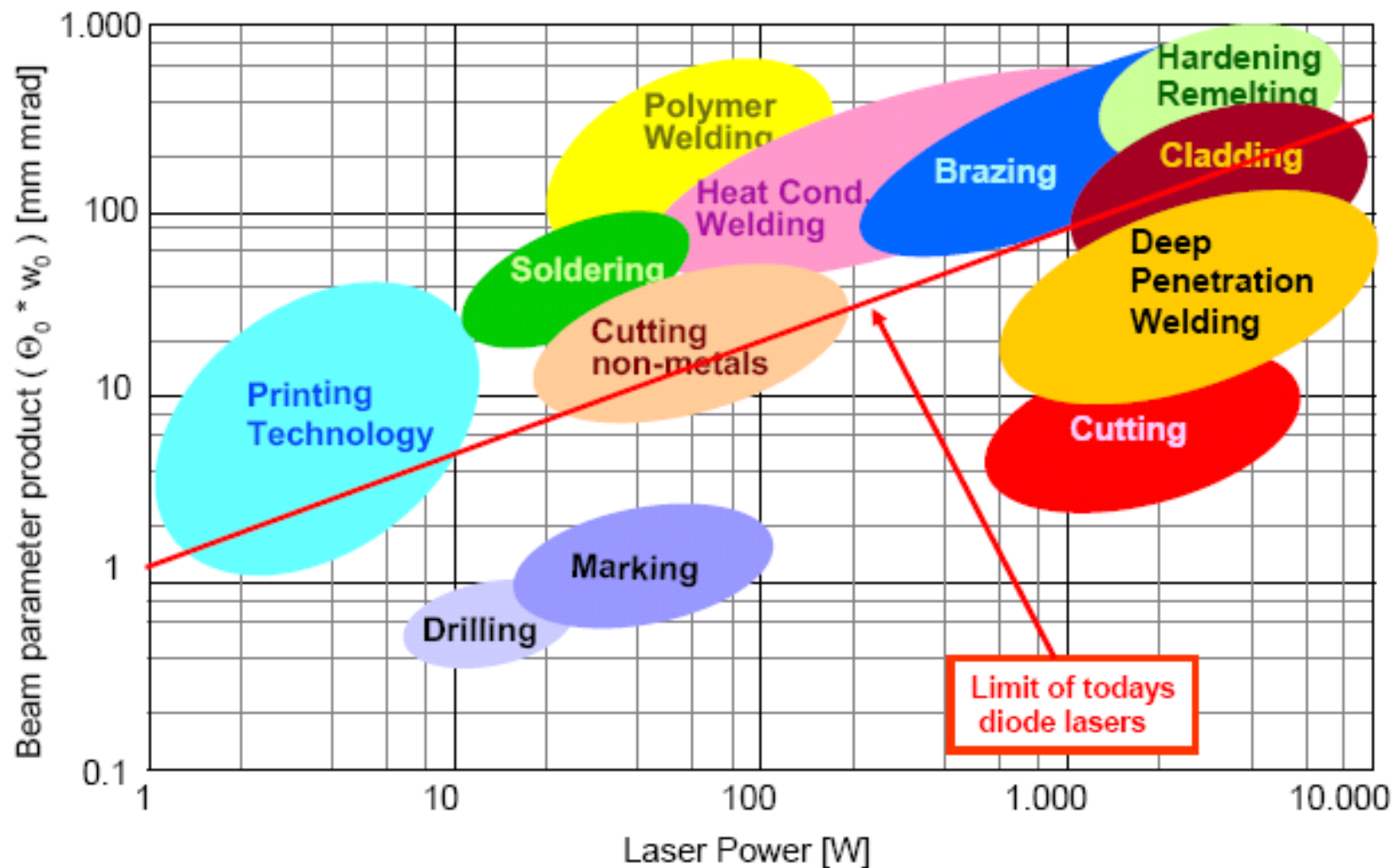
Product category	nLight product examples
Single Emitter Up to 7W	
Diode Arrays 40 to 100 Watts	
Stacks of Arrays >100W to many kW	
Fiber Bundled Arrays < 40 Watts	

