10TH ANNUAL DEPARTMENT OF ENERGY LASER SAFETY OFFICER WORKSHOP

Scalability of Fiber Laser Technology And the Challenge to Safe Installations

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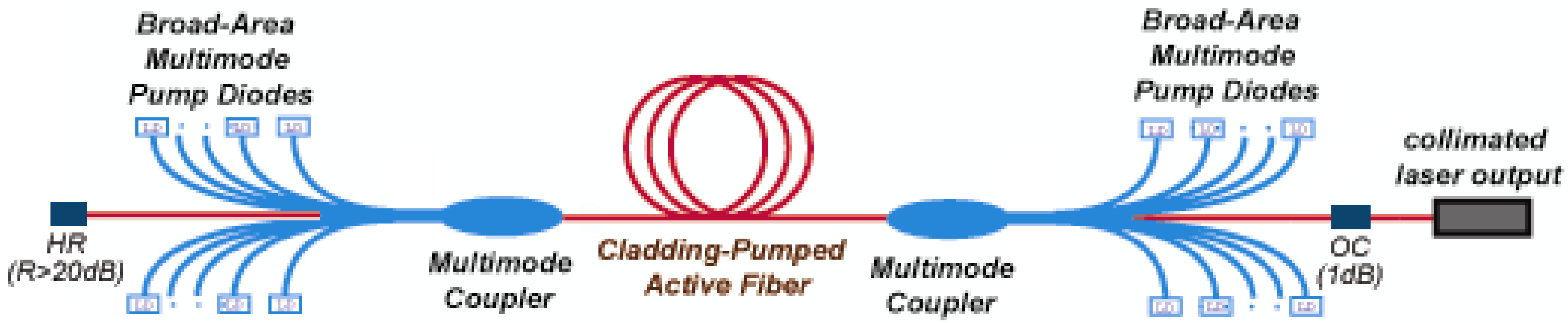
High Power Fiber Laser Configuration



Active Fiber:

Multi-Clad, Circular Cladding,

Low Diameter, ~2-10m Total Length

High Yb^{3+} Concentration

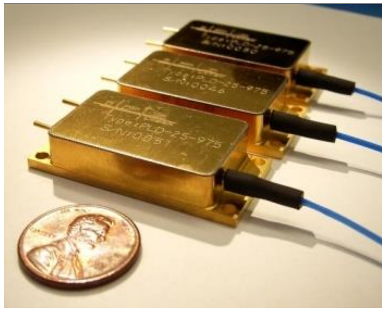
Pump Diodes:

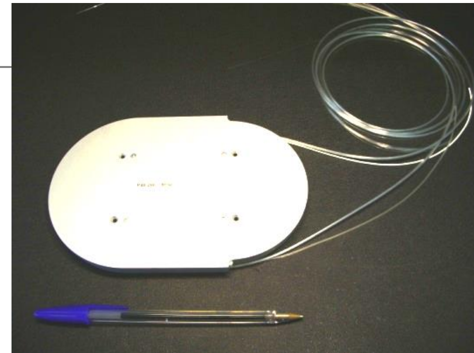
Multimode

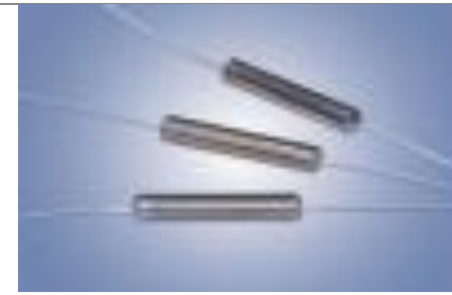
90μm stripe

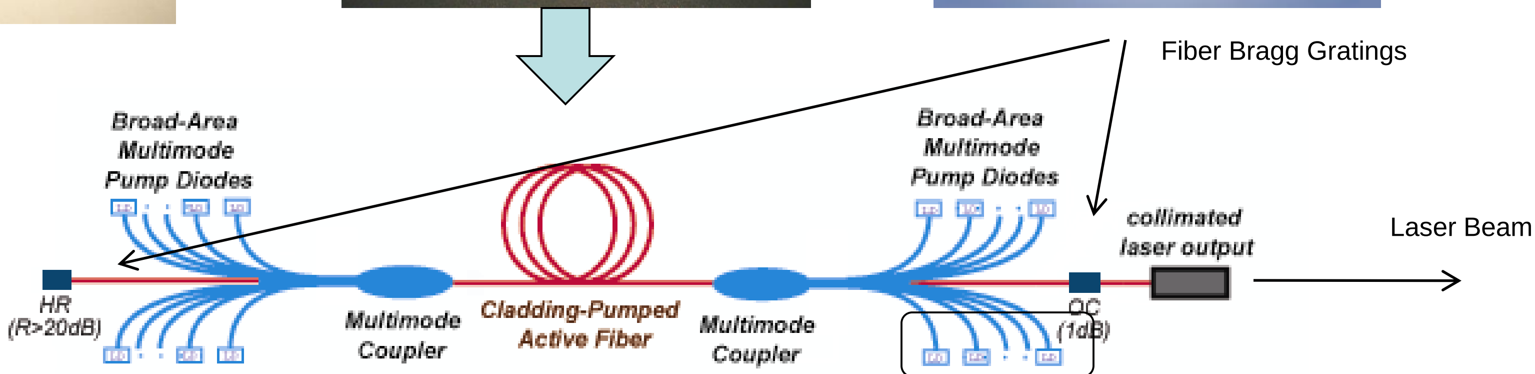
30W to 100W Output Power

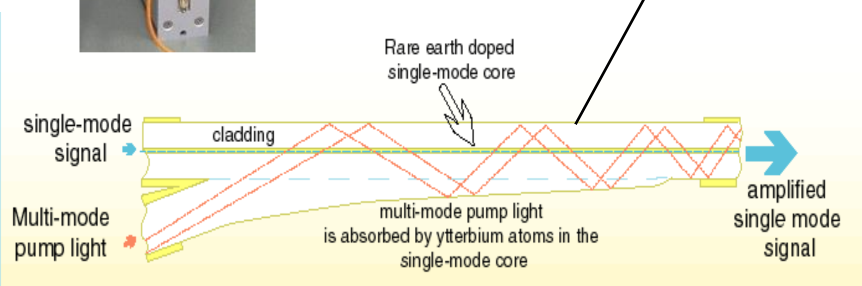
Fiber Laser Construction

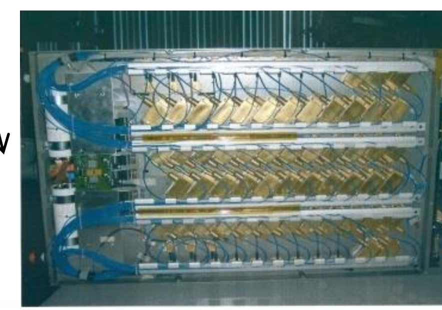




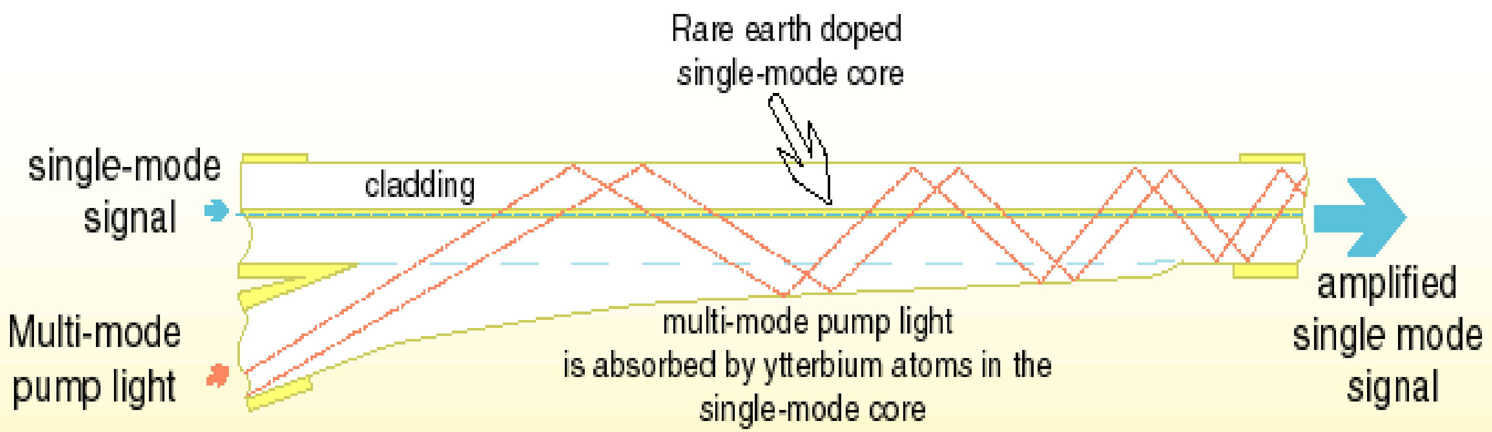








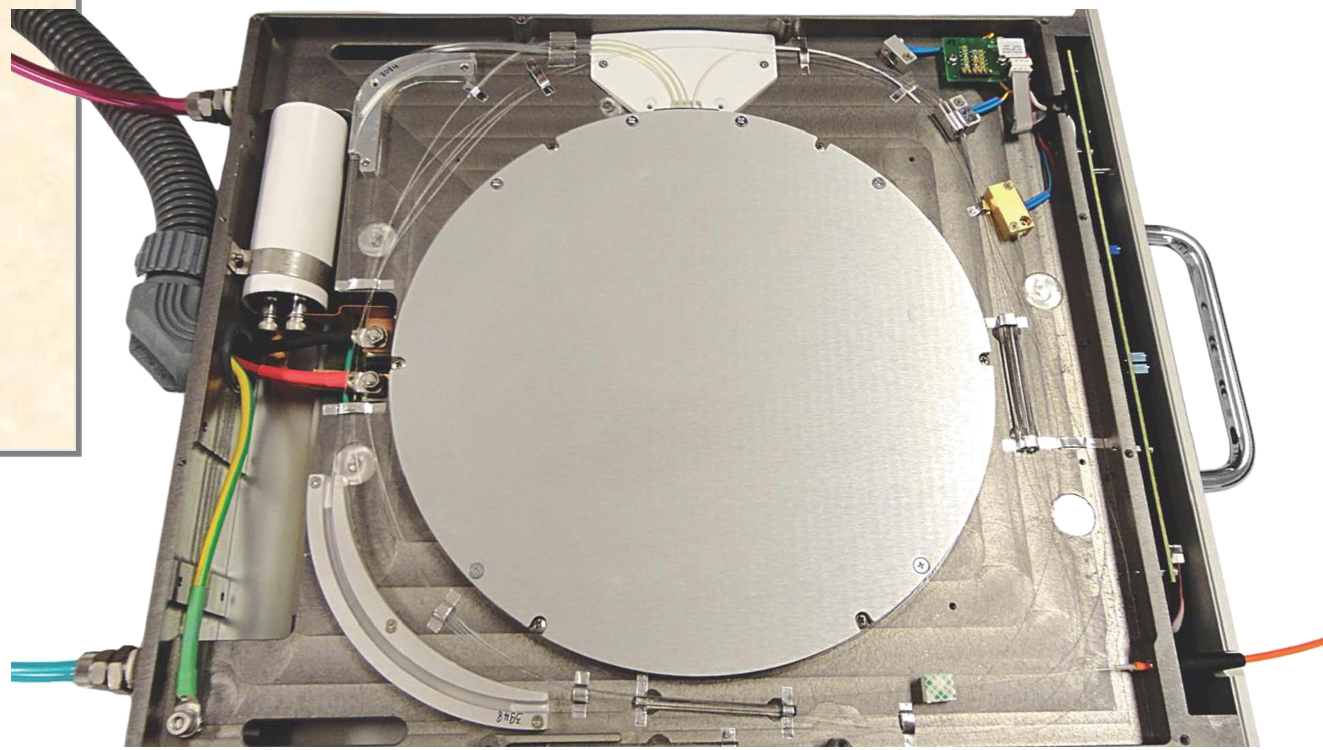
Proprietary Power Coupling Technology



- Double clad design, pump energy delivered through large core fiber, laser produced in 9um inner core, single mode output
- Scalable to Higher power, high reliability, broad stripe diodes
- No limitation on insertion of pump photons-can distribute gain
- No residual pump light in output
- Advantages:
  Scalability, Reliability and Performance

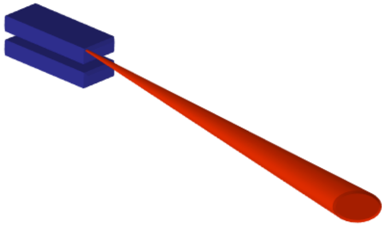
High Power SM Fiber Laser Modules

- P = 700 & 1000 W
- λ = 1070 nm
- BPP = 0.34 mm x mrad ($M^2 < 1.05$)
- WxHxD = 42x33x4.7cm
- DC wall-plug efficiency > 32 %

