Fiber Lasers for Material Processing
Bill Shiner VP Industrial
June 22, 2011
NEW ENGLAND FIBER OPTIC COUNCIL
Expanding our Global Reach

London, United Kingdom
Novi, MI, USA
Yuseong-Gu, Daejon Korea
Beijing, China
Moscow, Russia
Burbach, Germany
Strasbourg, France
Moscow, Russia
Burbach, Germany
Strasbourg, France
Beijing, China
Yuseong-Gu, Daejon, Korea
Kanagawa, Japan
Singapore
Hong Kong, China
Bangalore, India
Legnano (Milan), Italy
Santa Clara, CA, USA
Oxford, MA, USA
London, United Kingdom
Novi, MI, USA
Yuseong-Gu, Daejon, Korea
Beijing, China
Moscow, Russia
Burbach, Germany
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Yuseong-Gu, Daejon, Korea
Kanagawa, Japan
Singapore
Hong Kong, China
Bangalore, India
Legnano (Milan), Italy
Santa Clara, CA, USA
Oxford, MA, USA

Please note: IPG has 4 offices in China and 2 offices in Japan. Map excludes rep offices.
IPG Overview

- Manufacturer of high-performance fiber lasers and amplifiers
- IPG’s products are displacing traditional laser technologies and finding new applications for its lasers
- Products are sold globally to OEMs, systems integrators and end users for use in many industries
- Global operations with 1,800 employees
- Founded in 1990; IPO in 2006
- Headquartered in Oxford, Mass
Fiber Lasers: A Truly Disruptive Technology

Source: EALA, Automatic Feed Co., ALAW 2009
Broad Advantages Versus Traditional Solutions

Compared to traditional lamp/diode pumped Nd:YAG and CO₂ lasers, fiber lasers deliver many benefits:

- Superior beam quality
- Greater output power
- Higher electrical efficiency
- Lower maintenance
- Higher reliability
- More competitive on cost/watt
- Smaller footprint and size
- More mobile and rugged
- Ease of integration with robots

Bottom line: Dramatically lower total ownership costs
IPG Competitive Advantages

- Proprietary technologies developed over 19 years
- Vertical integration of critical components (diodes, specialty fibers)
- Significant manufacturing scale and low manufacturing cost
- Technology validated by a diverse base of users/OEMs
- No fiber laser competitors at high-power levels
- No laser competitors at super high-power
- Important early-stage IP portfolio
- ~150 people in R&D
Why IPG is Growing So fast

• Fiber Lasers have enabled manufactures to reevaluate the utilization of Lasers for their production applications to take advantage of the many benefits that the technology offers.
• Fiber Lasers eliminate the major objections usually associated with laser manufacturing.
• Fiber Lasers have provided unique solutions to manufacturing with lasers technology.
IPG Benefits from Vertical Integration

**Fab Operations**
- Semiconductor Wafer Growth
- Diode Processing
- Chip Mounting
- Burn-In

**Laser diode Packaging**
- PLDs 5-25

**Optical Preforms**
- Silica based glasses
- MCVD, OVD, PCVD, zole-gel methods

**Final Assembly**
- Combining
- Final burn in
- Shipment

**Fiber Modules**
- Up to 800-1000 Watts

**Fiber Blocks**
- Potting active fibers

**Components**
- Bragg Gratings
- Isolators
- Couplers

**Fiber Draw**
- 6 Draw towers
- Active fibers only
- >200 different fibers

Deep in technology
Deep in experience

IPG Proprietary. Cleared for Release to US Government Agencies and Contractors
Winning Market Share in Materials Processing

Diverse Uses and Markets

- Automotive
- Consumer Products
- Merchant Diodes
- Solar Processing
- Hybrid Battery
- Aerospace
- Electronics/Semis
- Wind Turbines

Representative Customers
Advanced Applications Drive Tomorrow’s Products

Applications
- Directed energy
- Obstacle avoidance
- LIDAR
- Optical pumping
- Counter-measures
- Sensing and instrumentation

Customers

[Logos of various companies]
Unique Products for Telecom/Medical Markets

**Telecom Applications**
- Broadband-fiber to the premises
- Broadband-cable video signal transport
- Metro and long-haul DWDM systems