Diode Laser Bar Performance And Cost Rapidly Improving

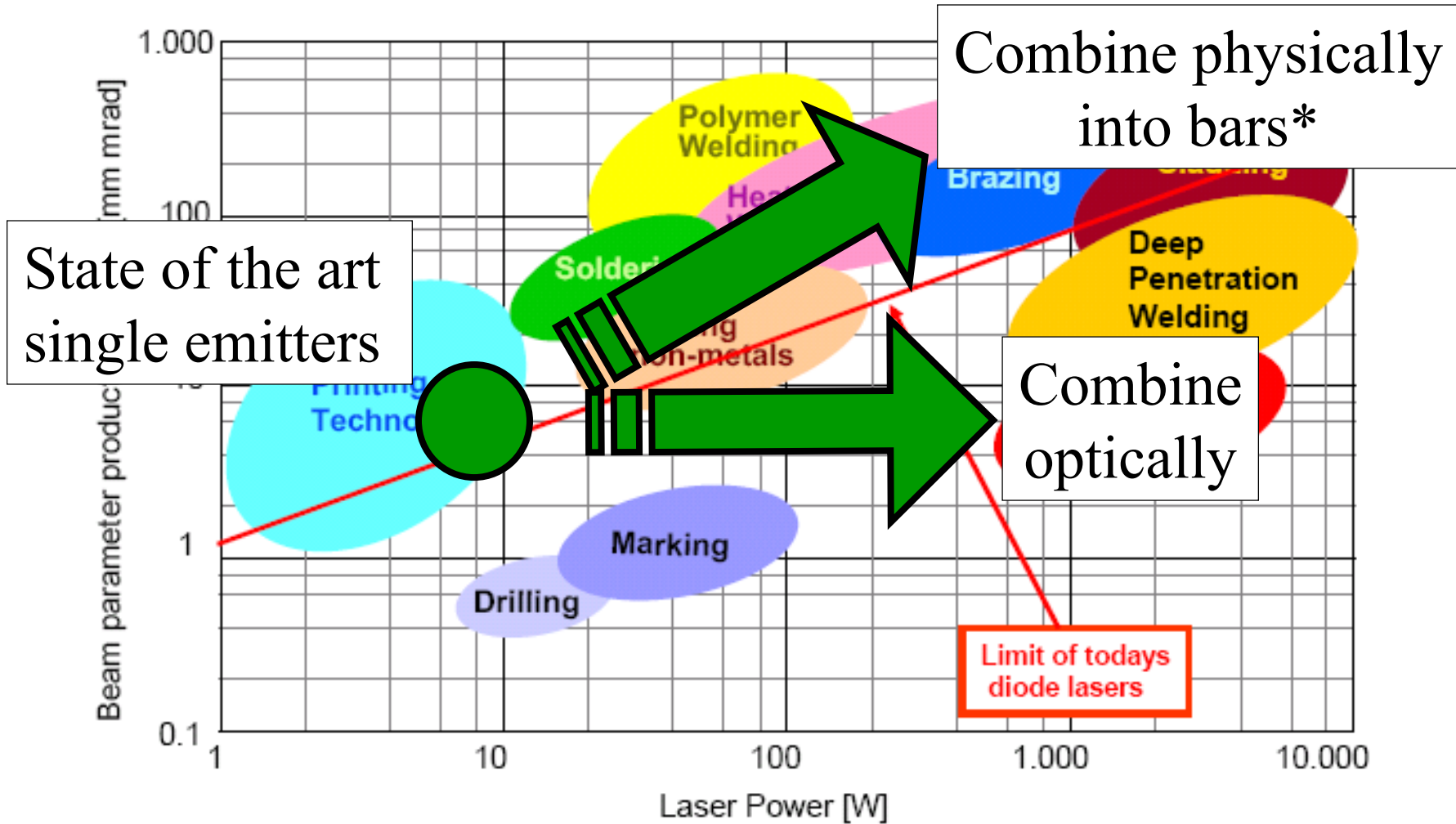


As power level per bar increases, \$/W falls

Segmentation of Market for Laser Material Processing

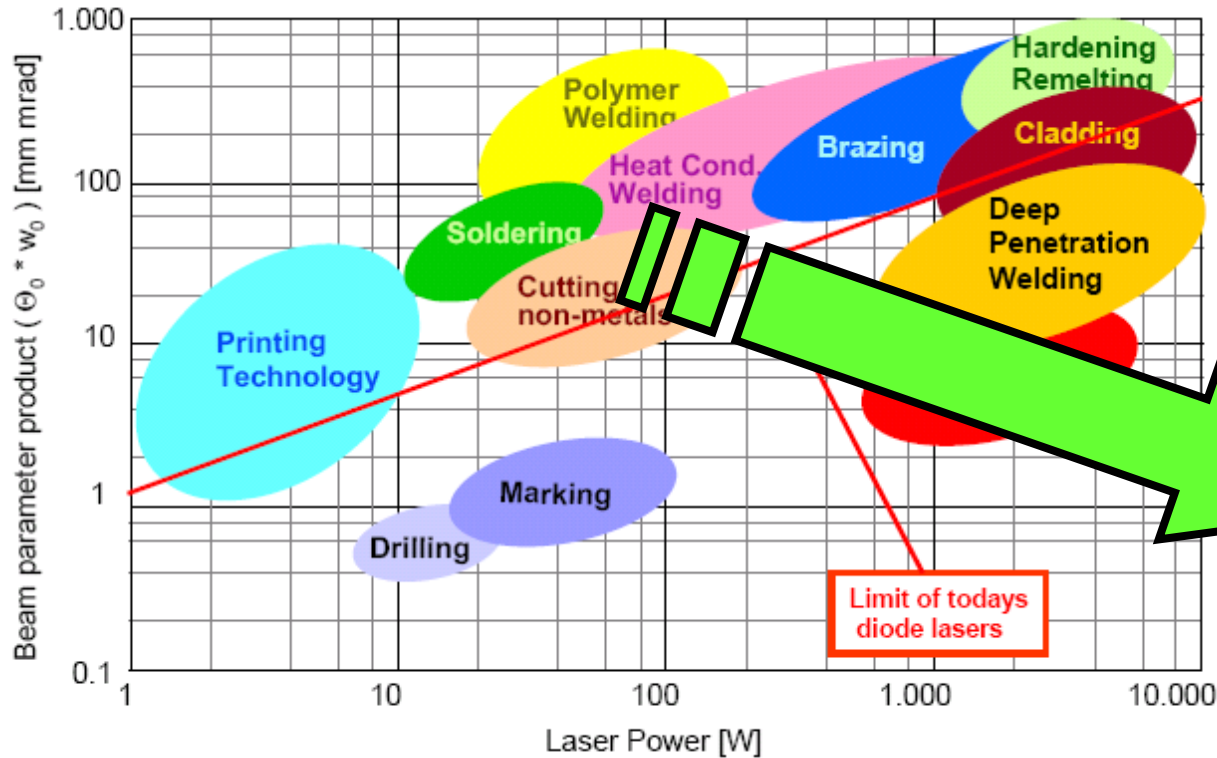


Single Emitters Allow Access to All These Markets



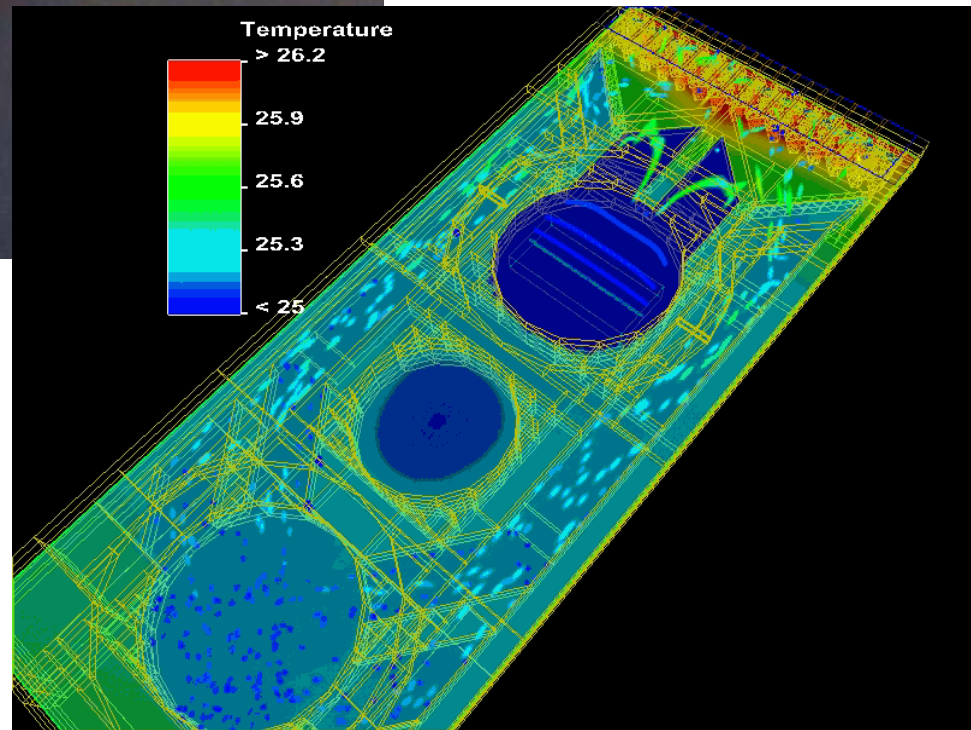
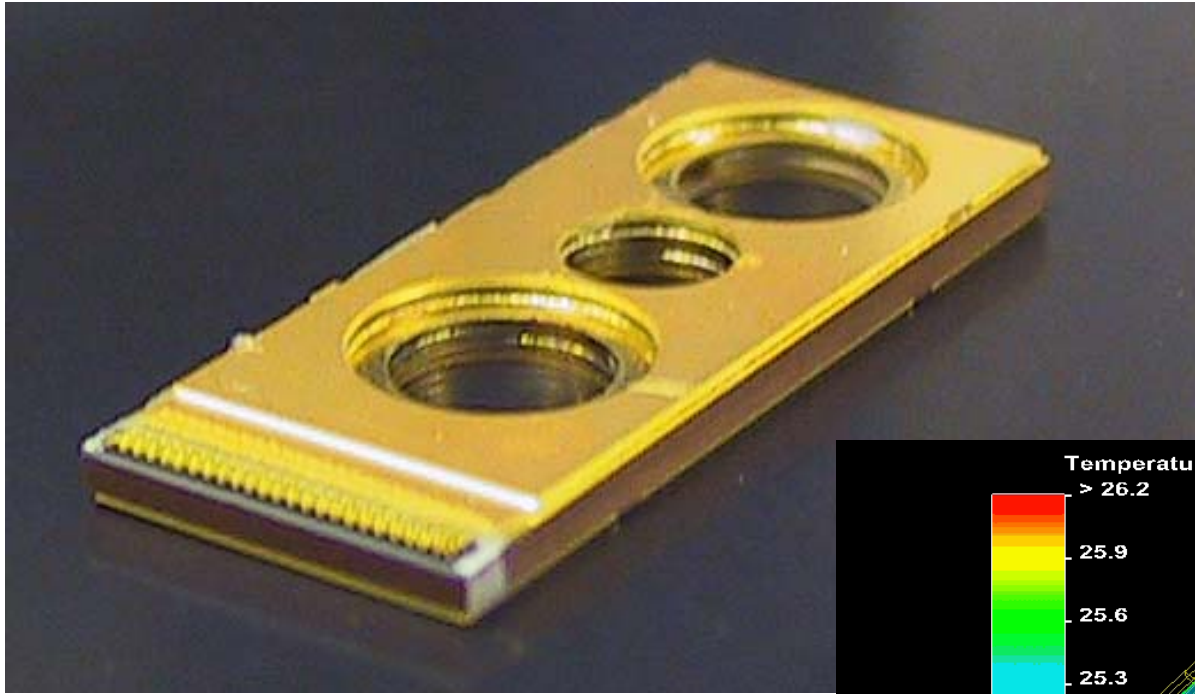
** The focus in this presentation*

DOD and Industrial Market Have Same Goal

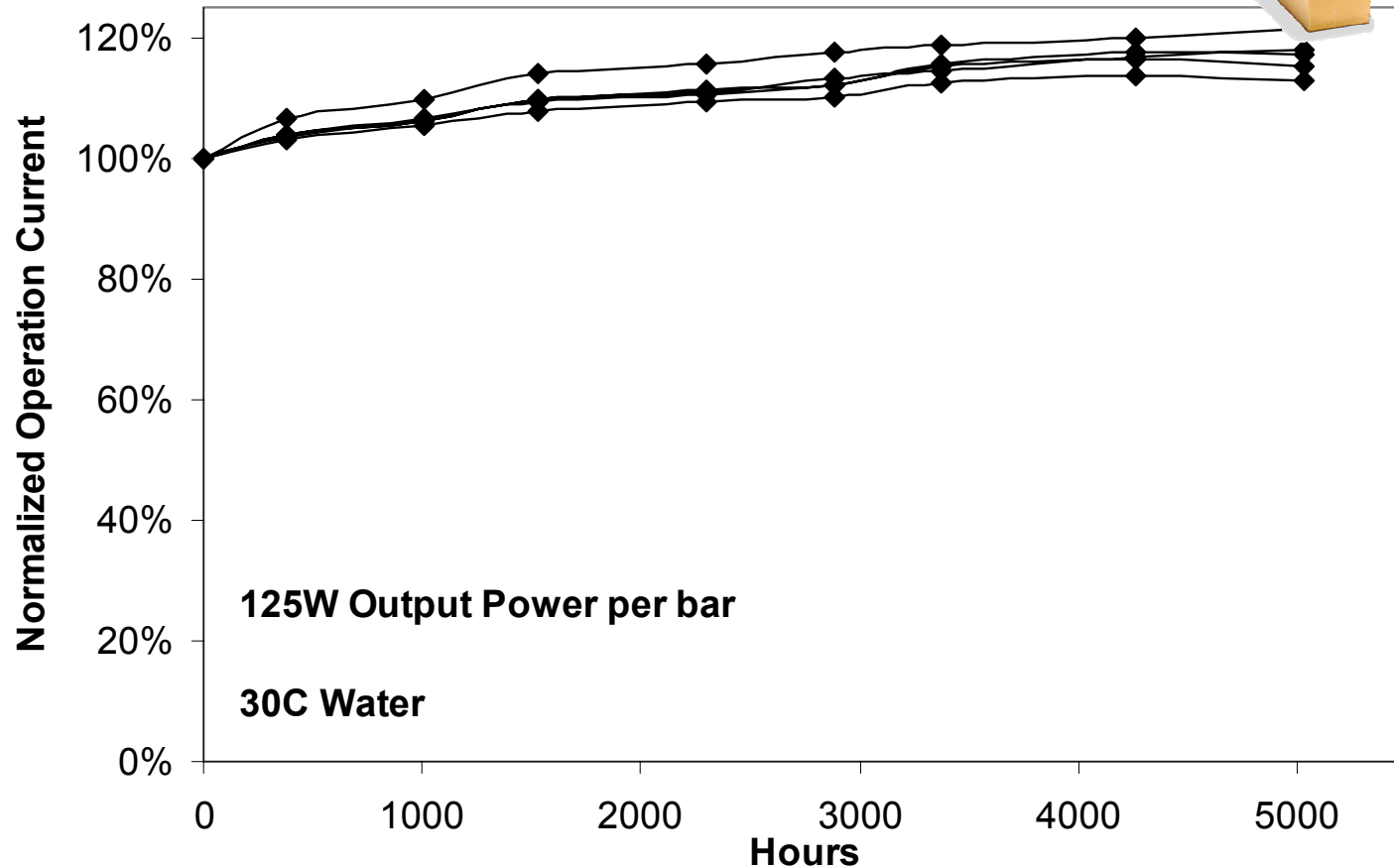
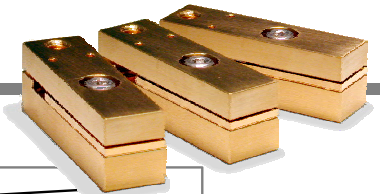


100kW
Laser
weapons

Water Cooled Micro-channel Heatsinks for Maximum Reliable Power



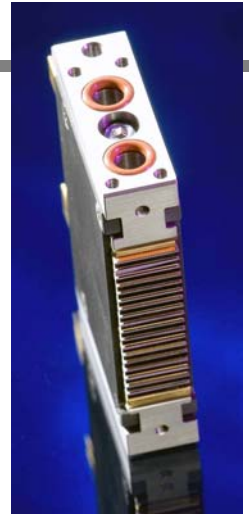
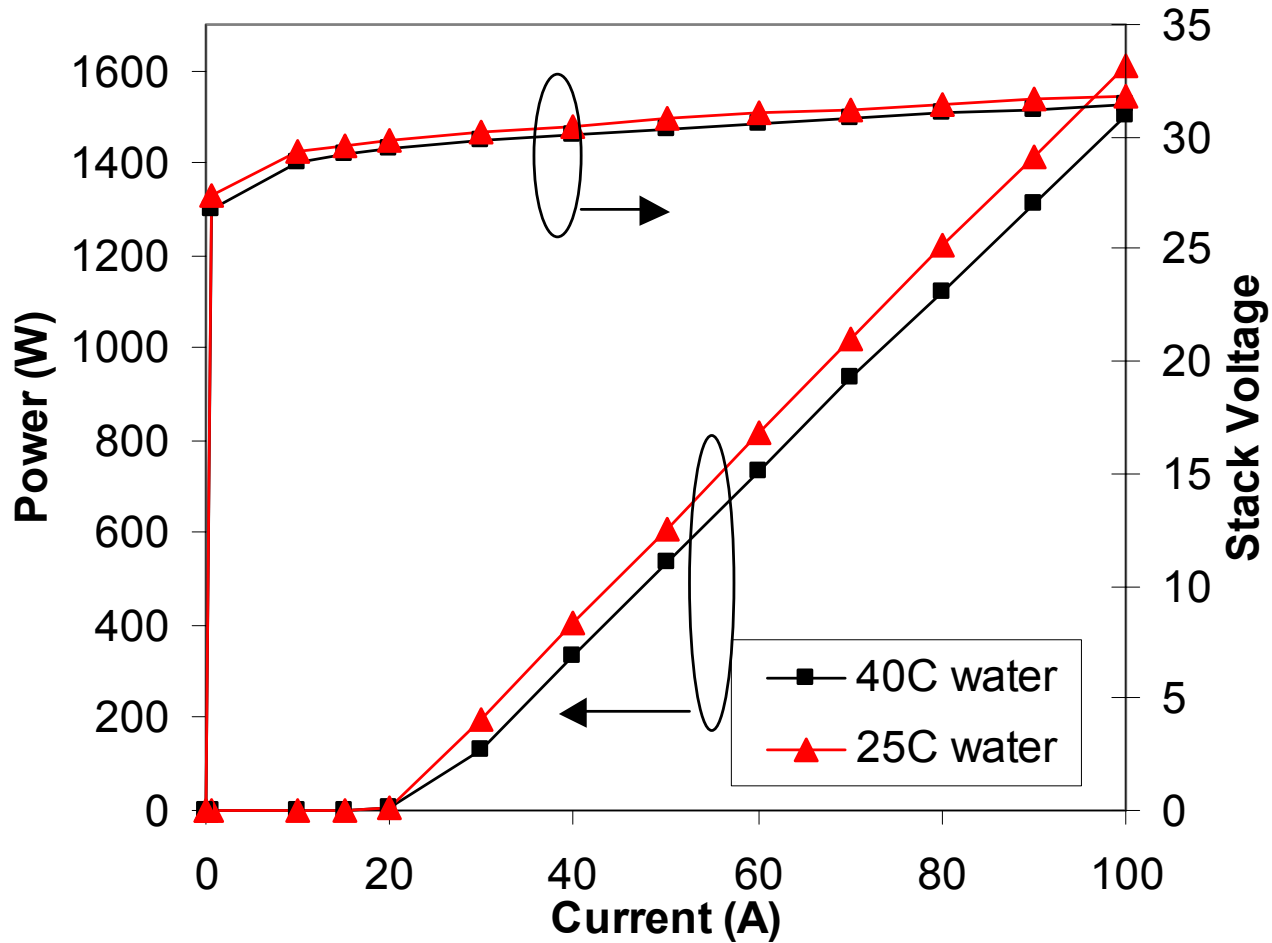
Temperature Control Enables Reliable 125W Operation



