



*Fiber Lasers - Actual Status & Targets*

*May 24, 2005*



# Outline

## *Present status*

- *IPG concept of high power fiber lasers*
- *High power single stripe laser diodes*
- *Industrial grade high power fiber lasers*

## *Future trends*

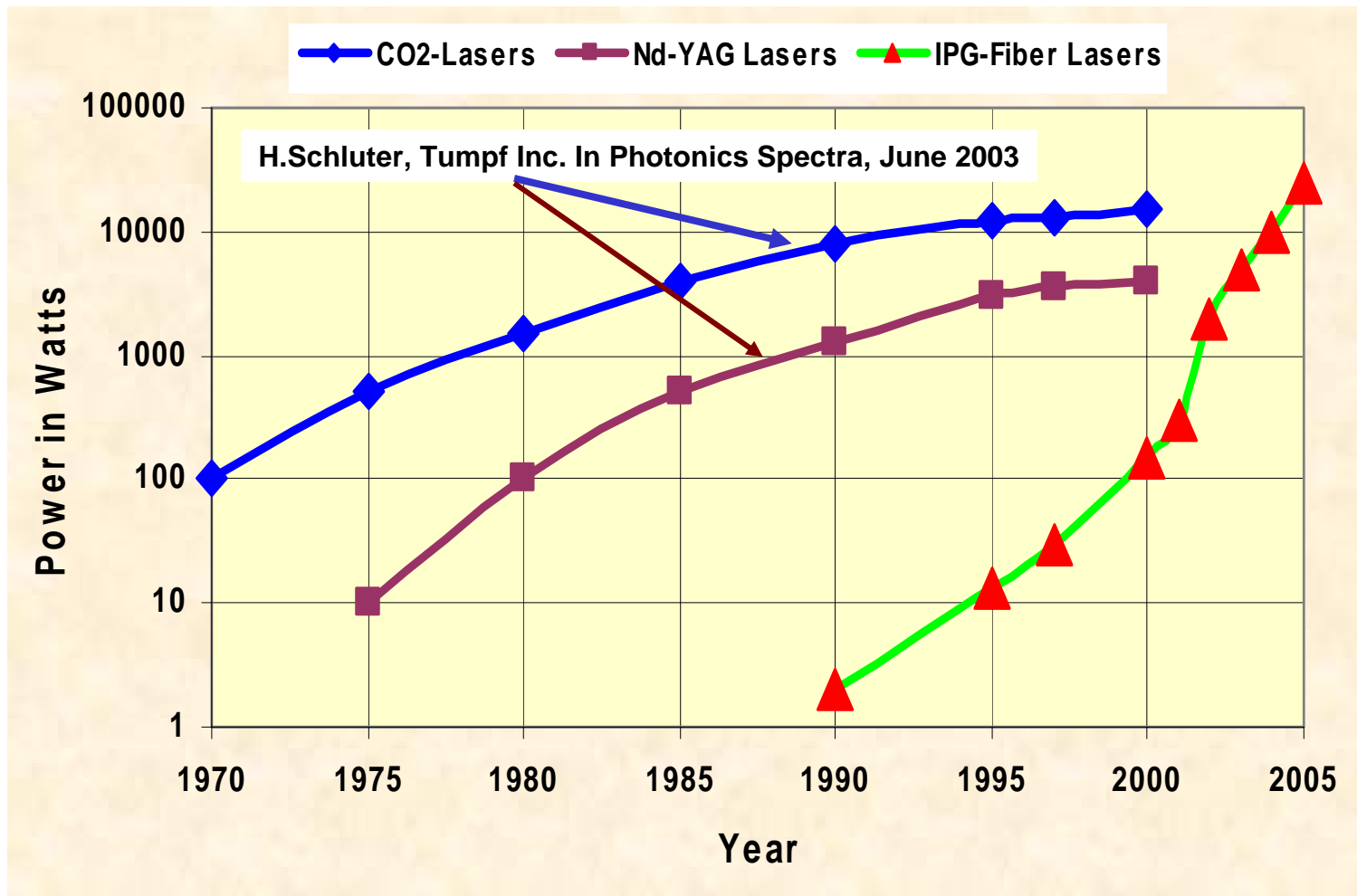
- *Super high power fiber lasers*
- *---“--- efficient fiber lasers*
- *---“--- beam quality*

## *Conclusions*



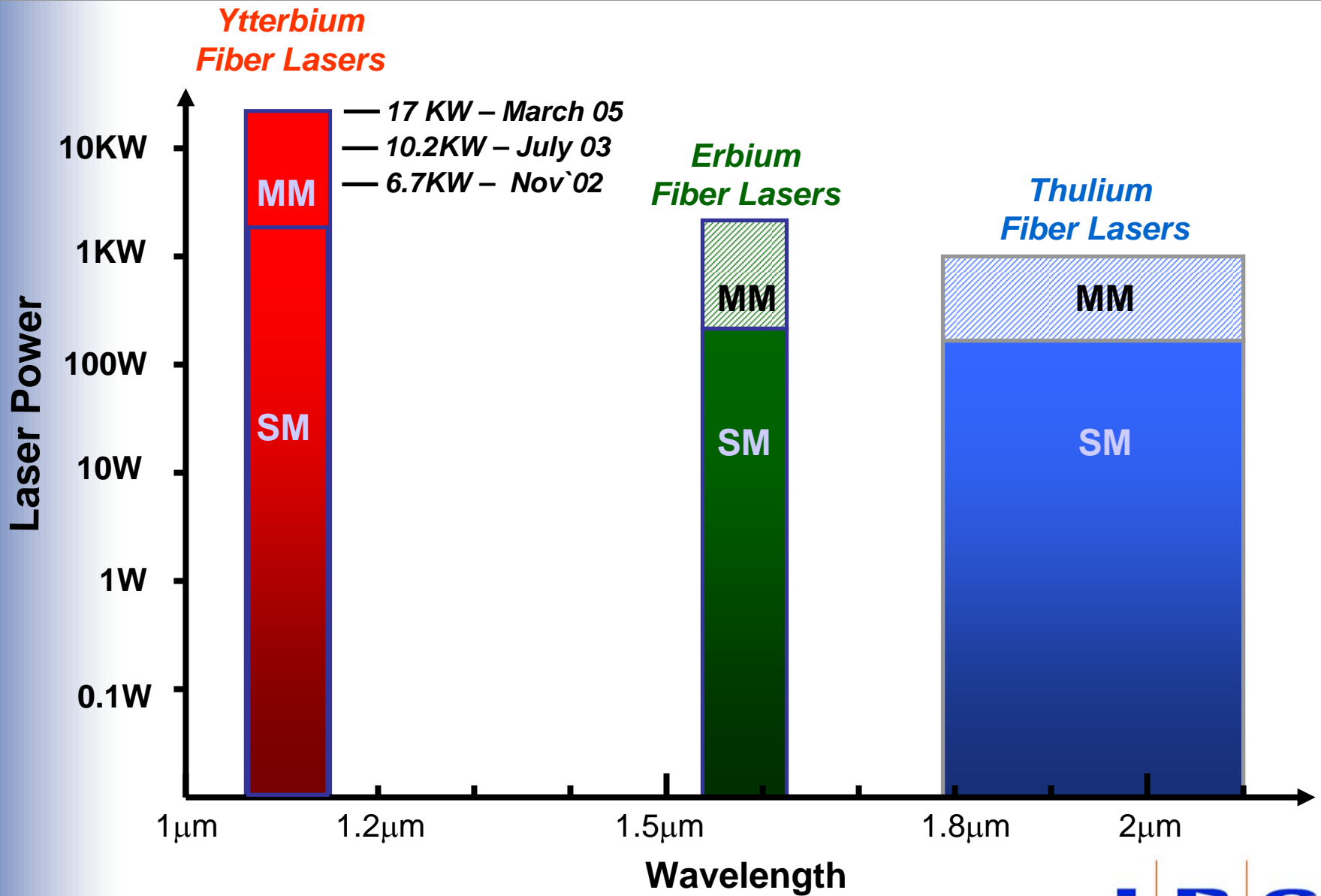
# Fiber Lasers vs CO<sub>2</sub> & Solid State Lasers