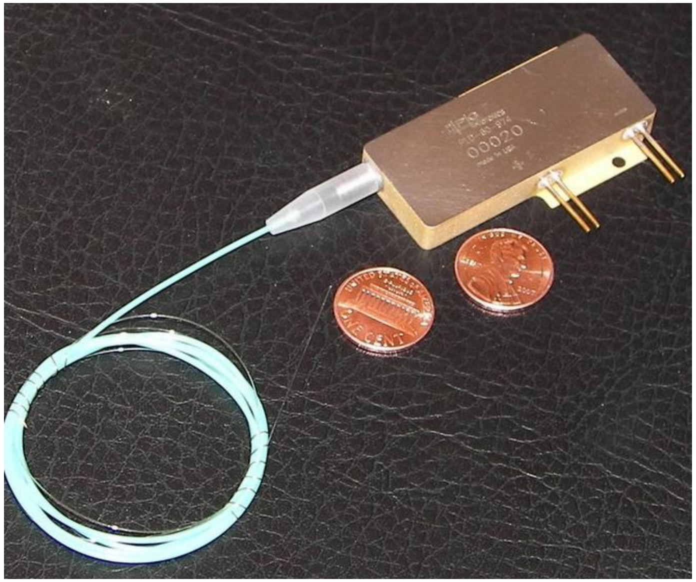


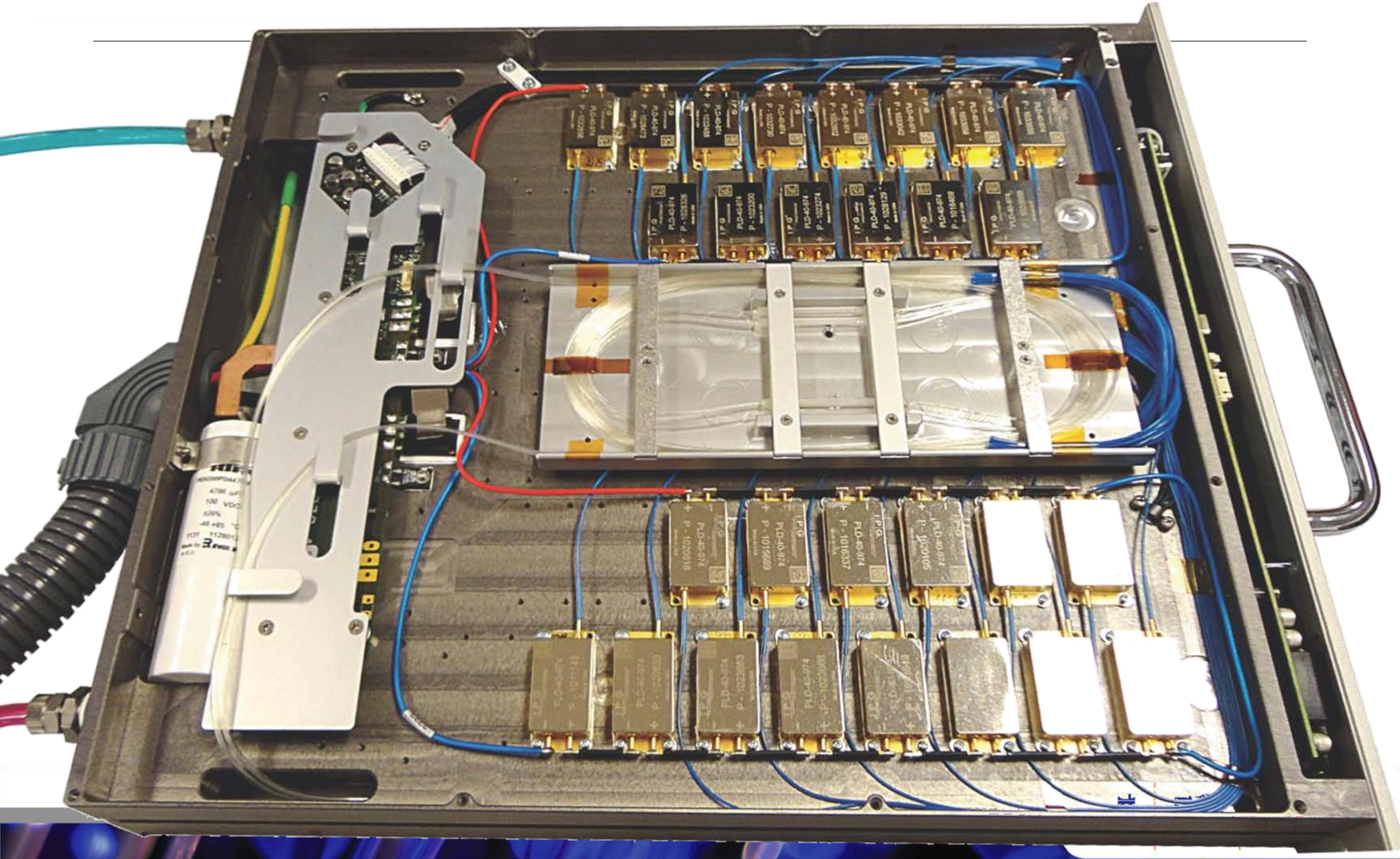
Pump Diodes - the Heart of the Laser

IPG Single Stripe Diode



Conventional Cooling
Low Current (5 amps)
Low Heat Dissipation
Easy to pigtail into fiber
Est. Lifetime > 100,000 hrs
Efficiency > 70%