Data for design with 364-W peak power

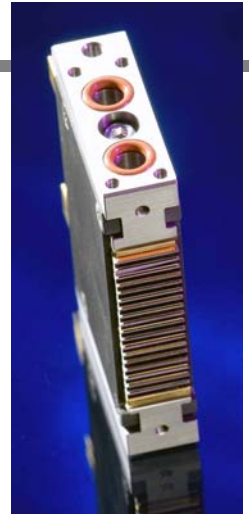
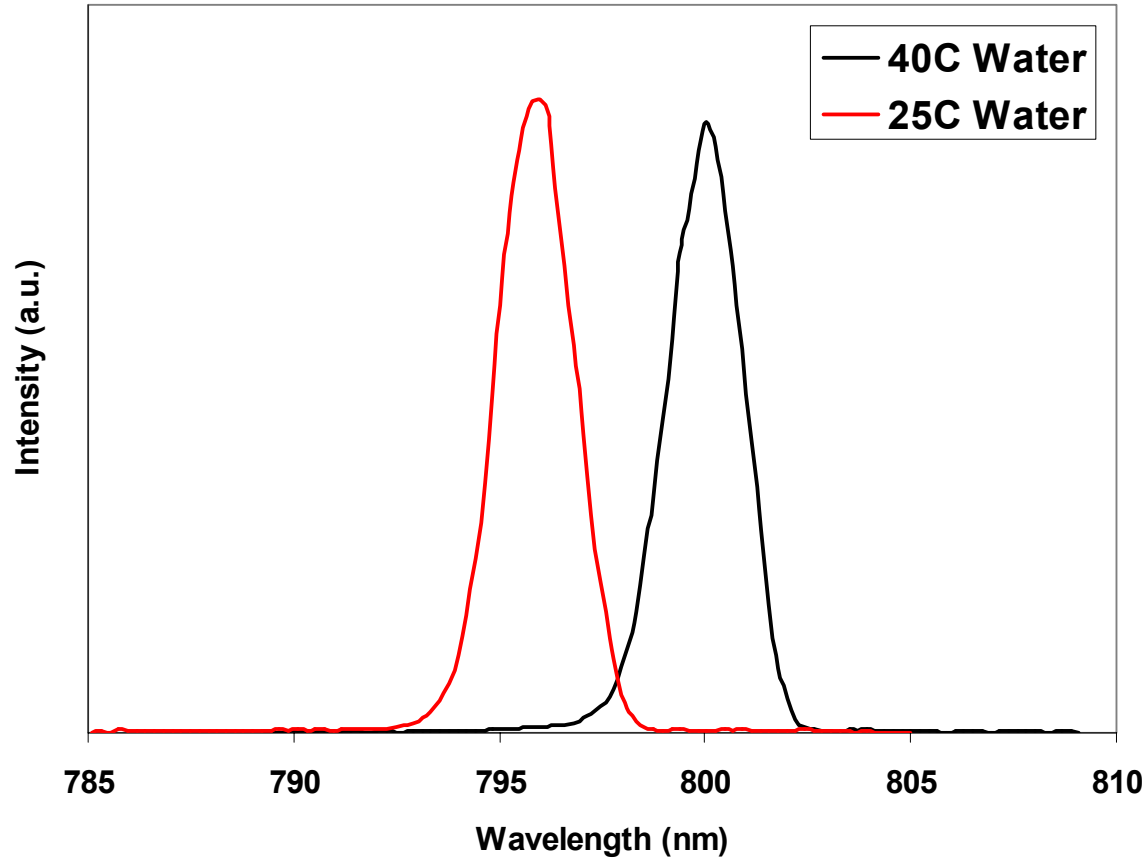
Rule of thumb – reliable power \sim 1/3 to 1/2 peak

Bars Combined in Stacked Arrays for > 1.6kW CW Output

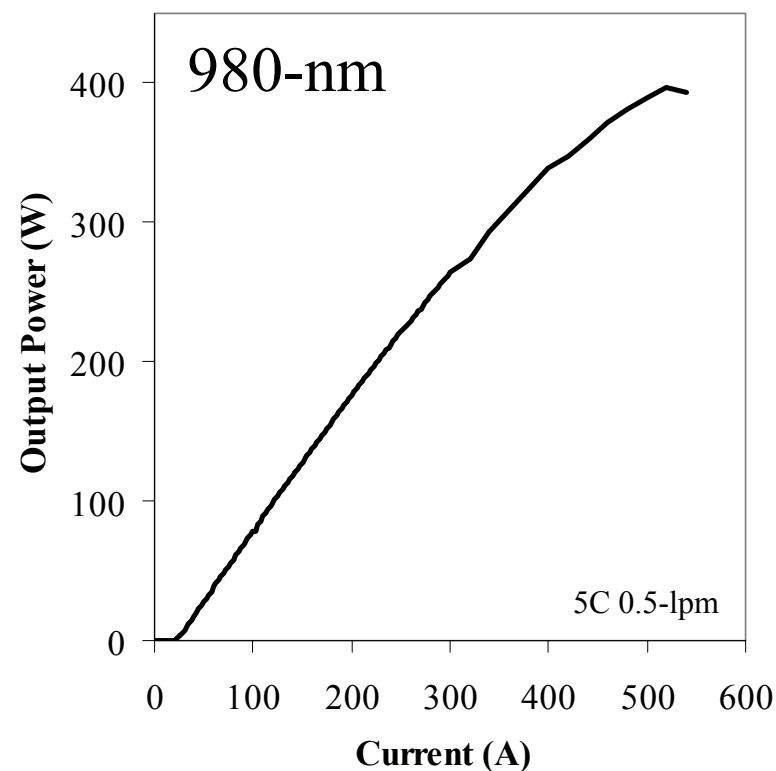
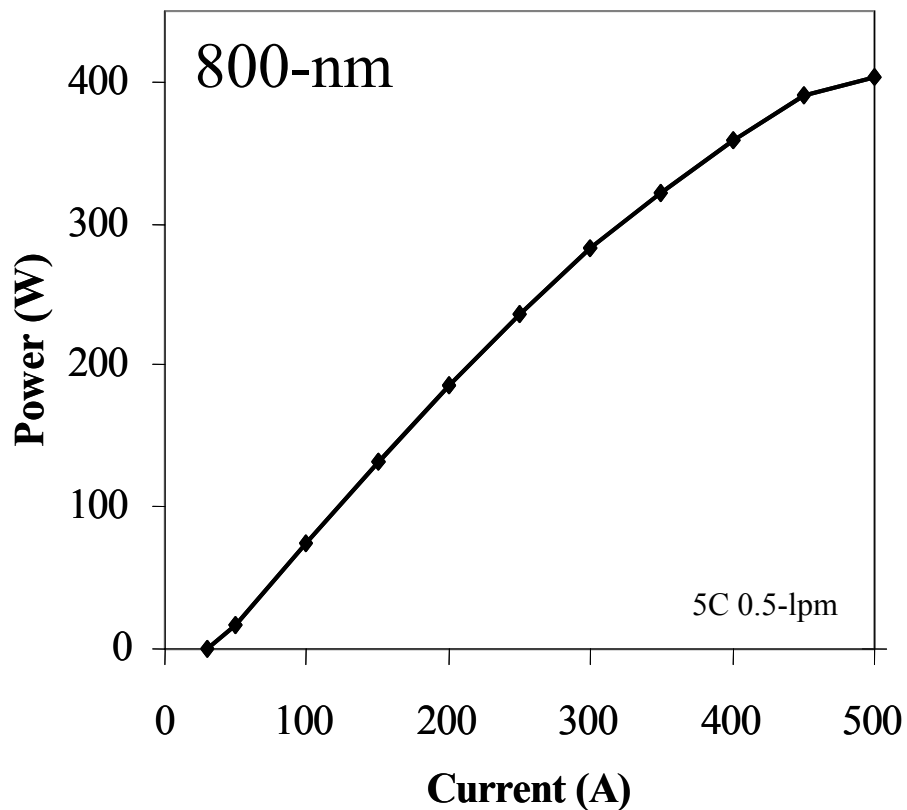
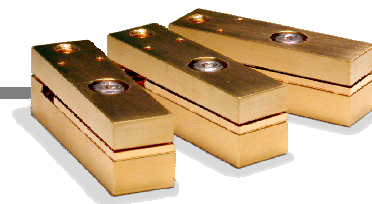


> 500W/cm² CW output power density directly from stack

Integrated Spectral Width < 2.2nm to High Temperature

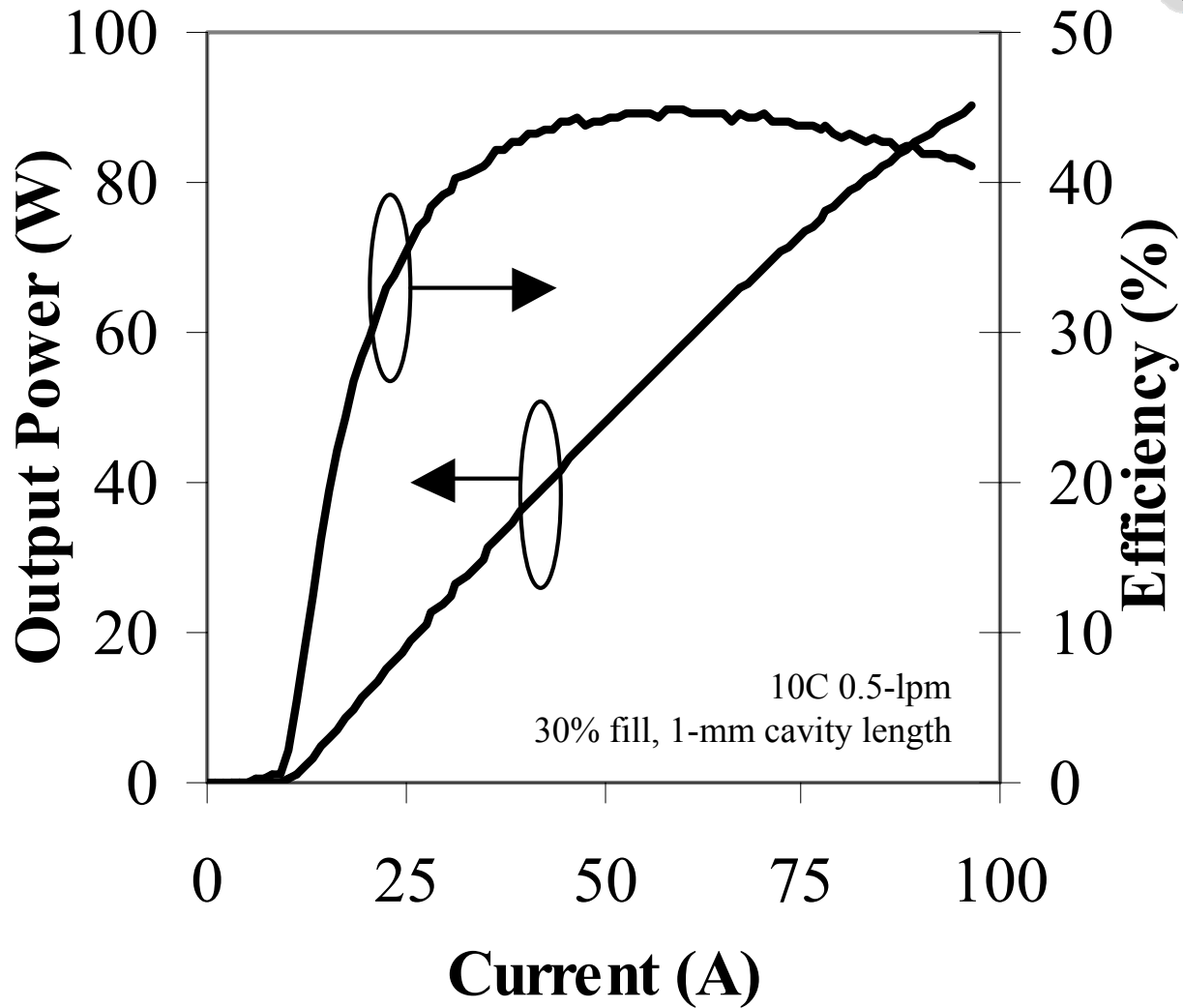
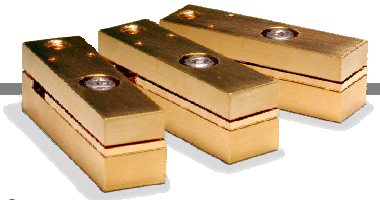