## Time scale of Development





# IPG Fiber Lasers – Power & Spectral Range





# IPG Fiber Lasers

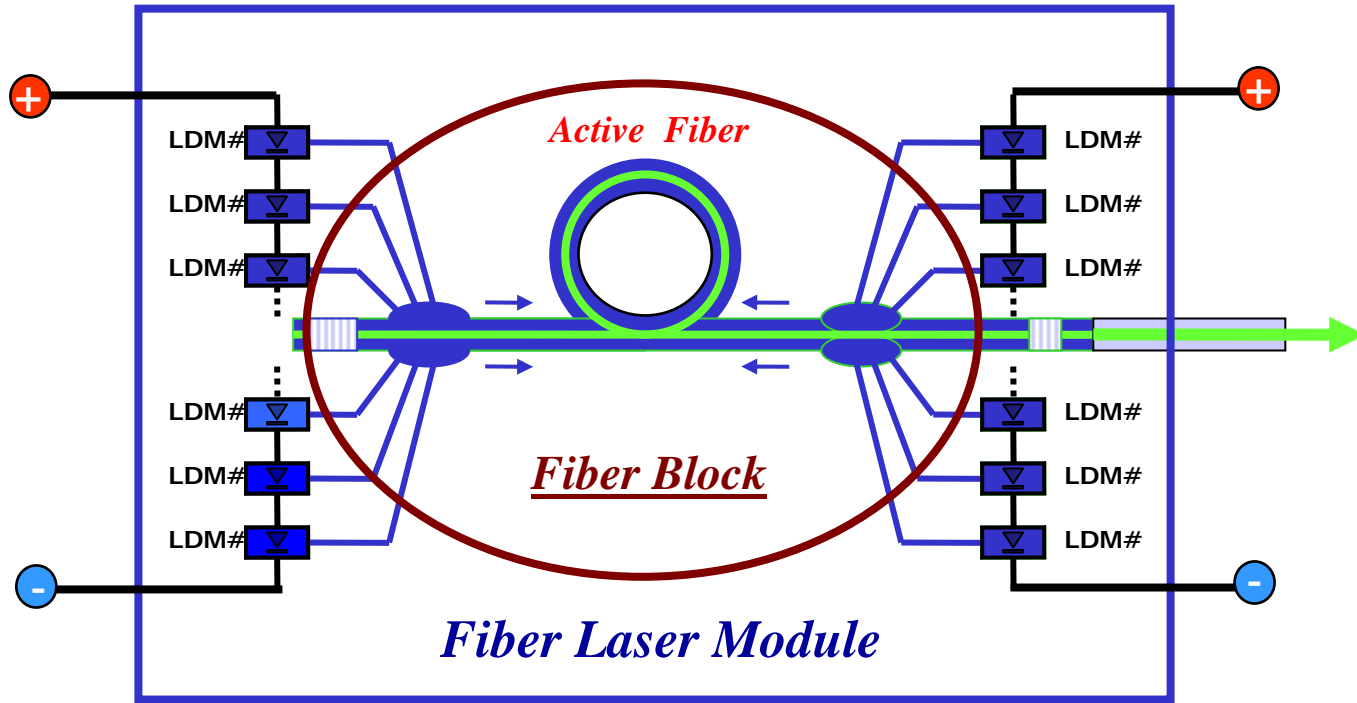
## **FAQ:**

**Why IPG fiber lasers are winner of competition with standard lasers for many applications?**

*Because :*

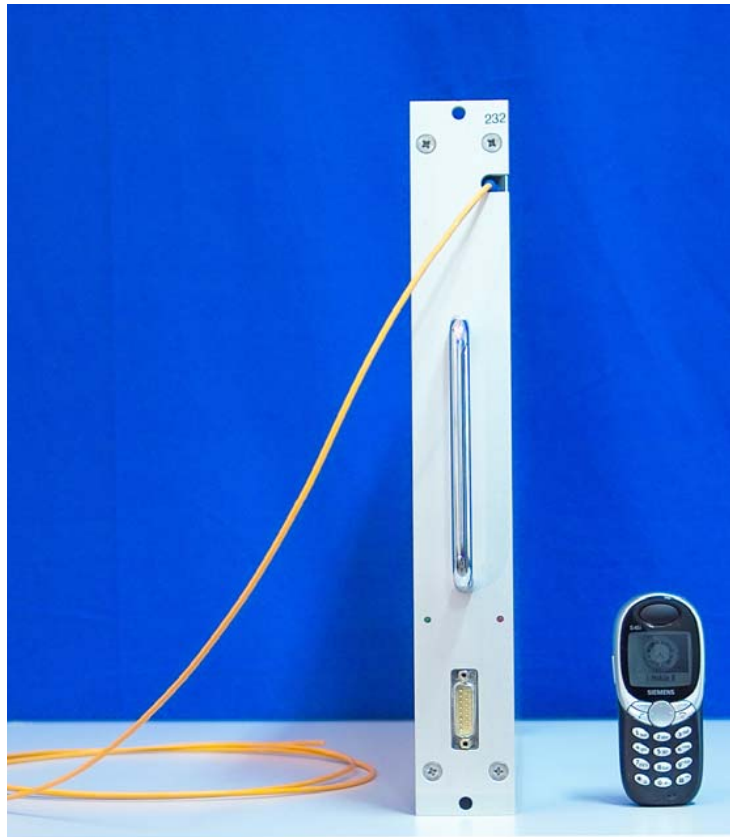
- *IPG produces all kind of passive and active fibers, and fiber based components for high power lasers*
- *IPG produces the best high power single stripe laser diodes*
- *IPG proposed and realized the integrated concept fiber lasers*
- *IPG supplied the first industrial grade high power fiber lasers*
- *Prices and operational cost of IPG lasers is less than DPSSL*

# Fiber Laser Modules Concept



- *Compact integrated optical design*
- *Parallel by single LDM pumping*
- *Single mode output radiation*
- *Robust mechanical construction*
- *Stable thermal characteristics*