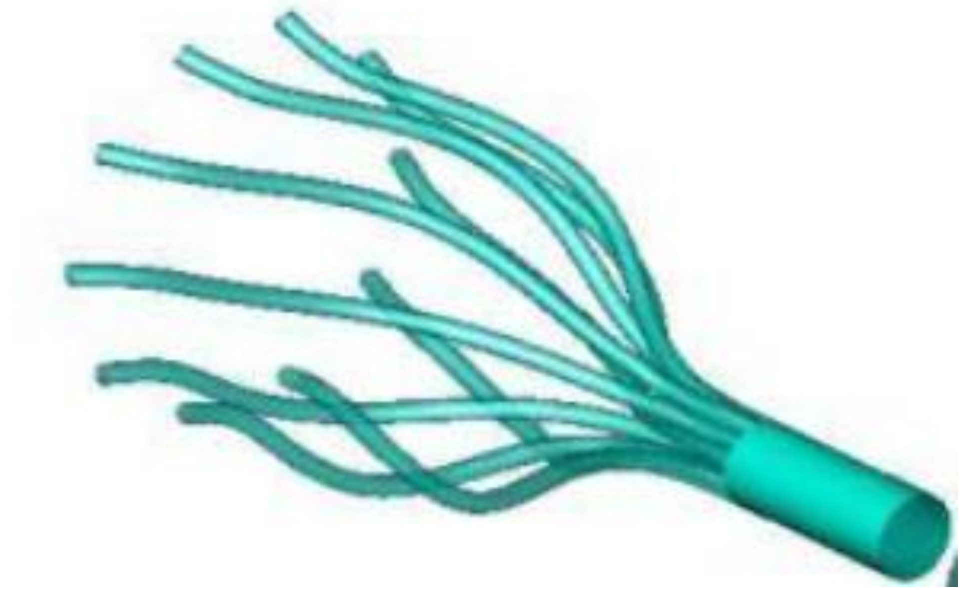




Common Modules

Fiber Combiner

Single Mode Fibers From Modules



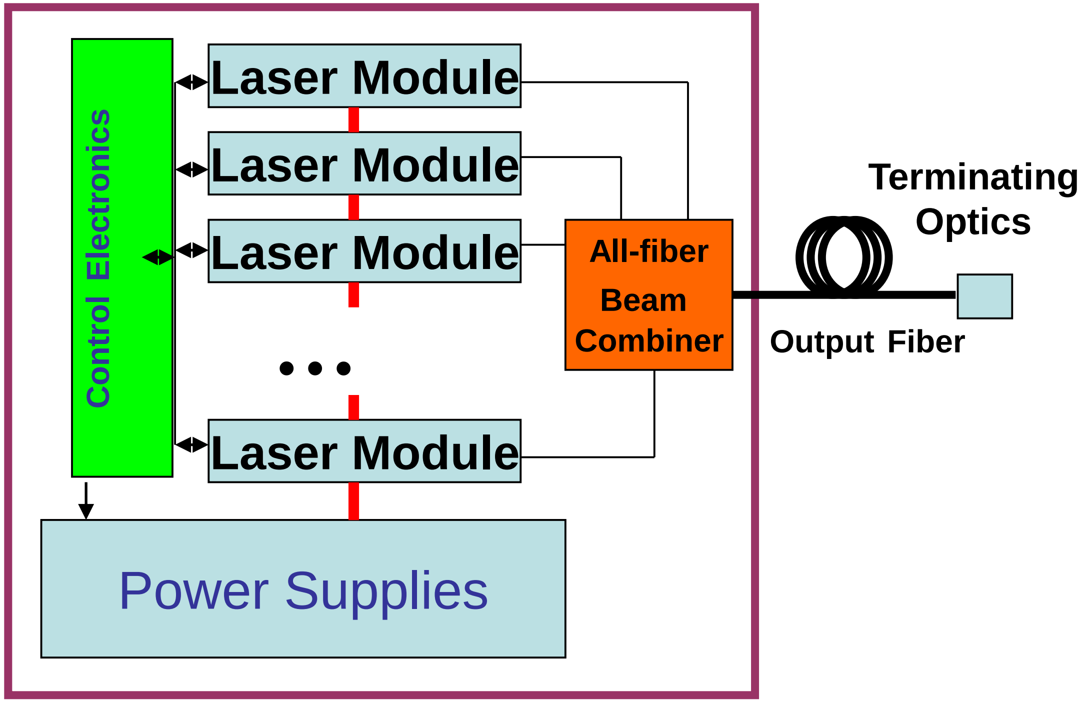
Multimode Fiber Output

10kW Fiber Laser – by Combining Modules

Modular Fiber Laser Structure

Multiple SM lasers are combined using all-fiber combiners

Combiner output spliced to a MM output fiber.



Ytterbium Laser System 20,000 Watt
100 µm Delivery Fiber

- Output power: > 20 kW
- Beam quality
  - 100 µm core Fiber: BPP ≈ 4.0 mm*mrad
  - 50 µm core Fiber: BPP ≈ 2.0 mm*mrad
- Delivery fiber length:
  - 100 µm core Fiber: 10 m
  - 50 µm core Fiber: 5 m
- Modulation: up to 5 kHz
- Consumption for 100 µm < 67 kW
- Consumption for 50 µm < 80 kW
- Wall-plug efficiency 100 µm: > 30 %
- Wall-plug efficiency 50 µm: > 25 %
- Dimensions: 1475 x 806 x 1402 mm
- Weight: 1200 kg

30kW Multimode

- Output beam quality BPP~10 M^2~30
- DC EOE ~ 33%
- Output fiber core diameter 200um
- Output NA ~ 0.085
- Output fiber length 15m
- Linewidth (FWHM) ~4nm

IPG PHOTONICS

Ytterbium Laser System 50,000 Watt
200 µm Delivery Fiber

• Output power:	> 50 kW
• Beam quality	
• 200 µm-core Fiber:	BPP<12 mm*mrad
• 100 µm-core Fiber:	BPP<4.5 mm*mrad
• Delivery fiber	
200 µm-core Fiber:	up to 25 m
100 µm-core Fiber:	up to 10 m
• Modulation:	up to 5 kHz
• Consumption	
200 µm-core Fiber:	< 170 kW
100 µm-core Fiber:	< 200 kW
• Wall-plug efficiency	
200 µm-core Fiber:	> 30 %
100 µm-core Fiber:	> 25 %
• Dimensions:	1800 x 2730 x 810 mm
• Weight:	3000 kg