Single Bars Deliver > 400W from 800-nm to 980-nm

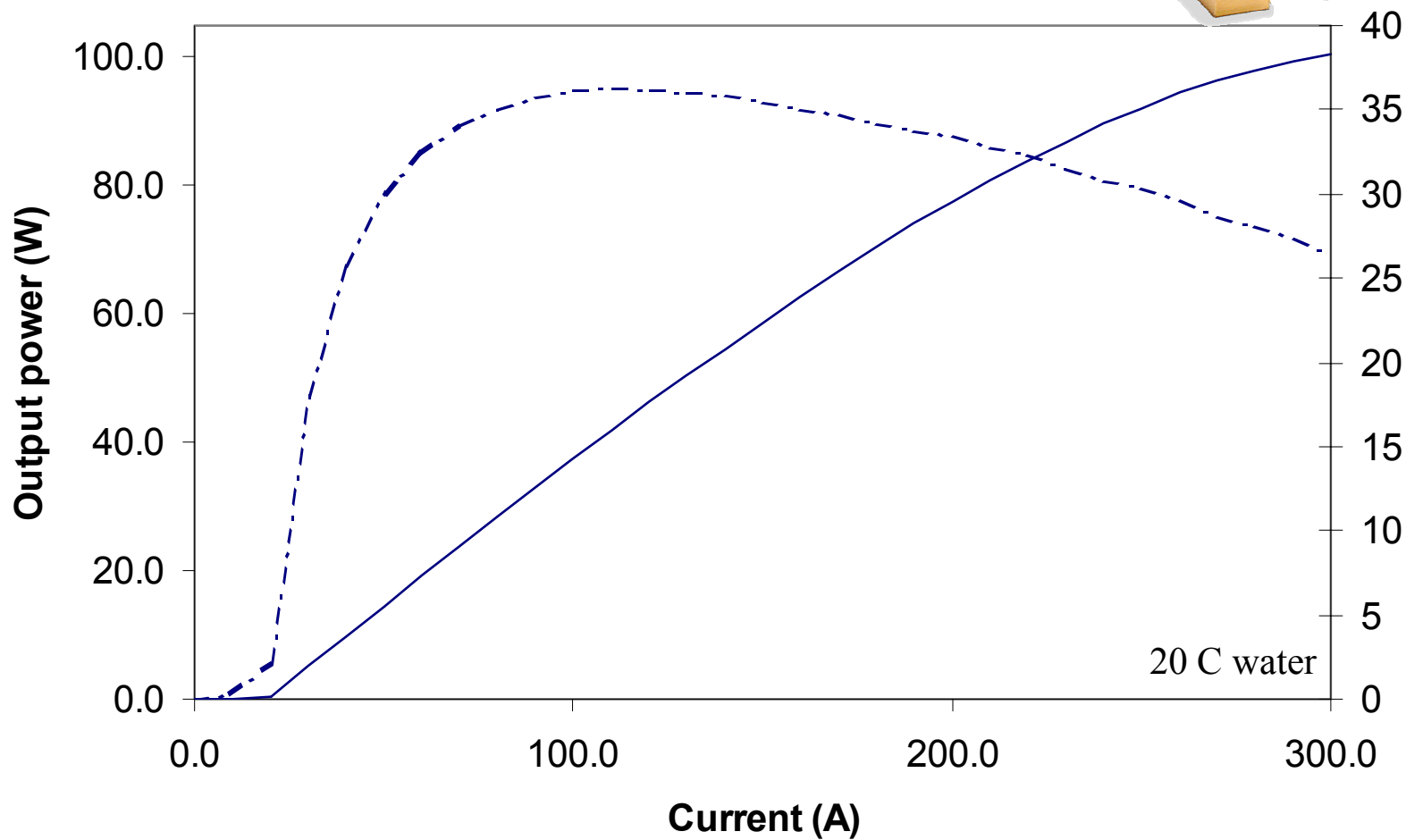
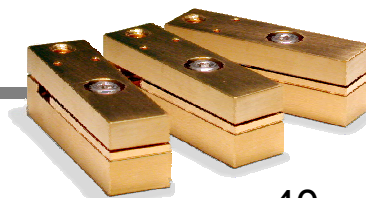


80% fill factor, 3-mm cavity
Water-cooled copper micro-channel

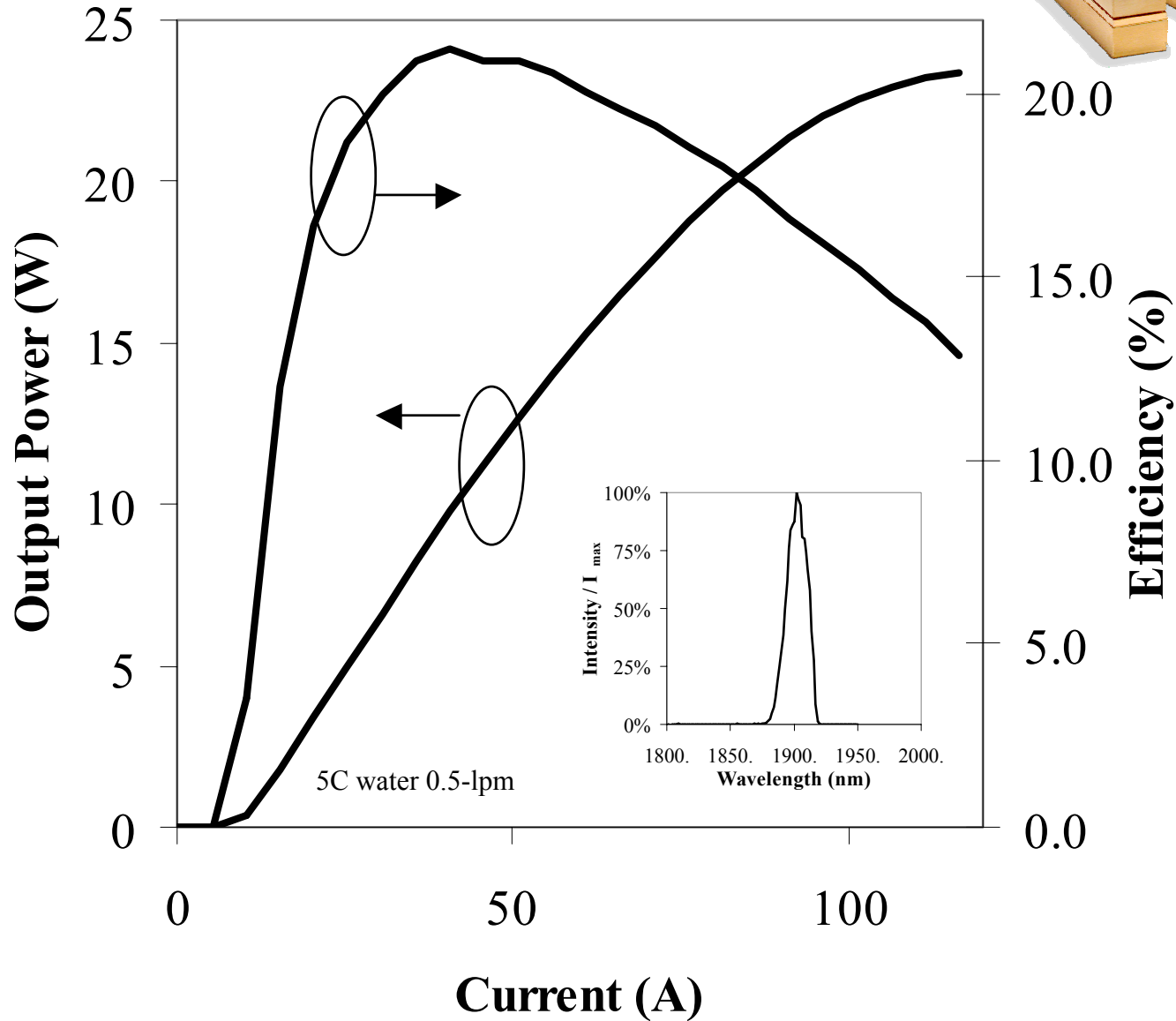
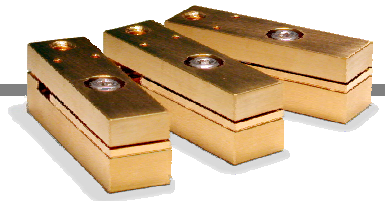
90W from single 660-nm Diode Laser Bar



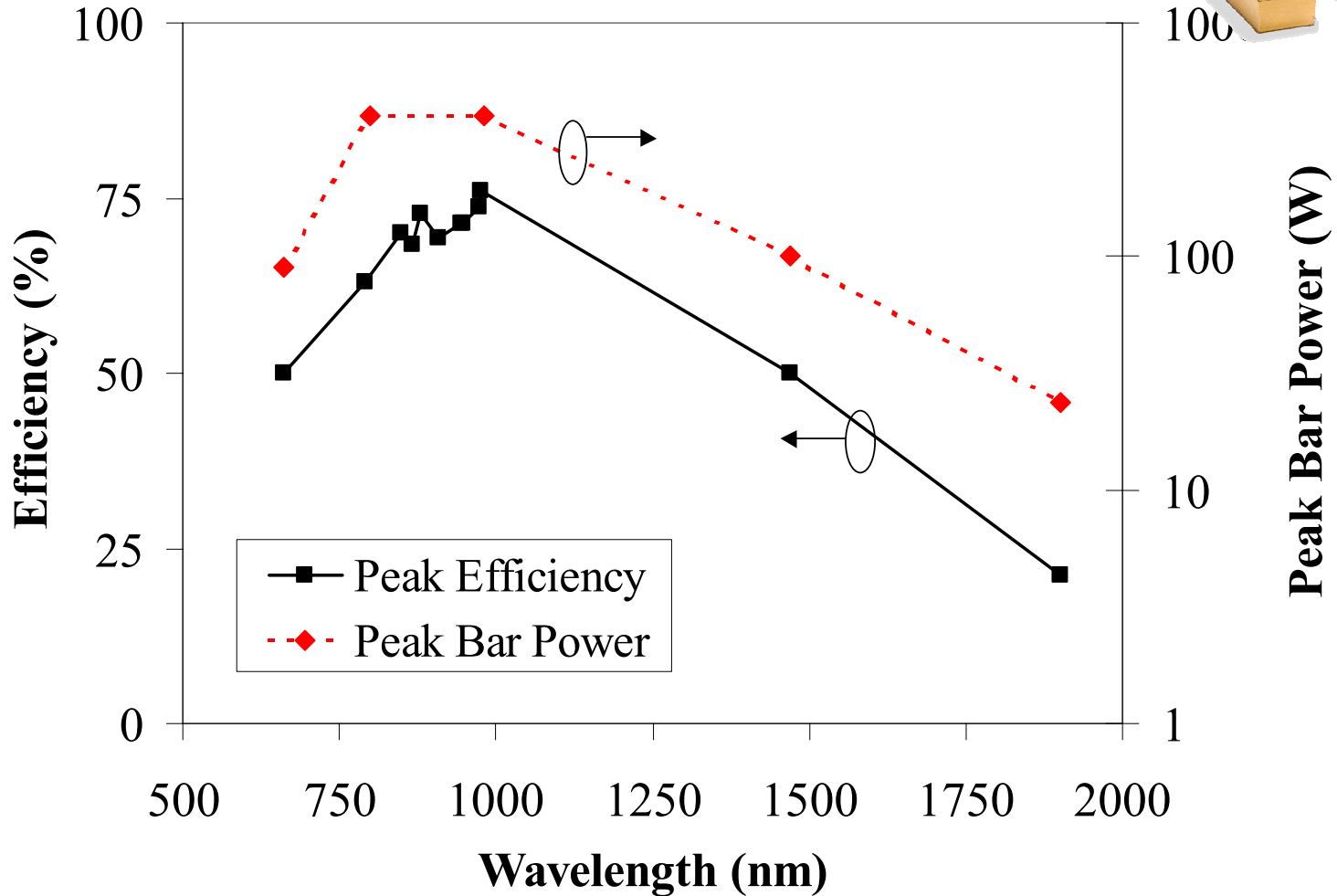
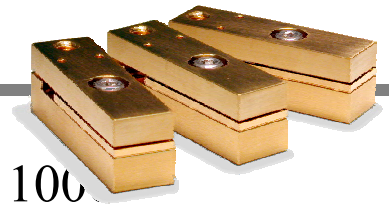
103W from single 1470-nm Diode Laser Bar