**Medical Applications**
- Skin rejuvenation and wrinkle removal
- Dental and ophthalmology
- Surgery/Urology

**Customers**

[Logos of various companies]
IPG Ytterbium Fiber Laser Product Line

• CW single mode Fiber lasers from 5 watts – 10000 watts (diffraction limited)
• Low order mode CW Fiber Lasers available from 100 watts to above 50kW
• Pulsed (Q-switched ) over 20 models with peak powers to 50 kilowatts and pulse energies to 50-milli-joules
• QCW laser with pulse energy to 6kW average power to 500 watts
• Pulsed and CW lasers operating a 532 nanometers
From Lamp Pumped to Fiber Laser

Lamp Pumped Solid State Laser

Diode Bar End Pumped Fiber Laser

Monolithic Fiber Laser (IPG Photonics)
**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
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
**Pump Diodes**

**Single Stripe Diode (100μm)**

- Conventional Cooling
- Low Current
- Low Heat Dissipation
- Easy to Pigtail
- Lifetime > 100,000 hrs

**Diode Bar (Array)**

- HP Water Cooling
- High Current
- High Heat Dissipation
- No Fiber Delivery
- Lifetime > 10,000 hrs
New: 60 W Diode Module, model PLD-60
Lifetime test of single stripe LDMs

36LDMs; I=9A; T_{case} =85^\circ\text{C}
Fiber Lasers - Available SM Power

Yb Lasers
- 10 kW
- 100W
- Raman Lasers 100W

Er Lasers
- 200W
- Raman Lasers 50W

Tm Lasers
- 200W

Wavelength, µm

Output Power
High Power SM Fiber Laser Modules

- \( P = 250 & 400 & 1000 \text{ W} \)
- \( \lambda = 1070 \text{ nm} \)
- \( \text{BPP} = 0.34 \text{ mm x mrad} \) (\( M^2 < 1.05 \) )
- \( W \times H \times D = 42 \times 33 \times 4.7 \text{ cm} \)
- DC wall-plug efficiency > 32 %
500 watt Ytterbium Fiber Laser

500 W CW Single Mode Output Power
TEM$_{oo}$ operation (M$^2 < 1.05$)
Single Mode Fiber Delivery Line
Size: 19 x 7 x 18 inches  Weight: 20kg  Air Cooled / 110-220V AC
Beam Quality

- **Single Mode**
  - TEM $00$, $M^2 = 1$, Pure Gaussian
  - Used for cutting, High speed welding, Micro machining
Properties of Single Mode Fiber Lasers

- M2 < 1.1
- Fiber diameter 7-15 microns
- Modulation frequency to 50 kHz
- Air cooled to 500 watts available to 10kW
- Output power to 10.0 kilowatts
- Delivery cables to 10 meters
- High wall plug efficiency
Modular Fiber Laser Structure

- 1 to 10kW Output Optical Power
- >50,000 hrs Estimated Diode Life Time
- High Brightness
- Wall Plug Efficiency ~30%

- Single or Multiple Output Fibers
- Air or Water Cooled
- 19” Rack Mountable or OEM Module Versions
Compact, Lightweight SM Modules

- $P_{OUT} = 800-1000$ W
- $\lambda = 1070$ nm
- $BPP = 0.34$ mm $\times$ mrad
  - ($M^2 < 1.05$)
- $W \times H \times D = 60 \times 33 \times 4.7$ cm
- DC wall-plug efficiency $> 35\%$
- Weight $\sim 10-12$ kg
- $W / \text{lb} \sim 40-50$
## High Power Fiber Lasers

<table>
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<tr>
<th>Power Level , kW</th>
<th>Beam Product, mm x mrad</th>
<th>Output Fiber, μm</th>
</tr>
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<tr>
<td>2</td>
<td>2.2</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>2.2</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>4.2</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>5.0</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>5.0</td>
<td>100</td>
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</tbody>
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Use of fiber-fiber couplers offers the opportunity to
- increase reliability by a fast exchange of high stressed processing fibers in case of damage
- achieve high beam quality by minimal losses of coupling
- adapt spot size by process fiber diameter
Fiber Laser Beam Coupler

- 50 Micron Input Fiber
- Coupler
- 600 Micron Output Fiber
Use of beam-switches offers the opportunity to
- increase reliability by a fast exchange of high stressed processing fibers in case of damage
- achieve high beam quality by minimal losses of coupling
- increase productivity and efficiency by high emission time of the laser
2 way Beam Switch