IPG PHOTONICS

100,000 Watts

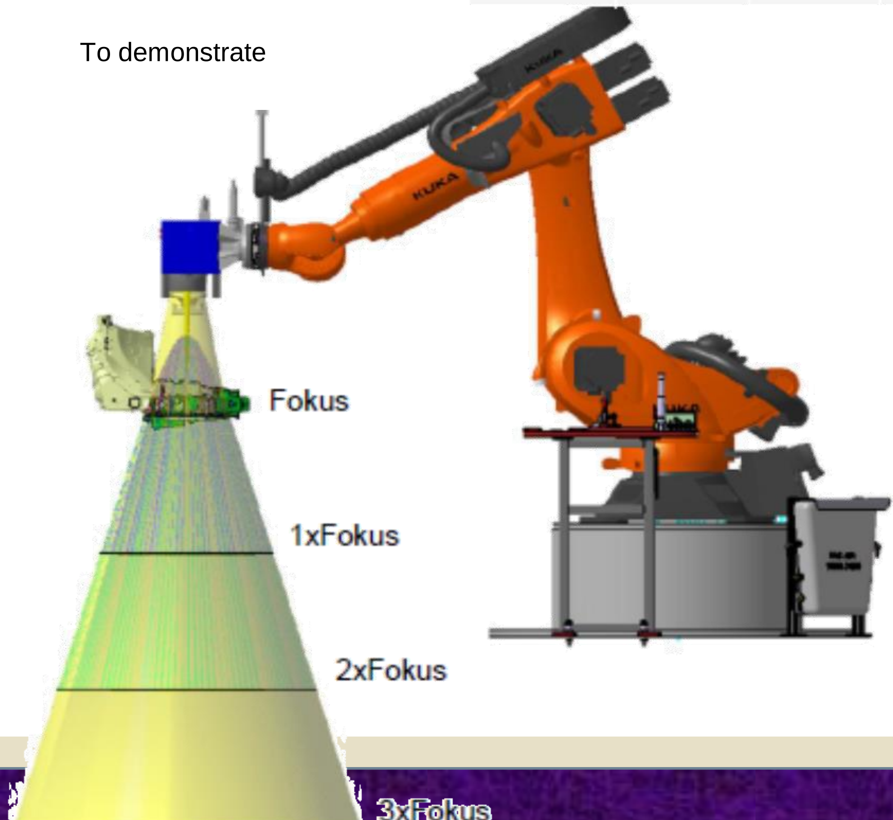
1.0 Optical Characteristics

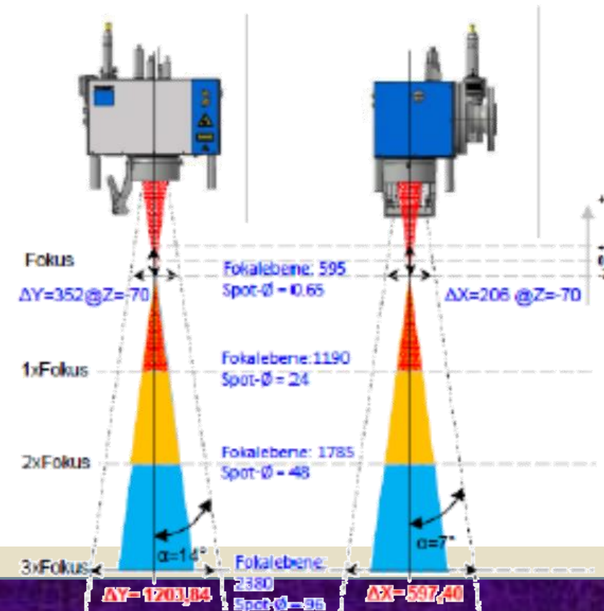
Mode of Operation	CW/ Modulated	
Nominal Output Power, W	**100 000**	
Emission Wavelength, µm	1.07	
Emission Linewidth, nm	3-6	
Switching On/Off Time, µs	20-100	
Output Power Modulation Rate, kHz	up to 5	
Feeding Fiber (HLC-24 Connector) Core Diameter, µm	300 10	
Optional: Fiber-to-fiber Coupler (FFC) Length, m	Integrated, Water-cooled, 3" Optics	
Process Fiber Length, m	≥50	
Beam Parameter Product, 86% Level, mm*mrad	Typ.	Max.
Feeding Fiber Core Diameter, 300 µm Process Fiber Core Diameter, 500 µm	13.0 23.0	15.0 25.0
Laser Interfaces: Standard Optional	Analogue Control Hardwiring Industrial Ethernet Safety Interface, Chiller Interface Fieldbus Interface	

Fiber Laser Safety

….so what are we supposed to do to adequately safeguard 100 kW?

To demonstrate





Fiber Laser Safety

. . . . *Same as before, just more of it ?*

21 CFR 1040.10 FLPPS

IEC 60825-1 Safety & Classification

ANSI Z 136.1 Safe Use of Lasers

ANSI Z 136.9 Manufacturing

Guidance Z 136.7 & 60825-4

Fiber Laser Safety

…. 21 CFR 1040.10 FLPPS

IEC 60825-1 Safety & Classification

21 CFR Protective Housing function for its purpose and environment throughout the life product

International adds reasonably foreseeable single fault level, and requirement for automation to survive 30,000 seconds w/o human intervention