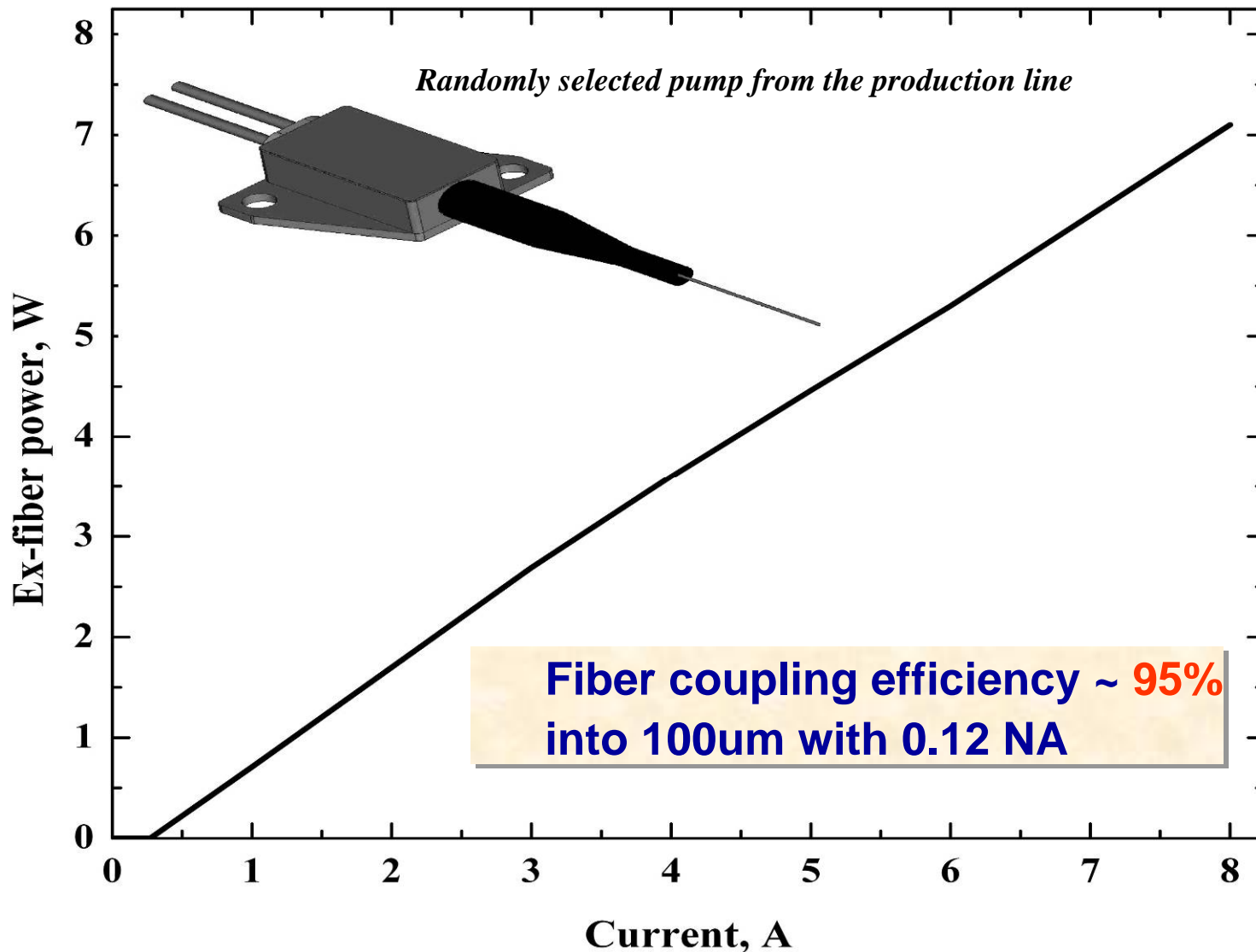
# SM Fiber Laser Module



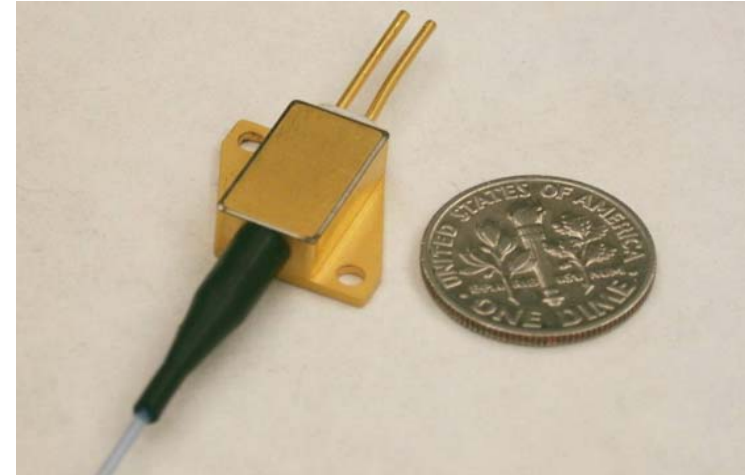
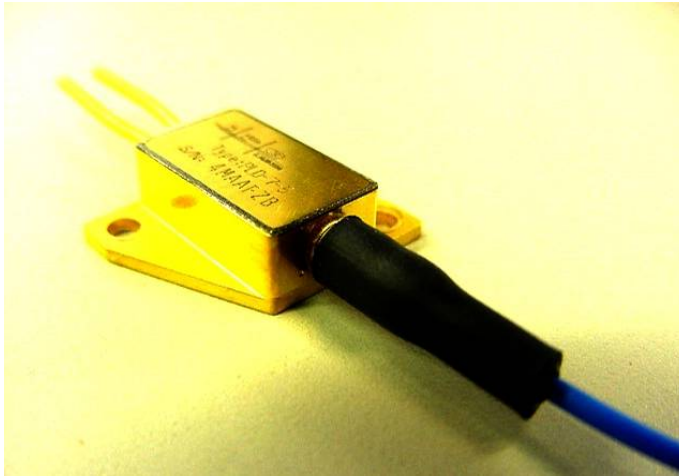
- $P$  [W]= 150 → 400 → 800
- $\lambda$  [nm]= 1070
- Fiber core [ $\mu\text{m}$ ] = 7
- BPP [mm x mrad] = 0.34  
(  $M^2 = 1.05$  )
- WxHxD[cm] = 42x33x4.7
- Wall-plug efficiency >30%