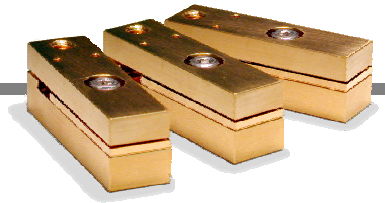


23.5W from single 1900-nm Diode Laser Bar

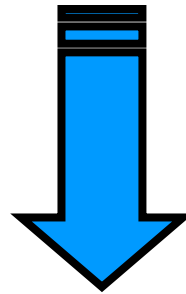


Peak Performance Summary



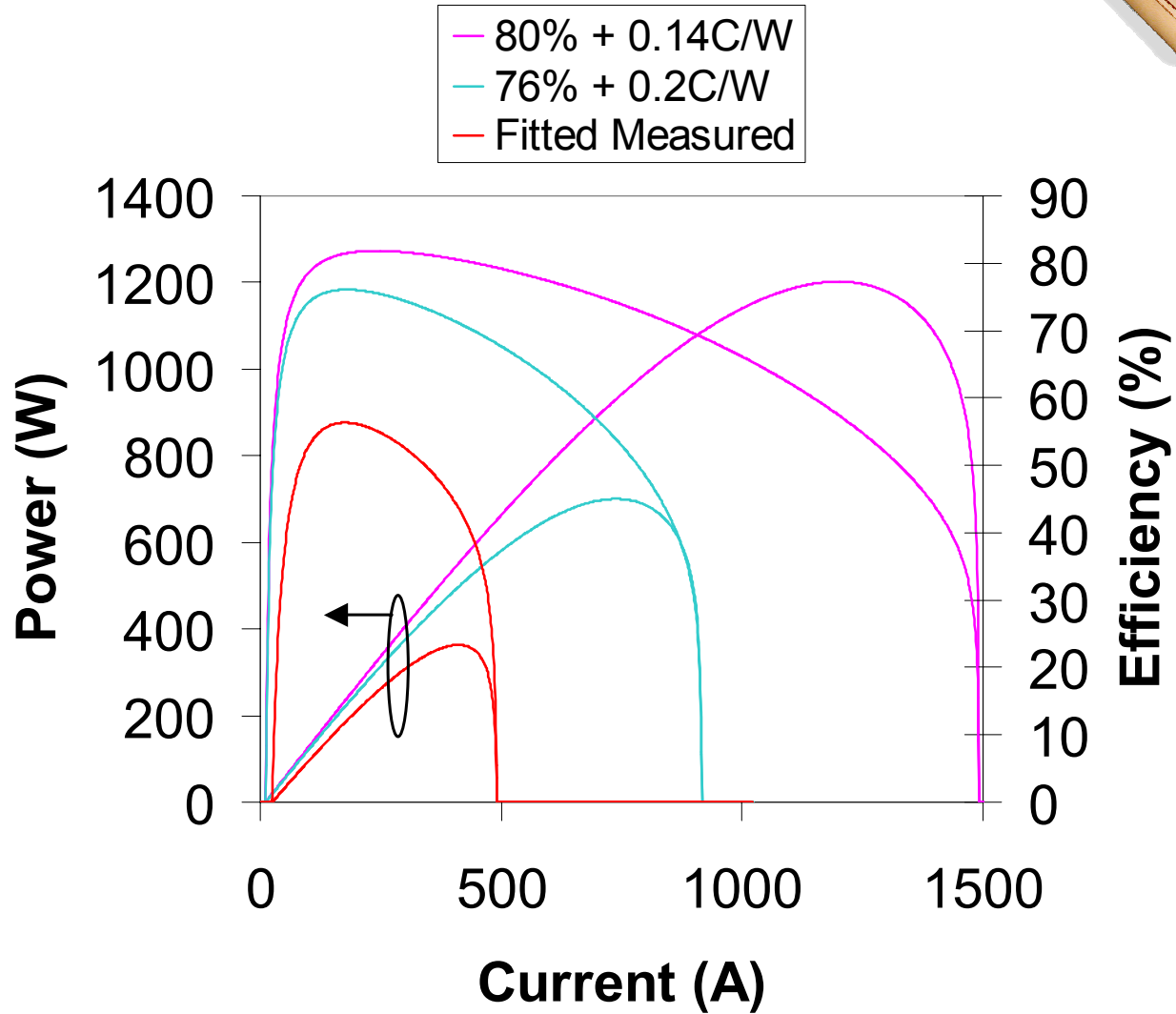
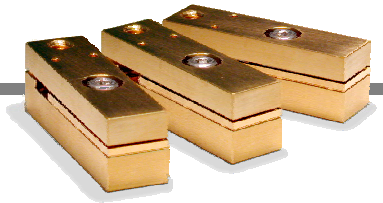


$$P(I) := \eta_d(T) \cdot (I - I_{th}(T))$$

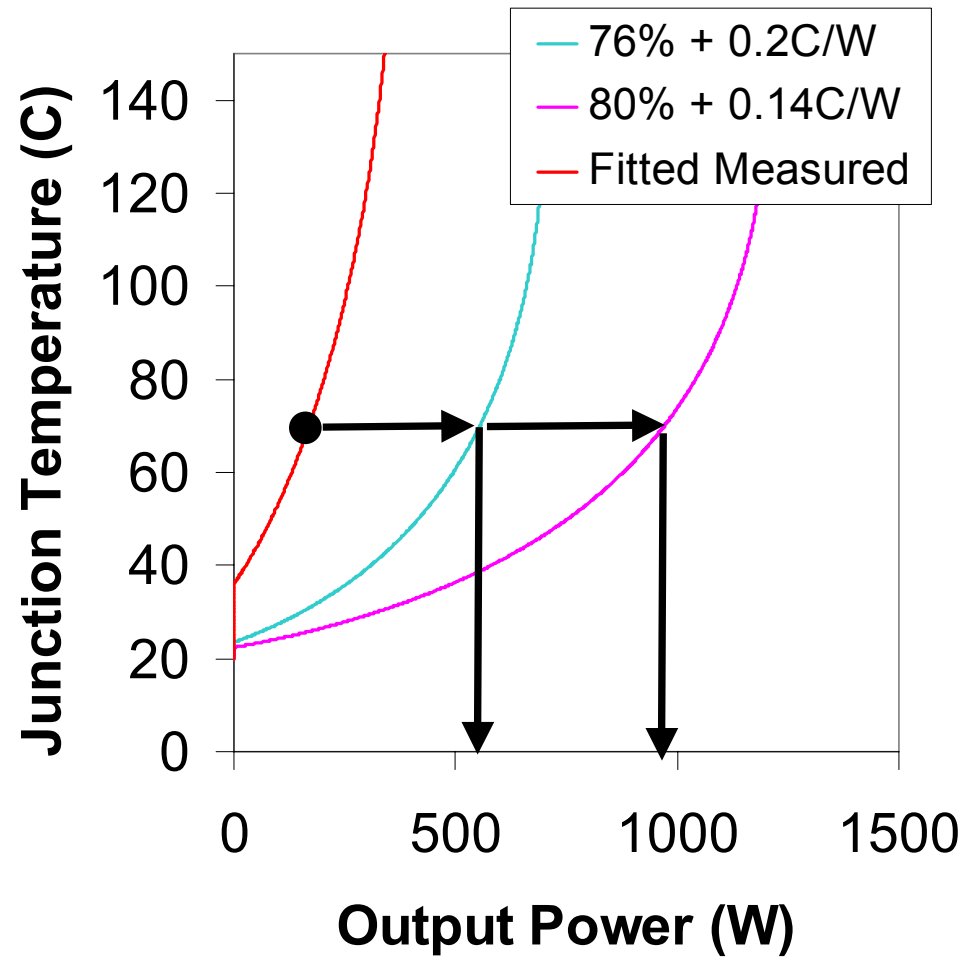
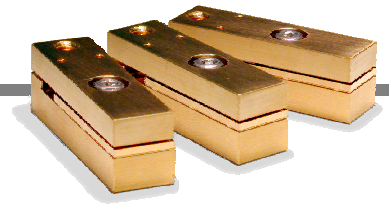


$$P(I) := \eta_d \cdot \exp\left[\frac{-R_{th} \cdot [(I \cdot V_0 + V_d) - P]}{T_1}\right] \cdot \left[I - I_{th} \cdot \exp\left[\frac{-R_{th} \cdot [(I \cdot V_0 + V_d) - P]}{T_0}\right] \right]^*$$

Extrapolate > 1kW Per 1-cm Bar



Junction Temperature Control Increases Peak Power



Key Parameters for Delivering 1-kW Bar

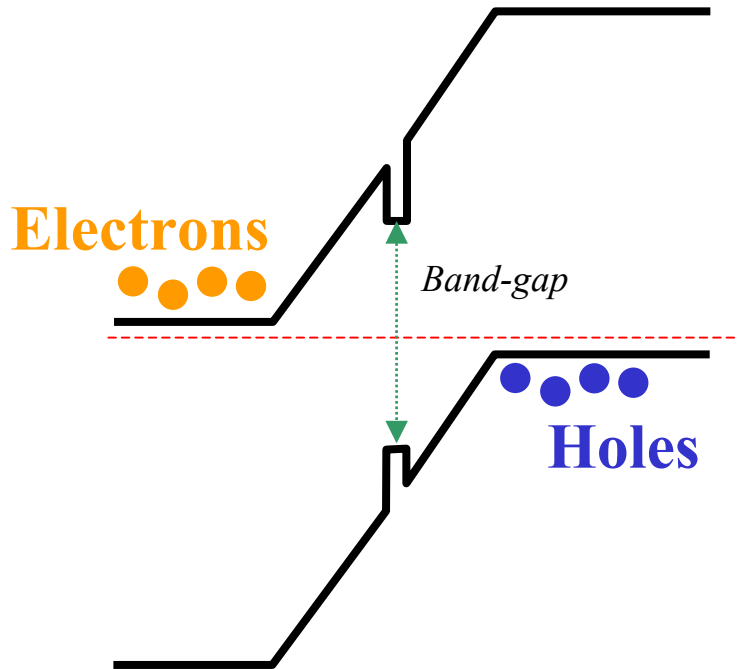
Parameter	Current 125W bar	Required for 1kW bar	Solution
Peak Efficiency	58%	80%	High η leveraging SHEDs technology
Heatsink Thermal Resistance (C/W)	0.35	0.14	Optimized microchannel
Junction Temperature ($^{\circ}\text{C}$)	70	70	n/a
Current Density (kA/cm^2)	1	7	Uniform solder
Dissipated heat per bar (kW/cm^2)	0.7	2.7	n/a
Optical Power Density ($\text{mW}/\mu\text{m}$)	16	126	Advanced facet passivation

Key Parameters for Delivering 1-kW Bar

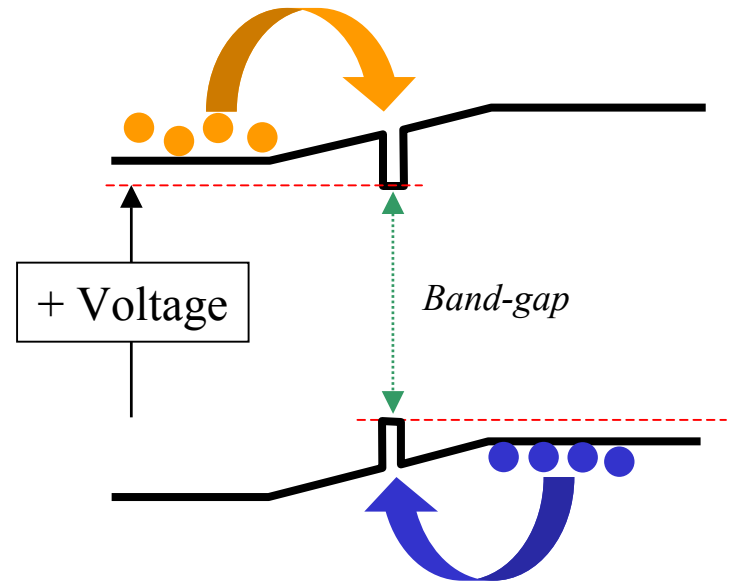
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Key Term: Voltage Defect

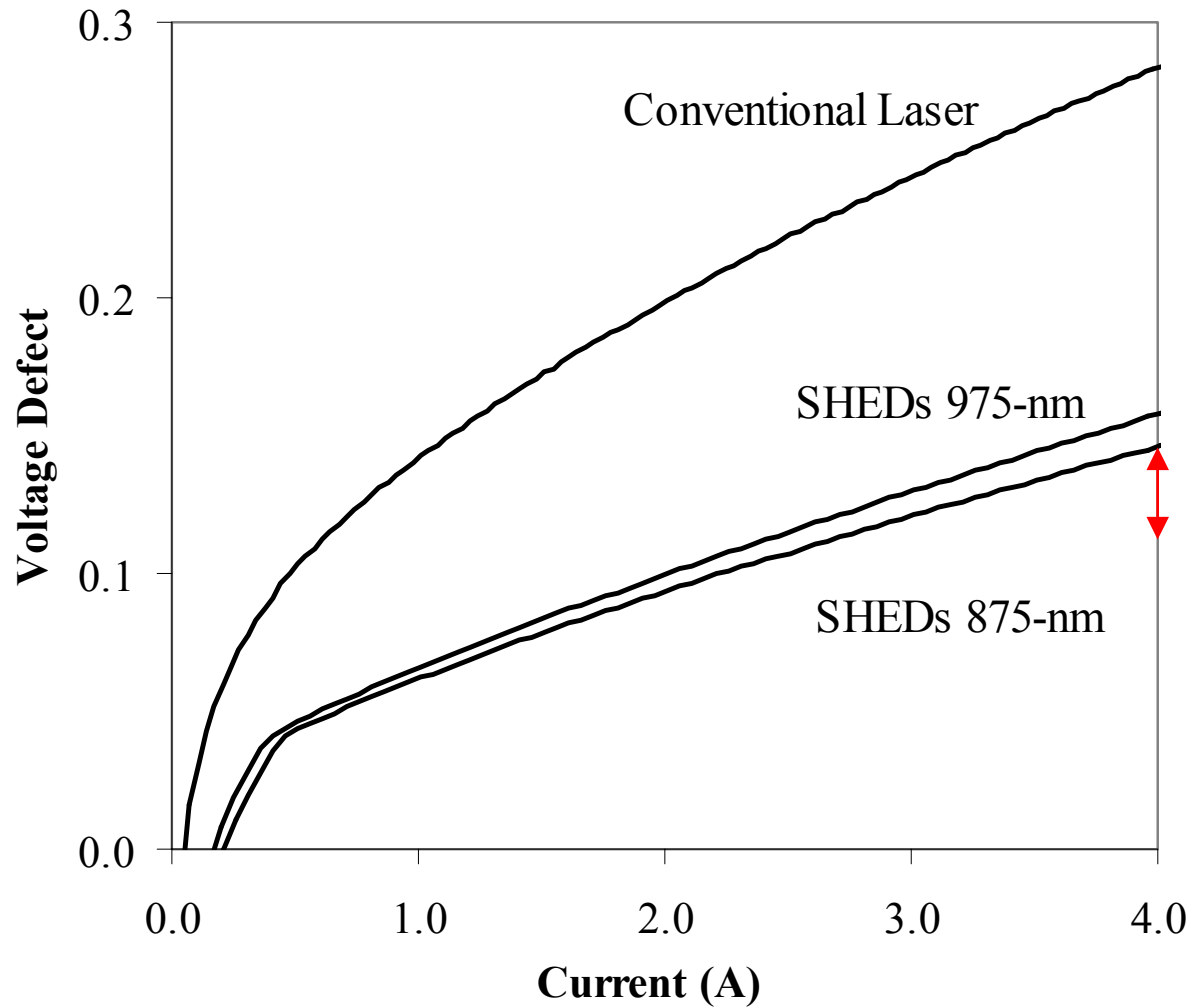
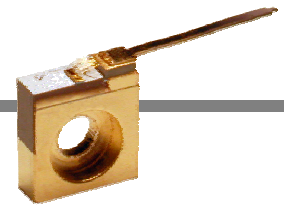
No voltage