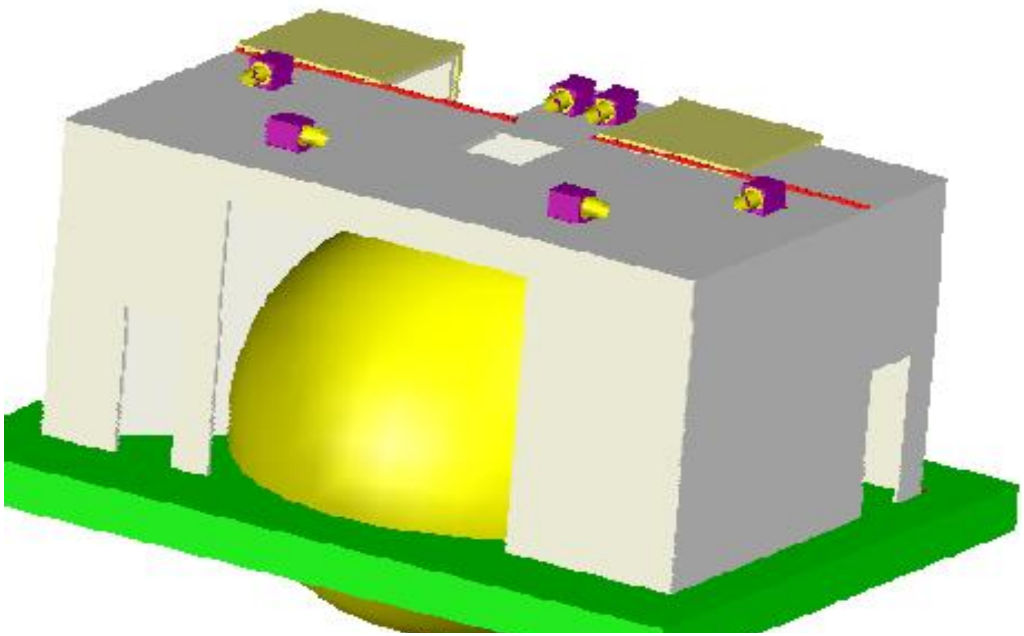
4 kW, 3 focal lengths past focus 10 seconds 9 mm. galv steel

Fiber Laser Safety

…. *Prime methodology*

Heat dissipation (cooling) as a safety provider

The radius of the robot arm plus the end effector plus the distance beyond the focal point at which damage to the inner wall could occur

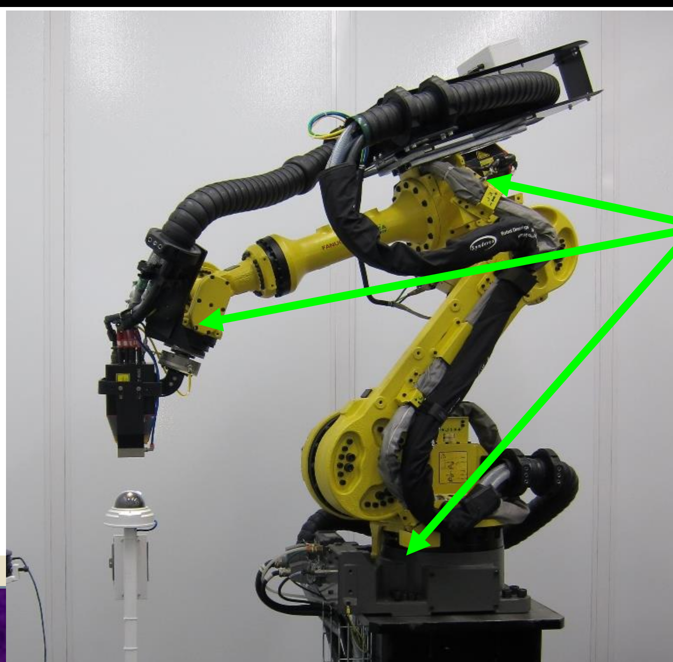


Aluminum dramatically outperforms steel for many powers up to crossover

Fiber Laser Safety

…. *Prime methodology*

In other words, insure the beam CANNOT point at the wall (or other surface) in a manner in which it could harm or breach the surface

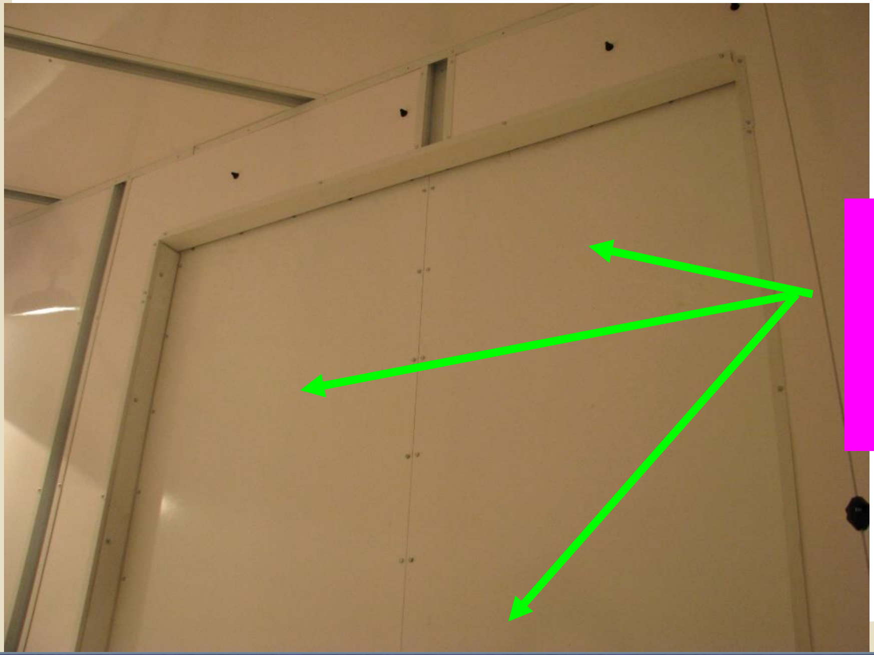


No fly zone mechanisms

Fiber Laser Safety

…. *And then*

Deal with the remaining energy as primarily either a long distance divergent beam (several focal lengths on the other side of the box) or diffuse reflected