# High Power, High-brightness ex-fiber Output



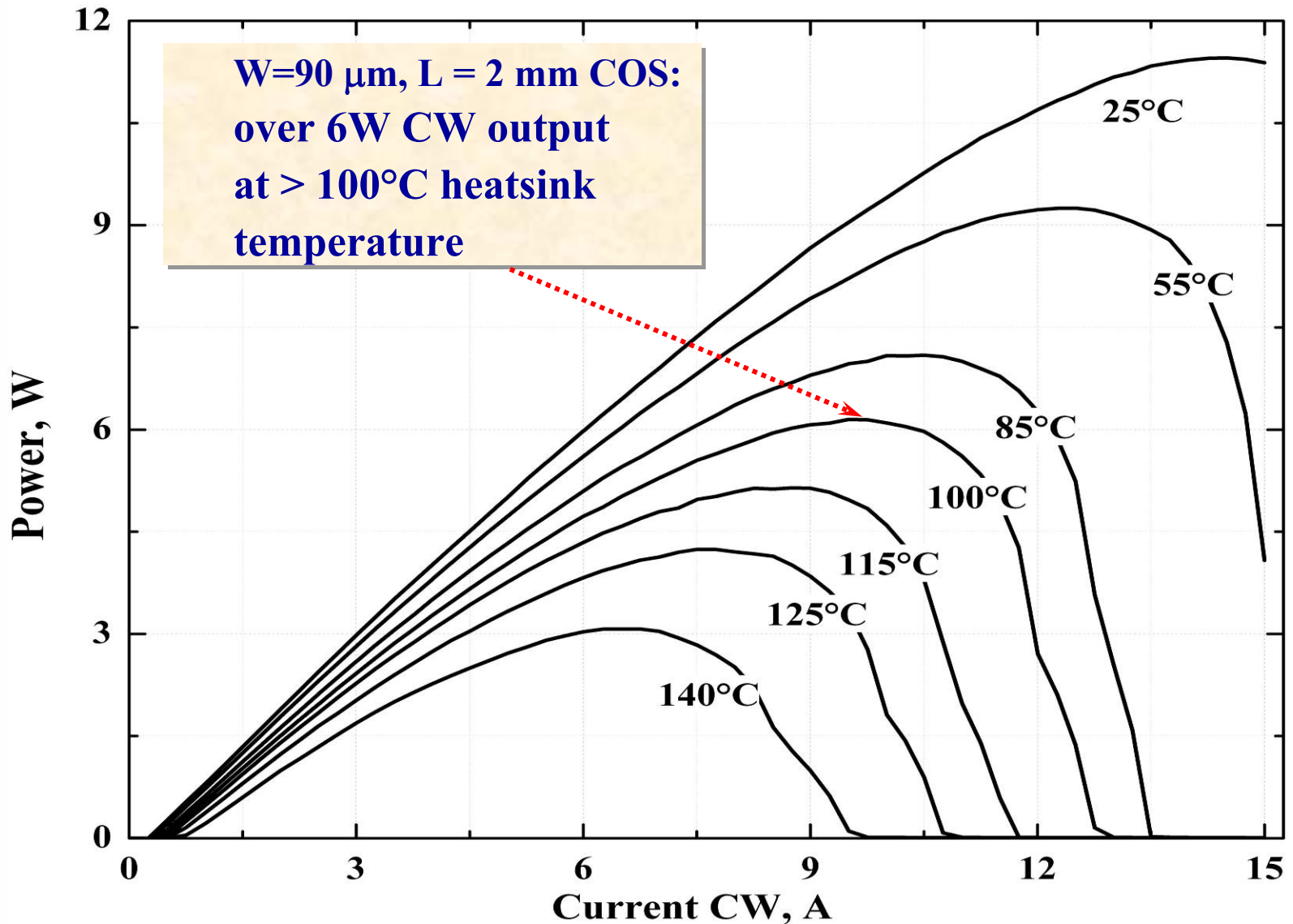
# Cooler-less Packaged Multimode Pumps



- *Extra-small footprint*
- *Low profile design*
- *High manufacturability*
- *Capable of over 15 A CW driving current*
- *Proven platform for the next generation packages:*
  - *15 W – in production*
  - *20 W – under qualification*