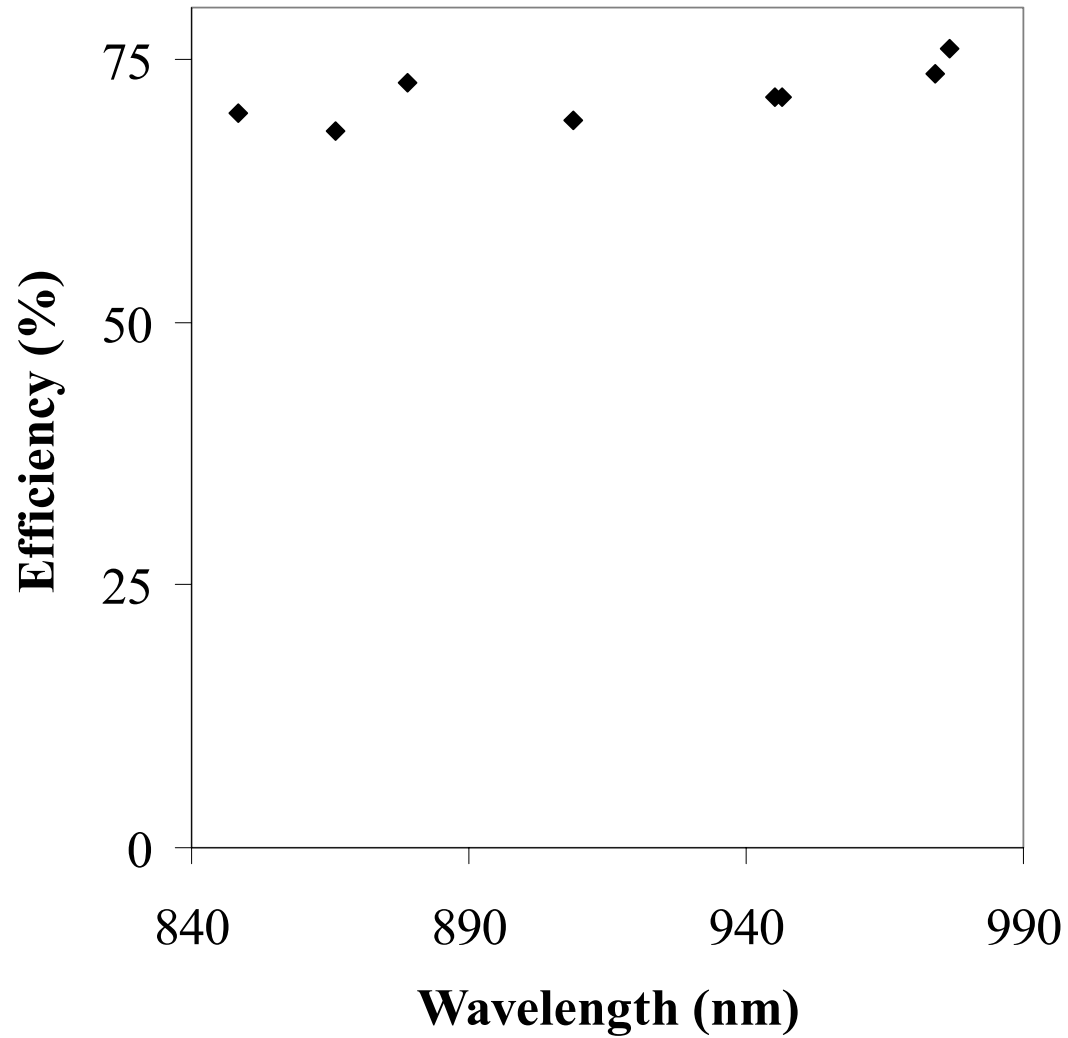
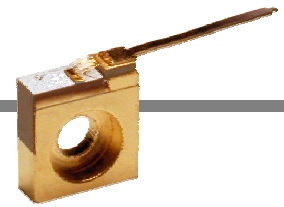
Minimum voltage for lasing



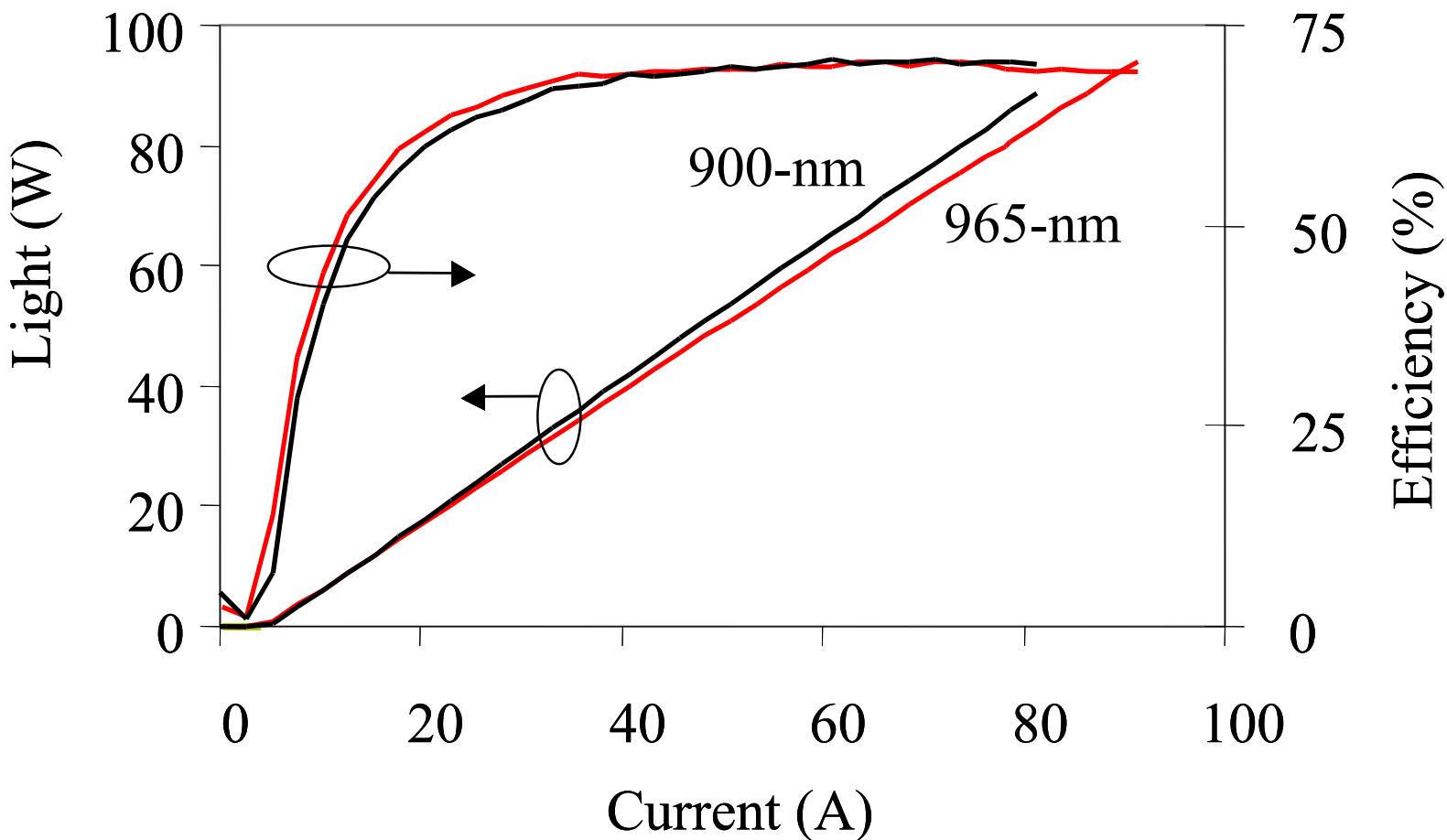
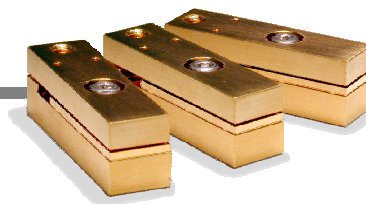
Minimum voltage is band-gap of quantum well
Any more is called the “voltage defect”



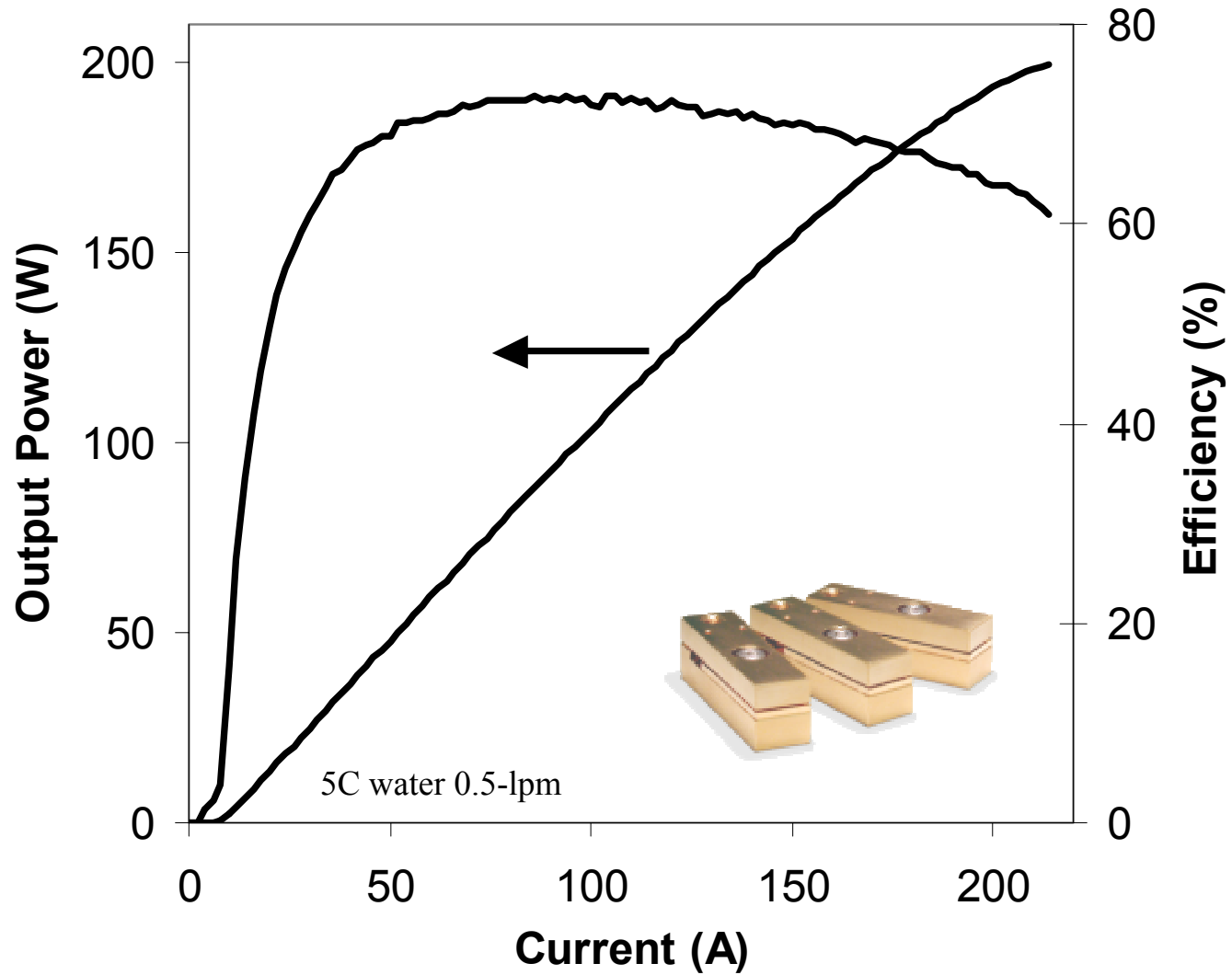
High Peak Efficiency from 850-nm to 980nm