Other Fibers
100 Micron
200 Micron
400 Micron
600 Micron
1mm

Square Fiber
☐ 600 Micron

50 Micron Input Fiber 200 Micron Output Fiber 600 Micron Output Fiber
Beam Profile of 4kW Fiber Laser
Switching ON/OFF

Switching On Time < 30 μs

Switching Off Time < 10 μs
4 kilowatt 8 hour stability run
New: Compact Low Mode Ytterbium Fiber Lasers
Model YLRC-2000 & OEM Design

- Output power: > 2 kW
- Fiber core diameter: 50 μm
- Beam quality: BPP < 2.5 mm*mrad
- Delivery fiber: up to 50 m
- Modulation: up to 5 kHz
- Consumption: < 7 kW
- Wall-plug efficiency: > 30 %
- Dimensions: 790 x 815 x 557.5 mm
- Weight: 130 kg
Focusing a Fiber Laser

Focal Length of Focus Lens = \frac{\text{Focal length of focus lens}}{\text{Focal Length of Collimator}} \times \text{Fiber diameter}

Collimated Beam Diameter = \text{Divergence} \times \text{Focal length of Collimator} \times 2

- Shorter Collimator → Larger Focused Beam → Smaller beam Diameter
- Longer Collimator → Smaller Focused Beam → Larger collimated Beam Diameter
- Smaller Fiber or Shorter focus Lens → Smaller Focused Beam
- Larger Fiber or Longer Focus lens → Larger Focused Spot
Remote Welding

- Conventional Focus head
- Fixed Beam / Short working distance
- Part or Head must be moved in x/y plane

- Galvo Welding
- Long Working distances
- Beam Moved to weld while part remains stationary
Remote Welding – Optical Set up

• For remote welding, a spot size of 500 um required at 1 meter

• $F_{\text{coll}} = F_{\text{focus}} \cdot \frac{FD}{SS} = 200\text{mm}$

GIVEN
• Fiber Dia = 100um
• Focal Length = 1 meter
**Benefits of Fiber Lasers**

- Maintenance free
- Wall plug efficiency >28%
- No mirror alignment or replacement
- Totally monolithic
- Diode life > 100,000 hrs
- Compact footprint/mobile
- Minimal spares requirement – sealed system

- Long working distance
- Low cooling requirements
- Delivery fiber to 200 m
- Suited for cutting, welding, drilling, bending, cladding
- Low acquisition cost
- Same unit can weld and cut
- On demand power
Low Power fiber laser production applications

- Stent cutting
- Cutting surgical blades
- Welding of blades
- Cutting solder-masks
- Silicon cutting (solar panels)
- Adjustment of disc drive flexures (bending)
- Laser engraving (rolls and flat plate)
- Welding of metal devices
- Laser sintering
Laser Sintering – 200W Single Mode
High Power low order mode fiber laser applications in production

- Cutting of hydro-formed automotive frames
- Blank welding for automotive industry
- Titanium welding of aircraft skins
- Laser cladding for Aerospace and Oil industries
- Battery welding for medical device industry
- Pacemaker welding for medical device industry
- Transmission welding for Automotive Industry
- Sheet metal cutting
Hybrid Welding

• Combination of laser and GMA welding
  – Lower heat input
  – Faster Speeds
  – Single Pass Welding
  – Gap Tolerance

• Industrial Applications
  – Shipbuilding
  – Construction
  – Tubing
Hybrid Welding

- Laser provides deep penetration
- GMAW provides filler
Laser Surface Treatment with a Fiber Laser + Faceted Integrator Optic

Transmissive Faceted Integrator Optic
- ZnS material; facets diamond turned
- Useful for making custom beam shapes, large spot sizes
- Round, square or rectangular shapes possible; custom build-to-order
- Example: ½” x ½” square for heat treating
Beam Profile from integrating optic
10kW CW Ytterbium Fiber Laser

Pipeline Steel X70, 12 mm

Laser Power: 10.2 kW
Fiber Core: 200 µm
Fiber Length: 80 m
BPP: 11.5 mm x mrad
Welding Speed: 2.2 m/min
Weld ability of cast-iron / steel dilution welds