Double walled steel panels buildings with calculated thicknesses and distances

Fiber Laser Safety

. . . . ***And then***

While discouraging viewing windows or making them double/triple thick to ensure adequate attenuation to Class I AEL (many times addition of detection was also need in the event a beam began to damage a window)

Double thick with fusible filament

L•A•I International
LASER ENGINEERING & CONSULTING - WORLDWIDE

Fiber Laser Safety

*.... **But do all these tactics work, as we cross over the 10* kW mark*** ***(*or some other arbitrary number)***

Or will we need literal fortresses to contain them

Fiber Laser Safety

. . . . ***Well, some and maybe yes***

we have anecdote and some empirical indication that even at current power there is reflected energy in significant energy concentration to cause harm, expecialy with longer focal lengths (which increase the reflected or directed irradiance)

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Fiber Laser Safety

*. . . . **So, although we will still ….***

- ***do some exercise in controlling the direction (robot & optics head)***
- ***maintain angles and distances***
- ***Calculate melting points, and use material which will dissipate energy without vaporizing***
- ***Discourage viewports***

x

Fiber Laser Safety

. . . .

We're gonna need a bigger boat . . . .

Fiber Laser Safety

*.... **We will likely need to add one or more functions we don't consider necessary now, or implement them to a greater extent***

- ***Add absorbing or dissipating thickness…even sacrificial static elements***
- ***Eliminate all windows (except very fast , single use destructible)***
- ***Employ active guard technology throughout***

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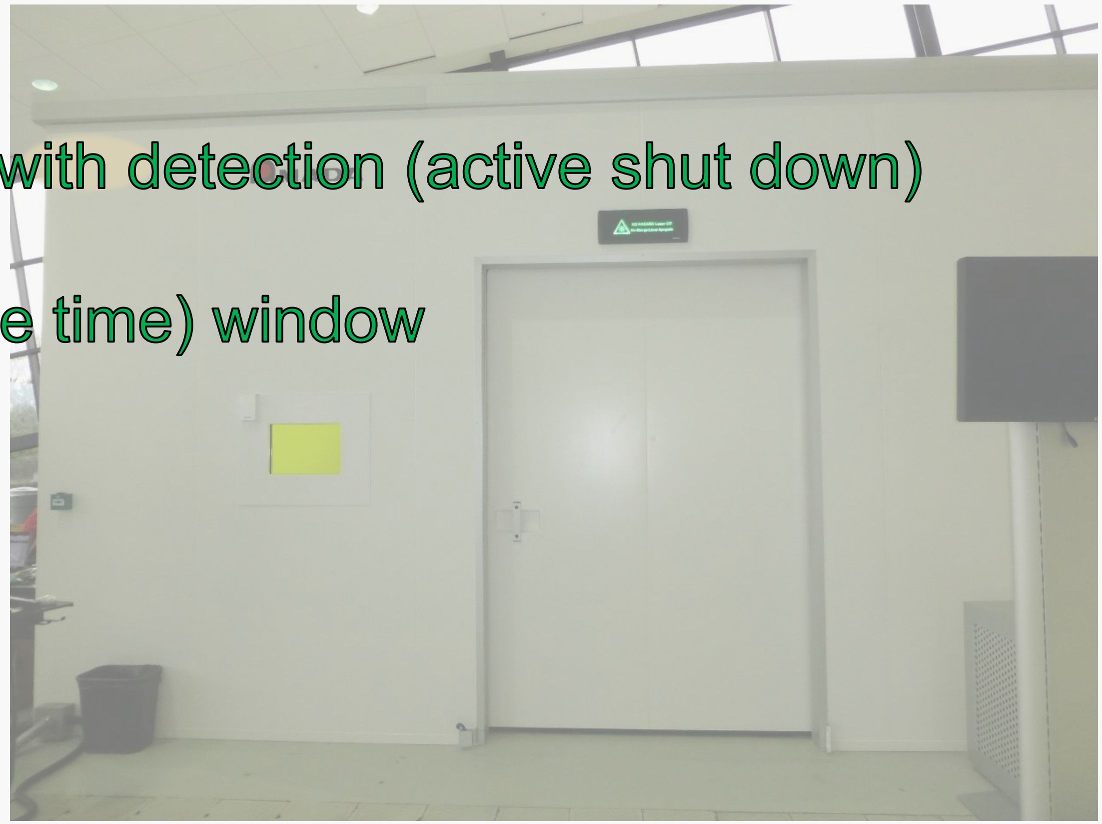
Fiber Laser Safety

- 5 inch thick walls, heavy gauge sheetmetal inside and out
- 5 surfaces with detection (active shut down)
- Fusible (one time) window



Example shown is a custom version of Lasermet Laser Castle but many brands are available

Fiber Laser Safety

. . . .

- So, life after the 10-12 kW threshold is possible
- Greater care in selecting enclosure design and material
- No windows
- As power increases, we will need greater reliance on active guard technology (absolute requirement in 50-100 kW automation appliacations)

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