71% Peak Efficiency from 900-nm to 965-nm

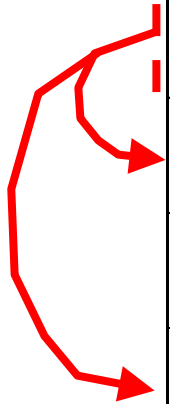


980-nm Bars Deliver 100-W Output at 73% Efficiency

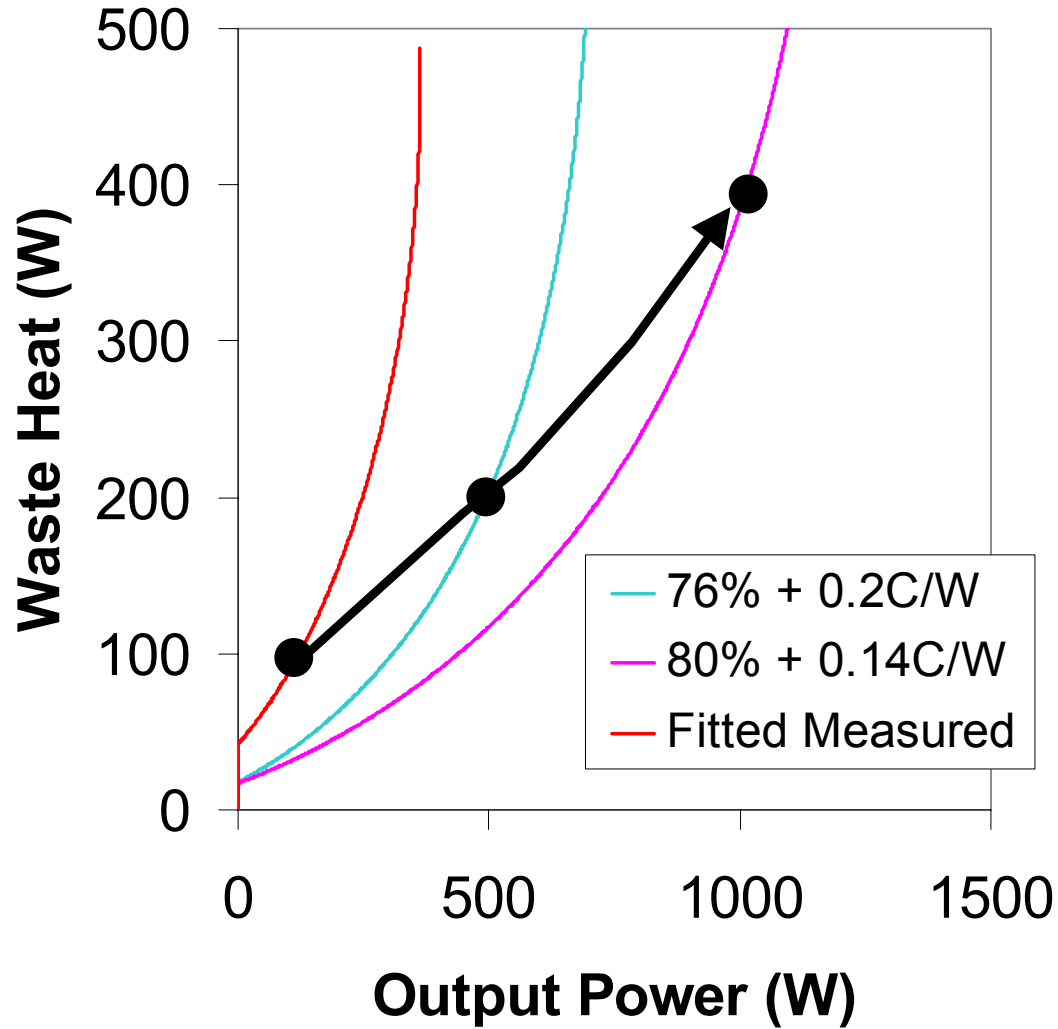
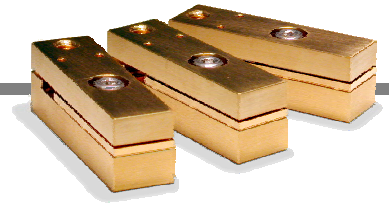


Key Parameters for Delivering 1-kW Bar

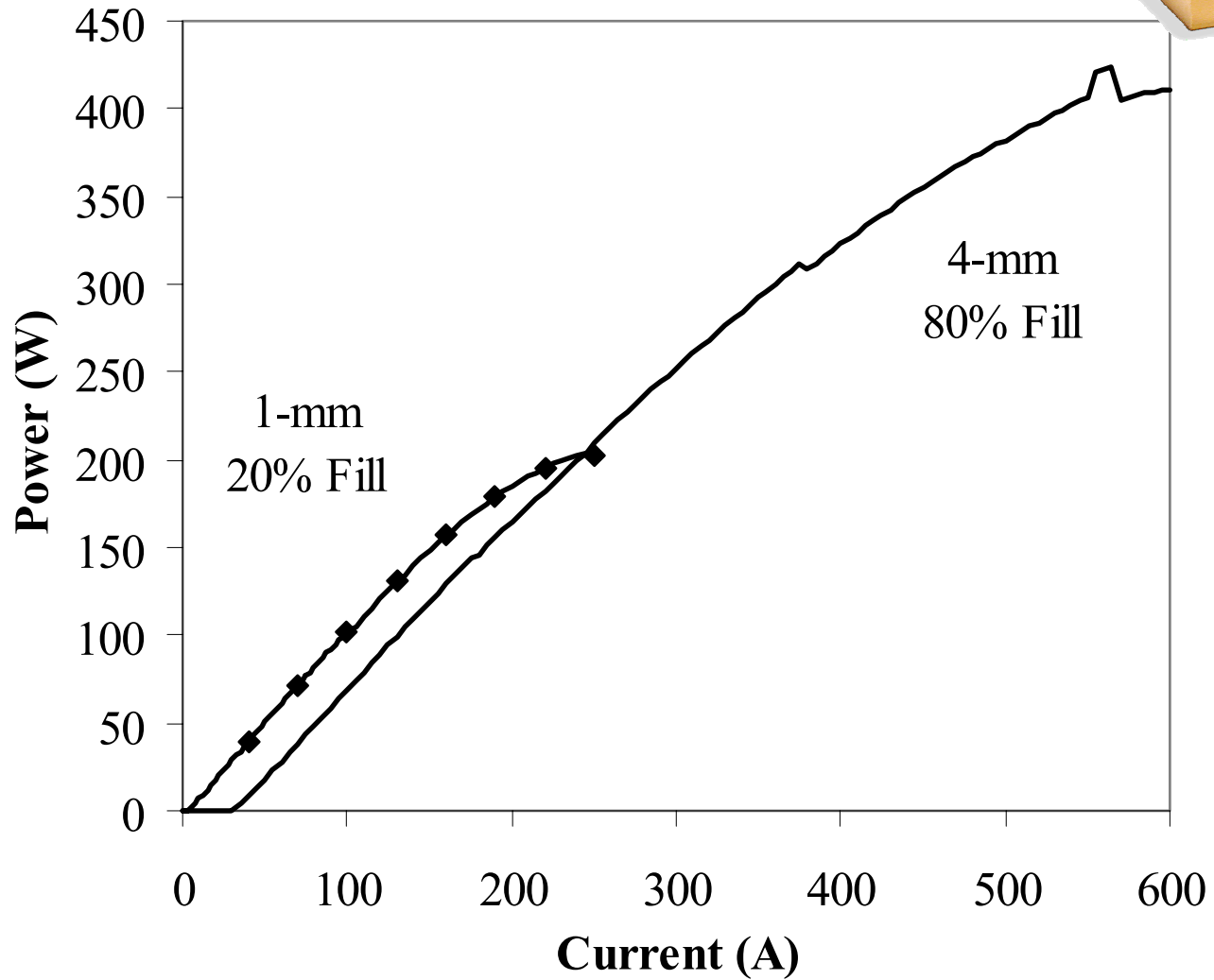
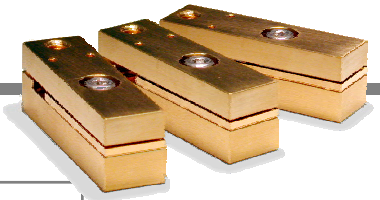
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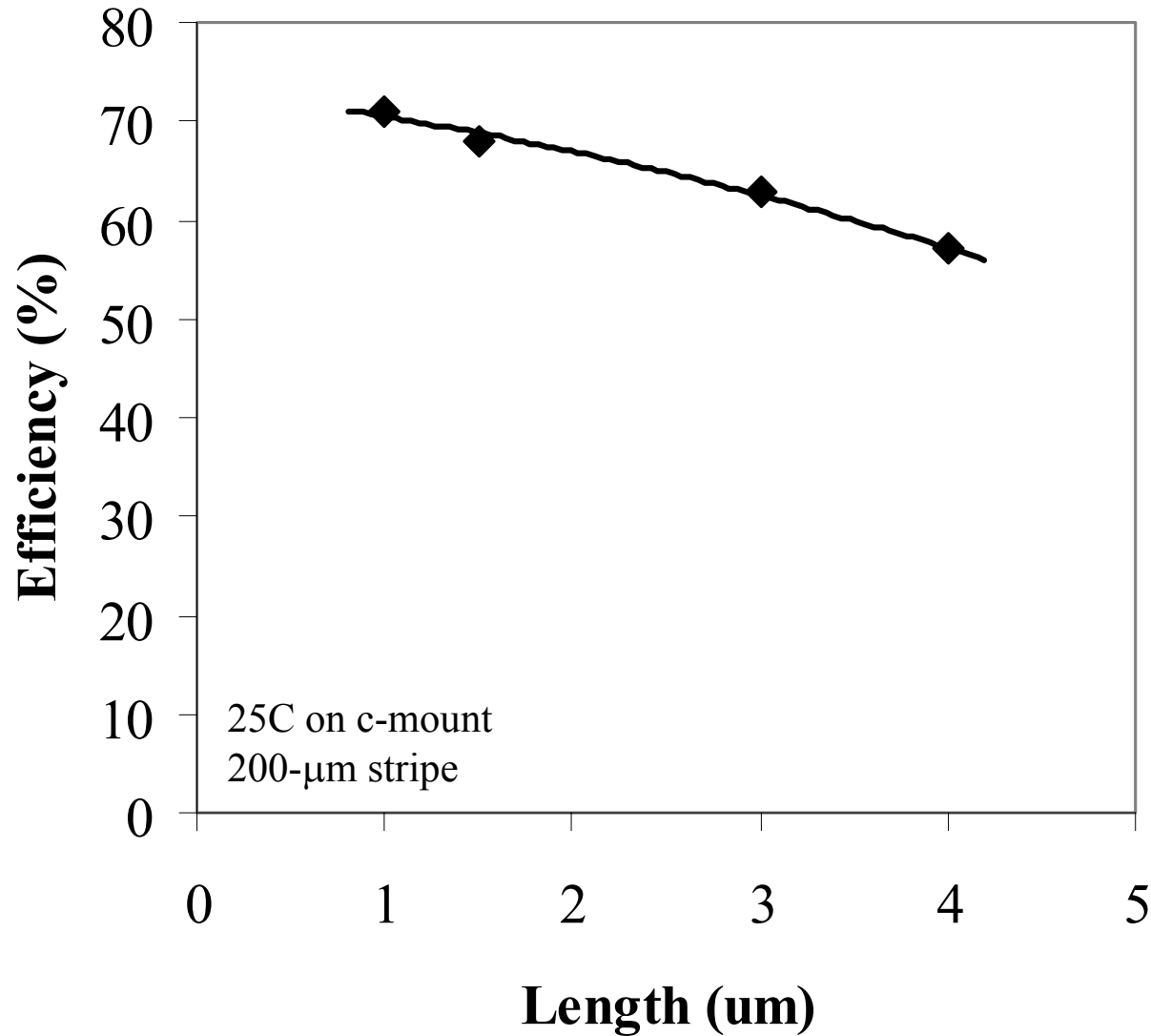
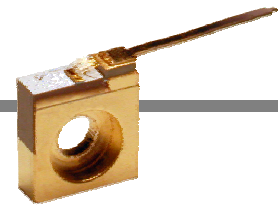
Waste heat Increases for High Power Bars