Potential application:
Differential gear
GGG 60 / 17CrNi6-6

series standard:
CO₂-Laser
6.0 kW
νₛ = 1.3 m/min
with filler wire
welding time 21 s

lab results:
fiber laser
4.0 kW
νₛ = 4.5 m/min
without filler wire
welding time: 6 s
14 mm S.S 10 kW compliments EWI Columbus Ohio
Mild Steel Welding (t=11.2 mm)

X70, t = 11.2 mm
P_L = 10.2 kW
v_S = 2.2 m/min

Laser GMA Hybrid Welding
X70, t = 11.2 mm
P_L = 10.5 kW
v_S = 2.2 m/min
I = 243 A
U = 25.3 V
**Welding of Aluminium**

**Laser MIG hybrid welding**

EN-AW 6008,

\[ t = 4 \text{ mm} \]

SZW AlSi5

\[ P_L = 10.5 \text{ kW} \]

\[ v_S = 8 \text{ m/min} \]

\[ PL = 10.5 \text{ kW} \]

\[ vS = 12 \text{ m/min} \]
Mobile Laser Components

Power source 10KW
Ytterbium:YAG – Fiber laser

Laser Welding Head
Saw Blade Welding

Laser Power

1.0 kW

\[ v_s = \begin{align*} 30 \text{ m/min} \\ 8 \text{ m/min} \\ 10 \text{ m/min} \end{align*} \]
Penetration of Stainless Steel
Material: Stainless Steel 1.4301
Laser: 8kW
Spot: 330µm
Why are Fiber Lasers outpacing market growth?

- Replacement of high maintenance and unreliable lasers (for the first time a replacement technology)
- Has made laser manufacturing more attractive
- Ease of integration to robots or multiple workstations
- Mobility
- Power levels never before achieved at 1 micron
- Superior performance on all applications when compared to both CO$_2$ and YAG lasers
- Multi-use from a single laser source
Processing Advantages

- Use of trans-missive optics
- 2-2.5 faster processing speeds than CO\textsuperscript{2} lasers at same power level
- Utilization of long focal length lenses for remote welding and scanner applications
- Multi-use welding, cutting, cladding etc.
- No requirement for He cover gas for welding
- Consistent spot size and profile over complete dynamic range
- Same laser can do both micro and macro applications
IPG Application & Geographic Diversity Lowers Risk

Broad End Uses\(^{(1)}\)

- Materials Processing: 84%
- Advanced: 8%
- Medical: 3%
- Telecom: 5%

Geographic Diversification\(^{(1)}\)

- North & South America: 21%
- Asia & Australia: 41%
- Europe, Russia & CIS: 37%
- ROW: <1%

\(^{(1)}\) For the year ended 12/31/2010
Laser Market 2010 - 2011

Growth Drivers

- Winning greater % of new systems
- Retrofit of existing systems
- Growing general laser market
- Addressing existing and new applications

- Materials Processing Historic CAGR through 2010 –17.99%

- IPGP share of total laser sources for materials processing in 2010 was approximately 16%

Expected Growth

YOY Growth 13.44%

Source: OptoIQ Annual Review Materials processing excludes semi-conductor lithography
Sales and Gross Margin Growth

(1) Gross margin includes stock-based compensation of $0.1mm, $0.3mm, $0.3mm, $0.6mm, $0.7mm and $0.5mm for 2006, 2007, 2008, 2009, 2010 and YTD 2011 respectively.
IPG’s Broad Range of Lasers & Amplifiers

FY 2010

- High-power Lasers: 40%
- Medium-power Lasers: 31%
- Pulsed Lasers: 8%
- Low-power Lasers: 5%
- Other: 16%
Improved manufacturing cost when utilizing fiber lasers

- Factory floor space - compact design
- Electrical requirements - high electrical efficiency
- Very low maintenance - long diode life
- No requirement for beam monitoring
- Reduction in service labor – no alignment or replacement required
- Low capital investment
- Ease of install & integration
- On demand power
- Multi-use
Conclusions

• Fiber Lasers have made major impact worldwide in the American material processing market.
• The reliability has been proven on multiple material processing applications at all power levels in production environments.
• The performance of fiber lasers exceeds previous laser technologies while offering substantial cost benefit to users.
• Fiber Lasers have expanded the market for laser material processing.
THANK YOU FOR YOUR ATTENTION