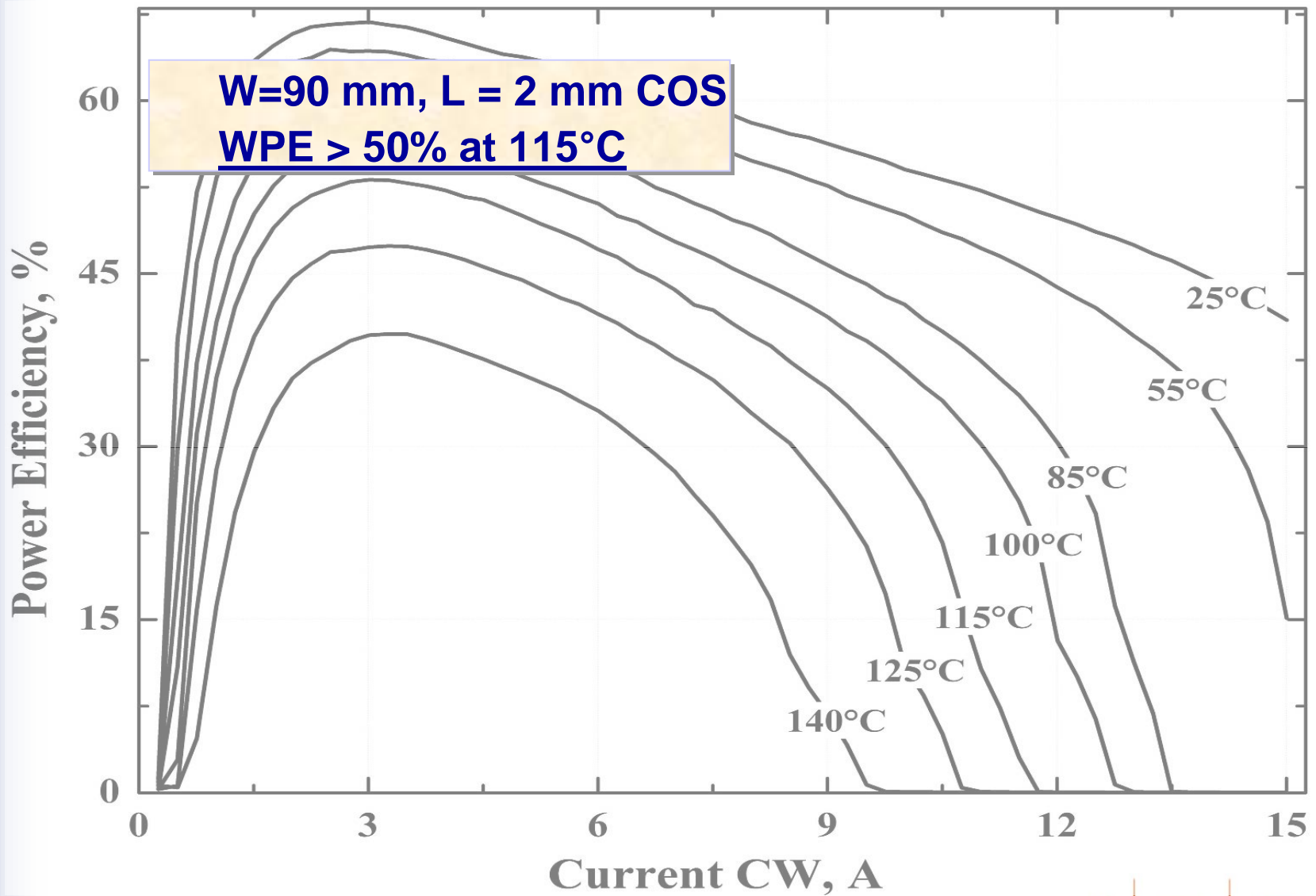


# Stable CW Cooler-less Operation : $W=90$ $\mu\text{m}$ , $L = 2$ mm COS: $970$ nm



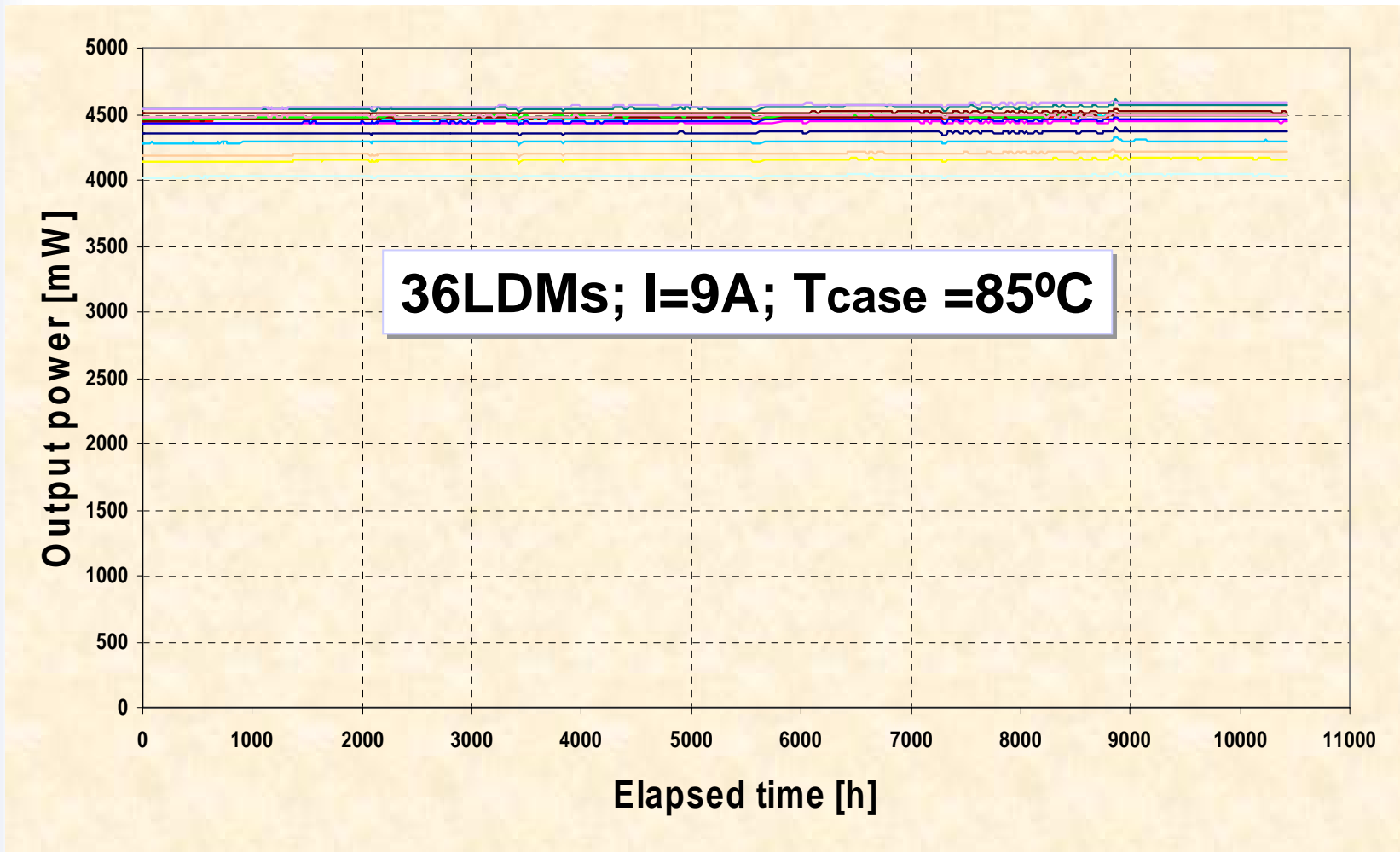


# Stable CW Cooler-less Operation : $W=90$ mm, 970 nm





# Lifetime test of single stripe LDMs



# Single Stripe BA Laser Diode Performance

<b>Parameter</b>	<b>Diode Bars Single emitter</b>	<b>BA LD- qualified</b>	<b>LD- under qualification</b>	<b>LD-under development</b>
<b>In-fiber power, W (100um, NA 0.15 )</b>	1.5	5.3	8	>20
<b>Life, hrs</b>	< 5,000	> 100,000	>100,000	> 100,000
<b>Case cooling</b>	+/- 1 deg C	n/a	n/a	n/a
<b>EO efficiency , %</b>	45 - 55	55	> 52	>52
<b>WPE, %</b>	< 30	46	> 43	> 45
<b>Thermal resistance, Deg C / A</b>	2-3	3-3.5	3.0	3.0
<b>Junction overheating, Deg C / A</b>	50 - 60	18 - 20	28-30	28 - 30



# IPG Pump Laser Diodes

1. Record high power and brightness COS:

- AlGaInAs/GaAs 9xx nm single emitter multimode COS are capable of over 20 W CW and brightness  $> 420 \text{ mW/mm}$  ( $65 \text{ MW/cm}^2$ )

2. Record high power efficiency COS:

- COS demonstrate of  $> 73\%$  efficiency at  $25^\circ\text{C}$ ;
- WPE  $> 50\%$  at heatsink temperature  $> 120^\circ\text{C}$ .

3. “Telecom-grade” reliability

*was demonstrated for high-power & high-brightness multi-mode pumps*

4. Packaged cooler-less pumps demonstrate:

- High reliability
- High power and efficiency,
- Have extra-small footprint and scalable technology.

# 250 W, CW Single Mode Fiber laser-AC



*Size: 460 x 175 x 420 mm; Weight: 15kg*

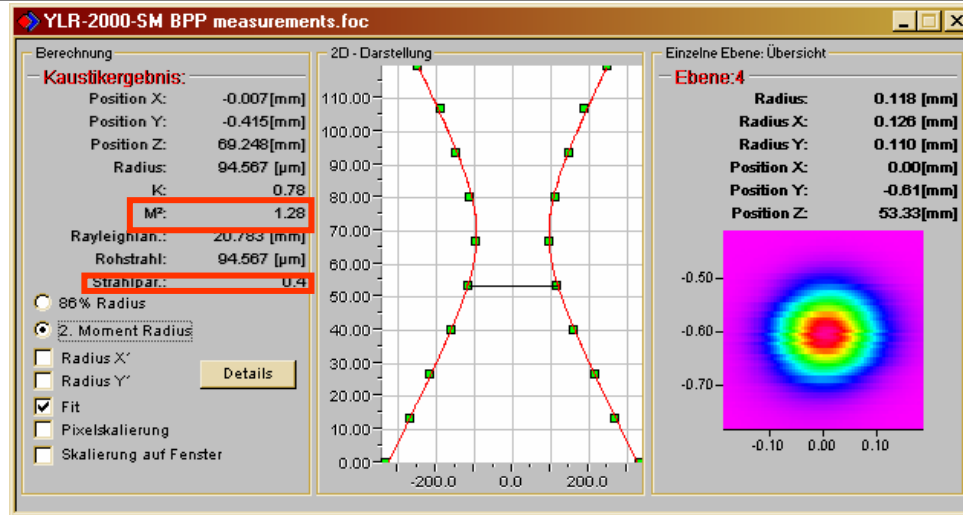
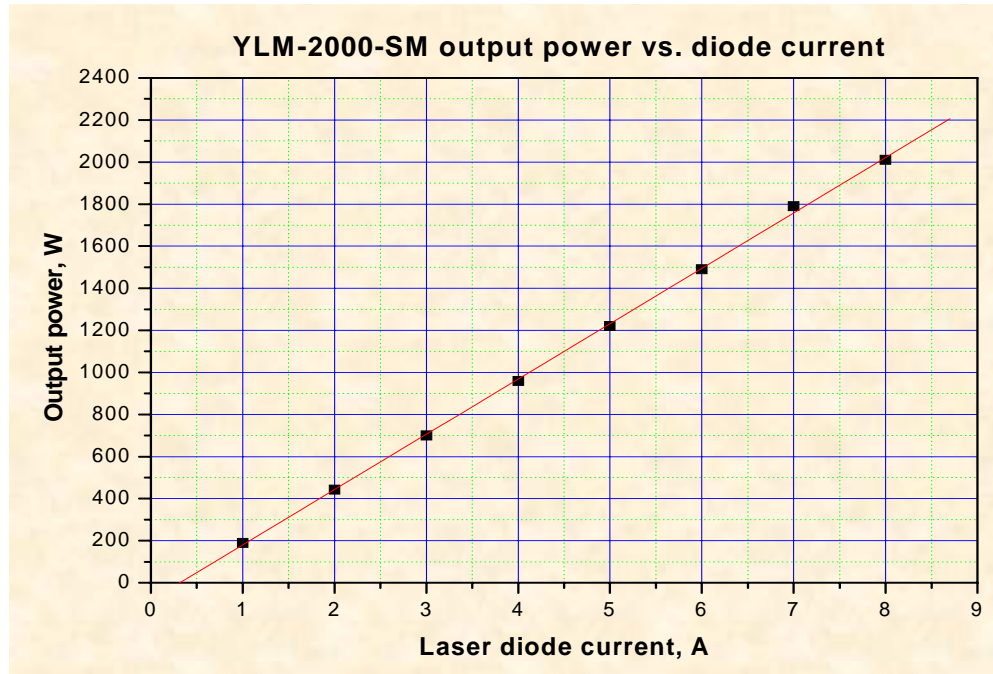
*Model YLR-250- Air cooled*