Improved Thermal Resistance Increases Peak Power



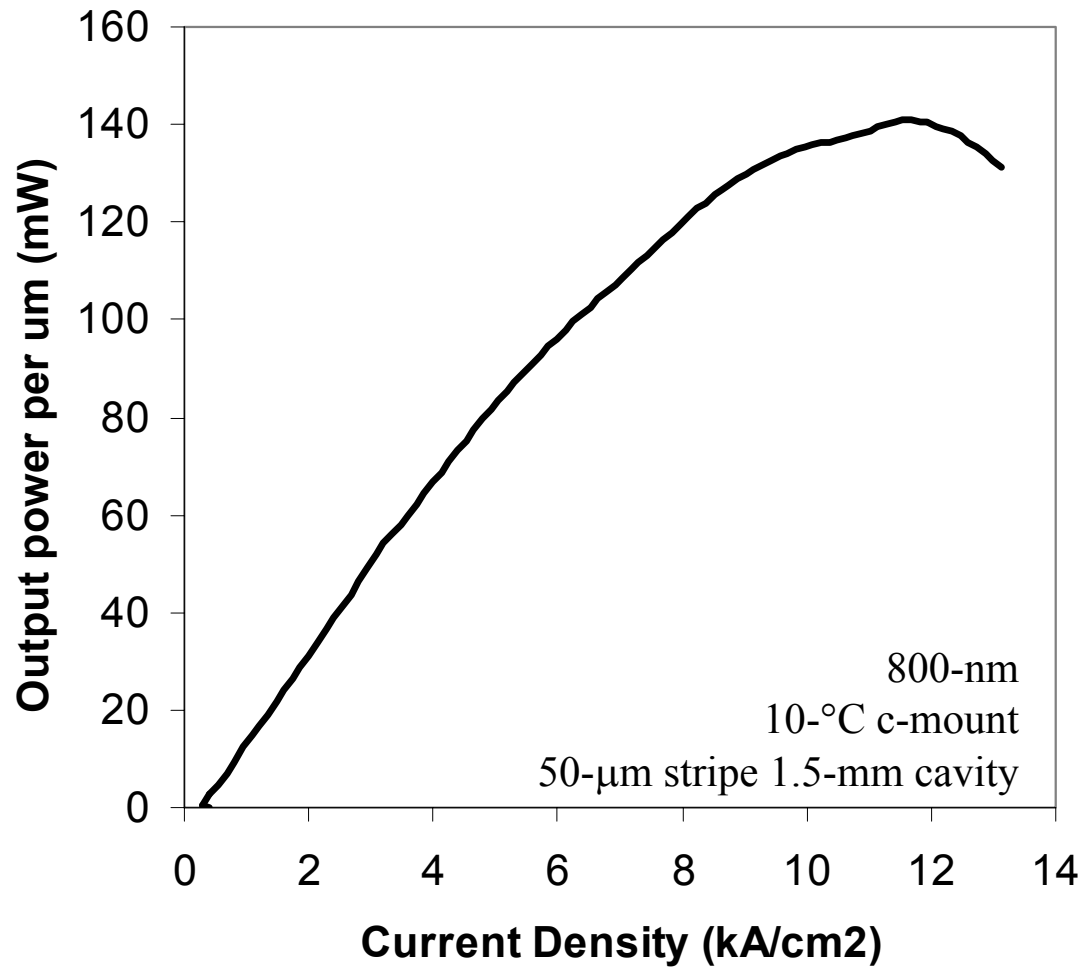
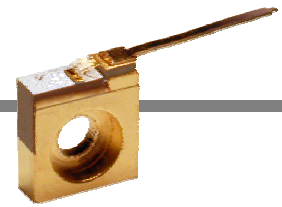
Material Efficiency Degraded for Large Device Lengths



Key Parameters for Delivering 1-kW Bar

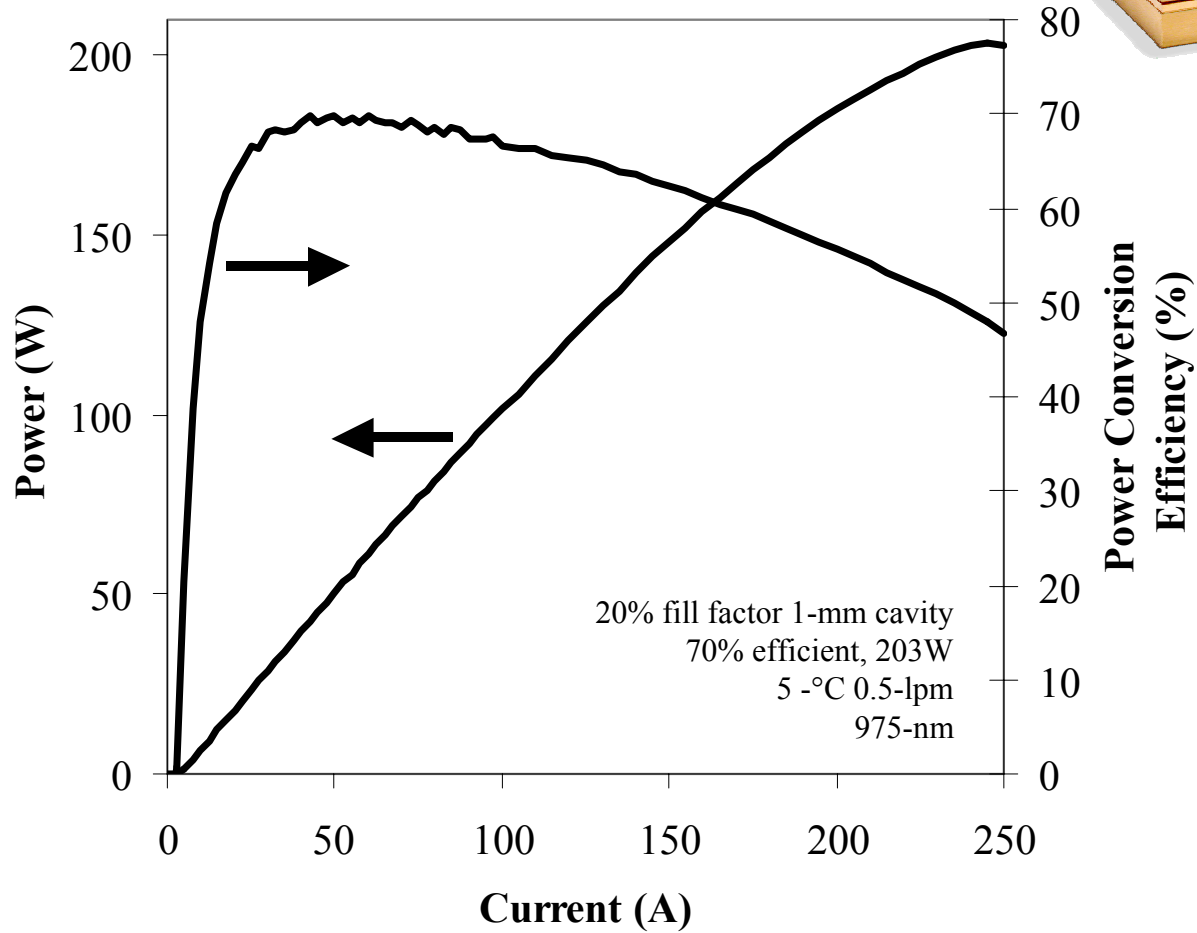
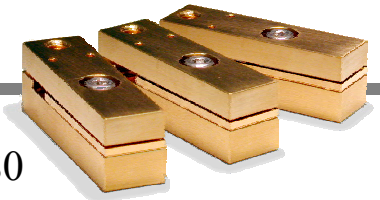
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Passivated Single Emitter Achieves High Power Density



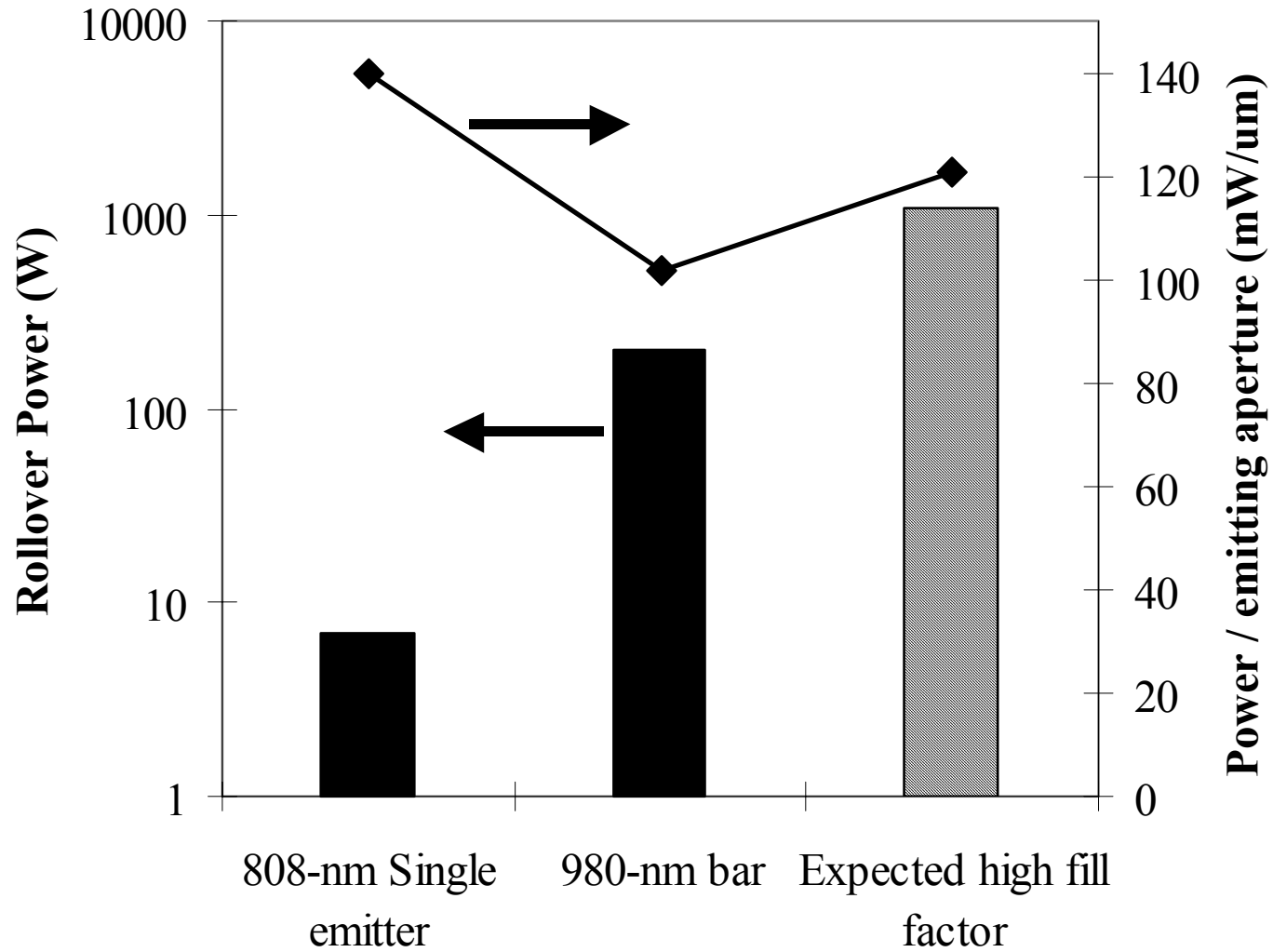
7-W peak power

Passivated Bar Achieves High Power Density



Equivalent to 800W per bar for 80% fill factor

Data Clearly Indicates 1kW Bar is Achievable



- **High performance over wide wavelength range**
 - 90-W at 660-nm, 23.5W at 1900-nm
 - 400W from 800-nm to 980-nm
- **High Efficiency from 850-nm to 980-nm**
 - Bars, single emitters > 65% efficiency product release
- **Project 1-kW peak per bar (~ 300W reliable per bar)**
 - Good progress against major limitations
- **Future is getting brighter!**