# Single Mode 1kW Fiber Laser



- $P_{\text{nom}} [\text{W}] = 1000$
- $\lambda [\text{nm}] = 1070$
- $\text{WPE} [\%] = 25$
- $\text{Fiber core} [\mu\text{m}] = 14$
- $\text{BPP} [\text{mm} \times \text{mrad}] = 0.34$   
 $M^2 = 1.05$
- $\text{Water} [\text{l}/\text{min}] < 4$
- $\text{W} \times \text{H} \times \text{D} [\text{cm}] = 56 \times 34 \times 60$

# Single Mode 2kW Fiber Laser ( $M^2 < 1.2$ ), prototype

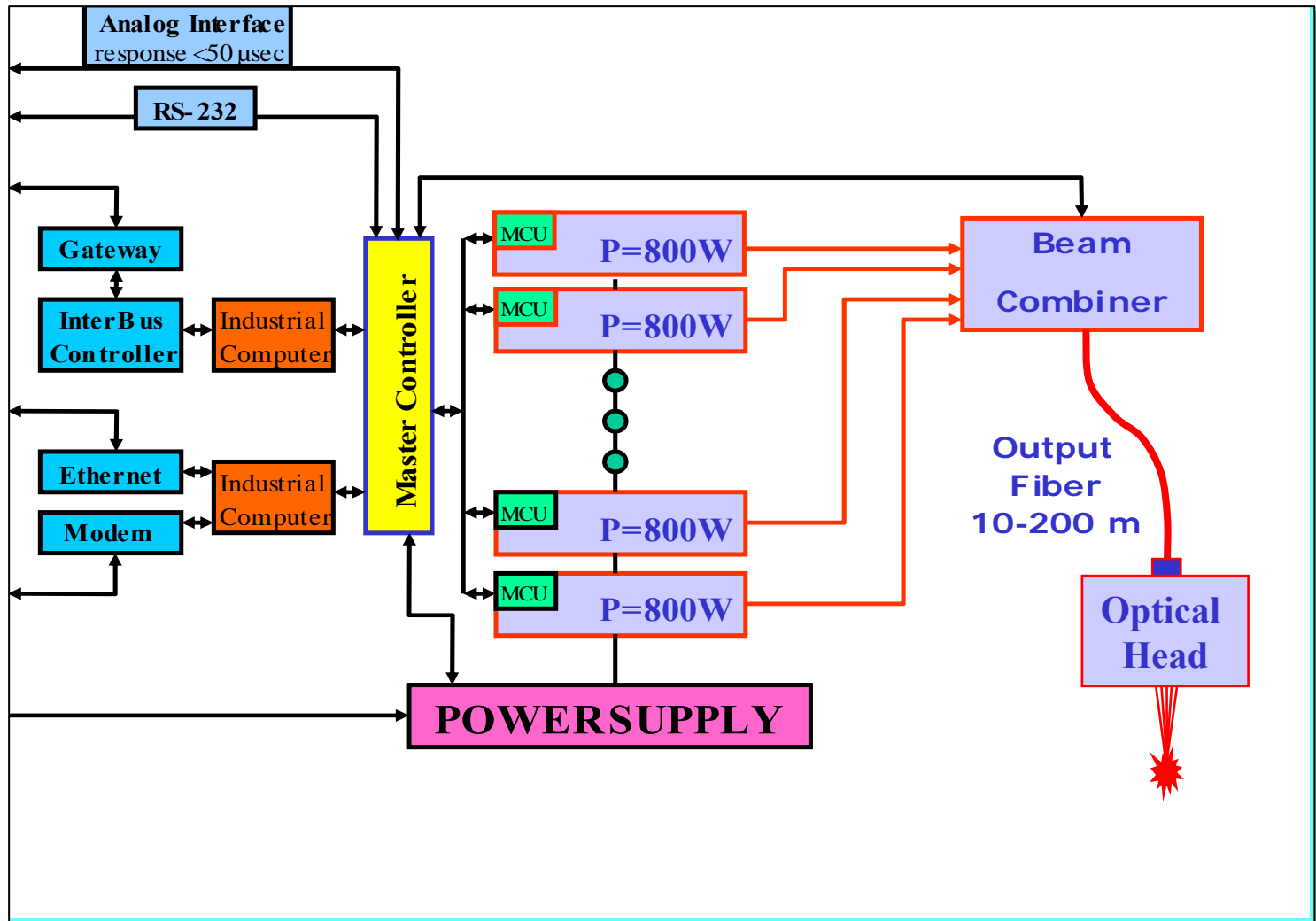




# SM Yb fiber lasers applications

<i>Applications</i>	<i>Power</i>
• <i>Marking of plastics and metals</i>	<i>10-100W</i>
• <i>Thermal printing &amp; engraving</i>	<i>20W - 1000W</i>
• <i>Micro cutting &amp; welding</i>	<i>50W - 500W</i>
• <i>3D prototyping - Syntering</i>	<i>50W - 300W</i>
• <i>LCD Trimming</i>	<i>20W - 200W</i>

# 1KW-20KW Fiber Lasers – Basic Concept





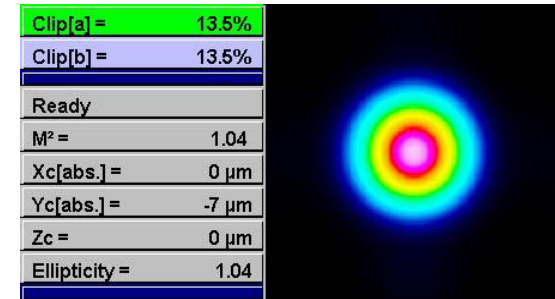
# Industrial grade kW Fiber lasers



# Fiber Laser – Beam Quality

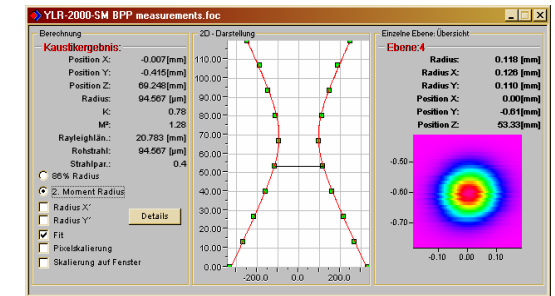
## Up to 500W 2kW CW Output Power

- ✓ TEM<sub>00</sub> operation
- ✓ Single Mode Fiber-14  $\mu\text{m}$
- ✓ BPP  $\sim 0.35 \text{ mm x mrad}$



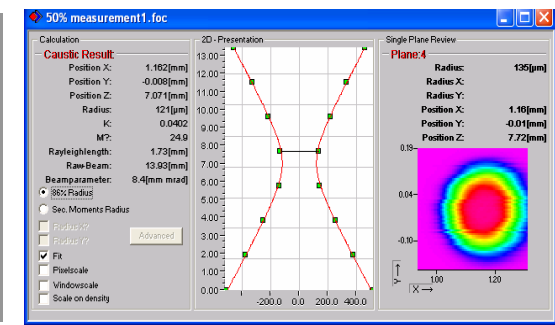
## Up to 3kW 5kW CW Output Power

- ✓ Beam Parameter Product < 2.5 mm x mrad
- ✓ Fiber Delivery - 50  $\mu\text{m}$



## Up to 10kW 20kW CW Output Power

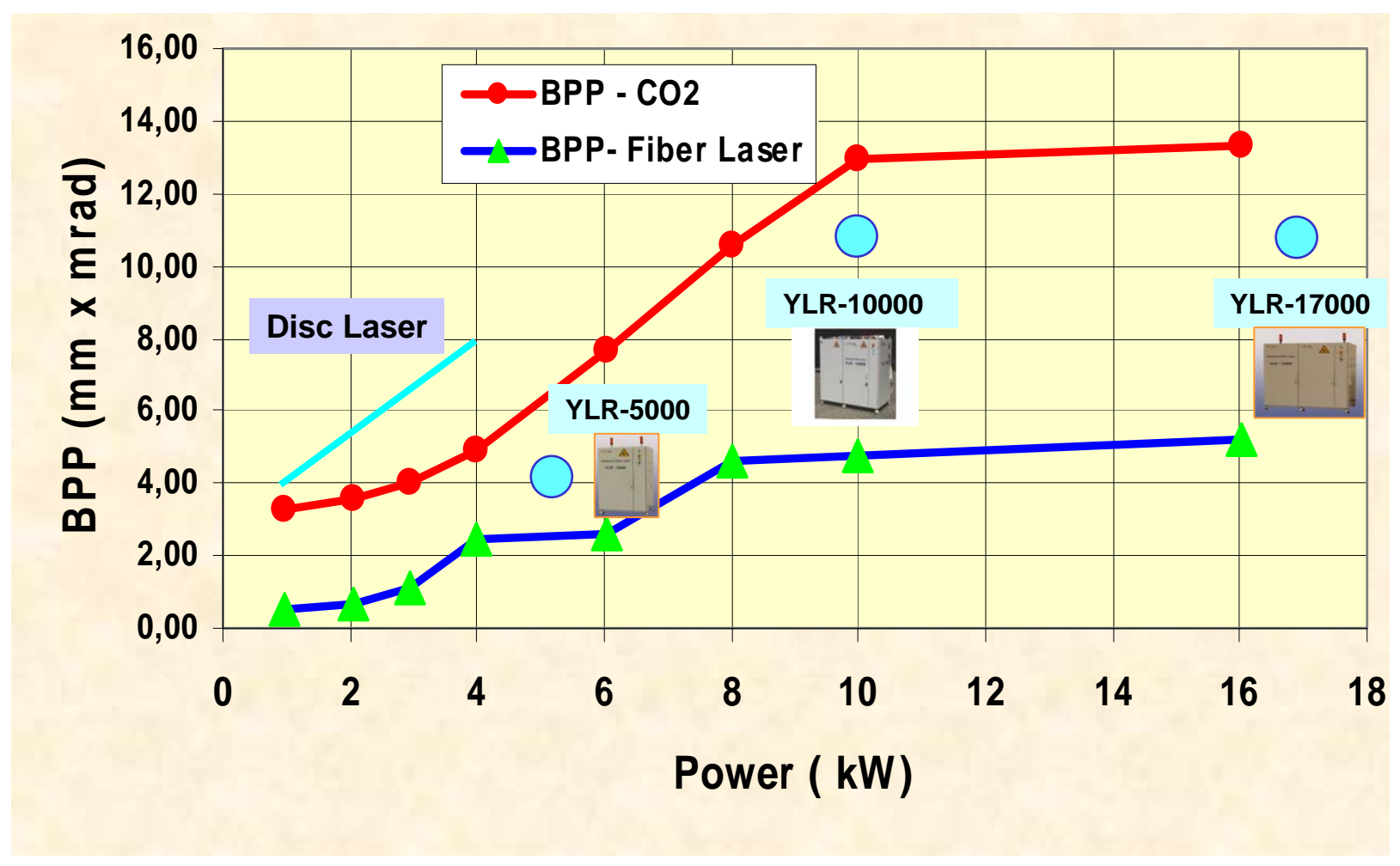
- ✓ Beam Parameter Product:  
10kW < 6 mm x mrad; fiber delivery 100  $\mu\text{m}$   
20KW < 12 mm x mrad; fiber delivery 200  $\mu\text{m}$



\* All output powers are specified at the work piece



# Beam Quality of Fiber Laser v.s CO<sub>2</sub>



● 2004 shipment-400W modules

▲ 2005 shipment -800W modules



# *MM Fiber lasers applications*

- *Metals Cutting*
- *Metals Welding including remote*
  - *Plastics cutting & welding*
    - *Concrete cutting*
- *Mobile laser machine for C&W*
  - *Special applications*

# New fiber laser for remote welding



<b>Nominal laser power</b> (at the workpiece)	<b>&gt; 5.0 kW</b>
<b>Maximum laser power</b>	<b>6.0 kW</b>
<b>Wavelength:</b>	<b>1070 nm</b>
<b>Fiber core:</b>	<b>100 (150* ) <math>\mu\text{m}</math></b>
<b>Fiber Length</b>	<b>up to 200m</b>
<b>BPP</b>	<b>&lt; 4.1 (5.8*) mm x mrad</b>
<b>Foot Print</b>	<b>800 x 860 mm</b>
<b>Height</b>	<b>1.500 mm</b>
<b>Cooling capacity</b>	<b>16 kW</b>
<b>WPE (wt cooler )</b>	<b>&gt; 27%</b>

\* with coupler and processing fiber



# New Fiber Laser, Model YLR-10000-S



Nominal laser power (at the workpiece)	10.0 kW
Wavelength:	1070 nm
Fibre optics core:	ø 150 µm
BPP	< 8 mm x mrad
Foot Print	800 x 1.460 mm
Height	1.500 mm
Cooling capacity	31 kW
WPE (wt cooler )	> 27%



# New Fiber Laser, Model YLR-17000-P

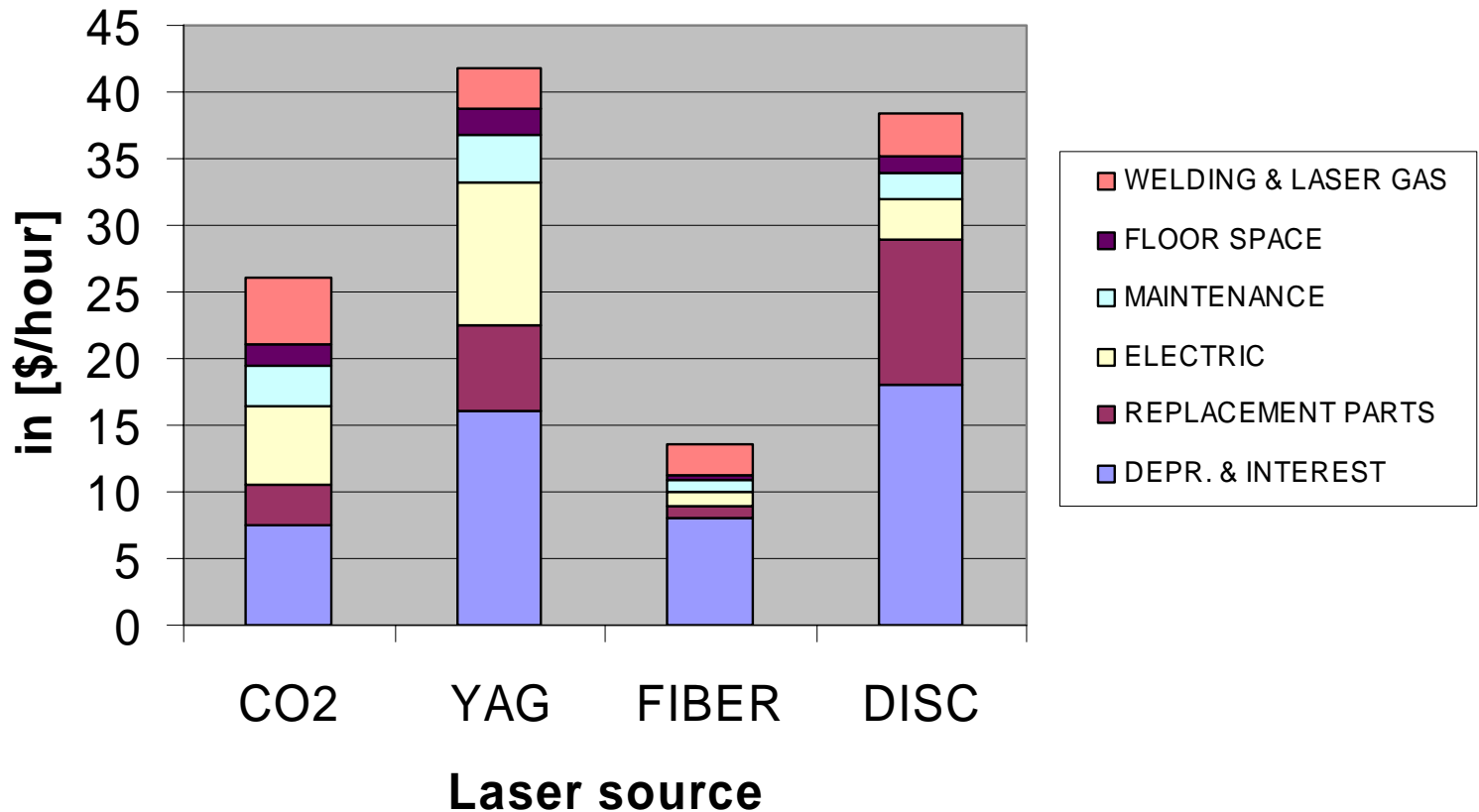


<b>Nominal laser power (at the workpiece)</b>	<b>15.0 kW</b>
<b>Maximum laser power</b>	<b>17.0 kW</b>
<b>Wavelength:</b>	<b>1070 nm</b>
<b>Fiber core:</b>	<b>ø 200 µm</b>
<b>Fiber Length</b>	<b>up to 50m</b>
<b>BPP</b>	<b>11mmxmrاد</b>
<b>Foot Print</b>	<b>800 x 1.460 mm</b>
<b>Height</b>	<b>1.500 mm</b>
<b>Cooling capacity</b>	<b>42 kW</b>
<b>WPE</b>	<b>&gt; 26%</b>



# Operating Cost

## Europe Laser Operating Cost ( 8 year in use )





# ***Fiber Lasers Create a New Applications***

- ***Aerospace Industry – Main Body Aluminum Welding***
- ***Shipyards Industry – Mobile “On Ship” Cutting and Welding***
- ***Pipe Lines - “In Field” Welding & Cutting***
- ***Remote cutting of large scale products***
- ***“In Field” Rock & Concrete Cutting***
- ***Heavy Industry – Deep Penetration Welding and Cutting***
- ***Car & Truck Service Centers***
- ***Gas & Oil Well Drilling***

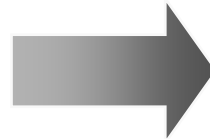


# IPG Fiber Lasers – Trends

- *Increase* **POWER**  
20kW → 50kW & 100kW
- *Decrease* **BPP**  
4mm×mrad → 2 & 1 mm×mrad
- *Increase* **WPE**  
25% → 30 %
- *Decrease* **PRICE**  
\$80/W → \$50-30/W



# New fiber lasers



Nominal laser power (at the workpiece)	> 5.0 kW
Maximum laser power	6.0 kW
Wavelength:	1070 nm
Fiber core:	100 (150* ) $\mu\text{m}$
Fiber Length	up to 200m
BPP	< 4.1 (5.8*) mm x mrad
Foot Print	800 x 860 mm
Height	1.500 mm
Cooling capacity	16 kW
WPE (wt cooler )	> 27%



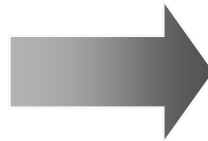
Nominal laser power (at the workpiece)	> 10.0 kW
Maximum laser power	11.0 kW
Wavelength:	1070 nm
Fiber core:	100 (150* ) $\mu\text{m}$
Fiber Length	up to 200m
BPP	< 4.1 (5.8*) mm x mrad
Foot Print	800 x 860 mm
Height	1.500 mm
Cooling capacity	32 kW
WPE (wt cooler )	> 28%



# New Fiber Lasers



Nominal laser power (at the workpiece)	10.0 kW
Maximum laser power	11.0 kW
Wavelength:	1070 nm
Fiber core:	∅ 200 μm
Fiber Length	up to 50m
BPP	11mmxmrاد
Foot Print	800 x 1.460 mm
Height	1.500 mm
Cooling capacity	32 kW
WPE	> 26%



Nominal laser power (at the workpiece)	20.0 kW
Maximum laser power	21.0 kW
Wavelength:	1070 nm
Fiber core:	∅ 200 μm
Fiber Length	up to 50m
BPP	11mmxmrاد
Foot Print	800 x 1.460 mm
Height	1.500 mm
Cooling capacity	64 kW
WPE	> 28%





# Main Advantages of IPG Fiber lasers

- *Compact integrated design*
- *Superior wall-plug efficiency*
- *Unparalleled laser diodes reliability*
  - *Superior beam quality*
  - *Long fiber delivery*
- *Exceptionally low maintenance and operational cost*

# Conclusions

- *IPG has demonstrated, realised and started mass production more than 300 different models fiber lasers*
- *More than 3000 fiber lasers were shipped by IPG to customers in Year 2004*
- *In welding and cutting IPG high power fiber lasers successfully compete with DPSSL and CO2 lasers*
- *IPG fiber lasers open a new markets for laser applicaitons*