IPG Fiber Lasers: What’s New in Applications for Fabricators

ALAW Laser Applications Workshop
13-14 May 2009

Randolph Paura, P.Eng.
Regional Manager, Canada
Materials Processing Consultant
Agenda

- Introduction
- Company background
- Fiber laser basics (power supply review)
- Fiber laser adoption and growth
- Advantageous characteristics of fiber lasers
- Why fiber lasers are outpacing market growth
- Recent market statistics
- Fiber laser advantages
- Market drivers for growth, development and applications
  - Fiber laser power sources (single mode versus multi-mode)
  - Fiber laser cutting example
  - Fiber laser applications: single mode (SM) and multi-mode (MM)
  - Fiber laser applications: Laser Additive Materials
  - Fiber laser applications: Welding
  - New process regimes for fiber lasers
  - Future: Outgrowth of continuous improvement
  - Fiber laser summary and conclusions
- Thank you

Hybrid Laser Welding Images
Courtesy of SMU: Center for Laser Aided Manufacturing
Introduction

Randolph Paura, P.Eng., IPG Photonics, Regional Manager Canada

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Lifetime Member, Laser Institute of America (LIA)
Lifetime Member, SPIE
Member FMA
Network Member, Materials & Manufacturing Ontario (O.C.E.)
Vice-Chair, ANSI Z136 SSC-9
Member ANSI Z136.1 ASC

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ALAW 2008, “Fiber Lasers for Fabricators”
ALAW 2007, “Doing more with less (Harnessing Fiber Lasers)”
Co-Chair, ICALEO 2003 Laser Solutions Courses
ICALEO 2002, “Orthotropic SUV Frame Design (LBW enabled)”
ICALEO 2001,
    Laser Solutions Course Instructor, Weld Quality Monitoring
ICALEO 2001,
    Laser Solutions Course Instructor, Robotic Laser Cutting and Welding
IPG Fiber Lasers: The company
**IPG Fiber Lasers**

*Growth of Yb:HPFL SM (near diffraction limited)*

- Power (W): 3, 10, 20, 35, 50, 100, 500, 1000, 2000, 3000, 5000, 10kW

*10kW in 2010!*
IPG Fiber Lasers

A single module can supply:
- 250, 400, 800, 1000+ W of laser power
- Wavelength of 1070nm (NIR)
- One 7 or 15 um fiber core
- 0.34-0.41mm*mrad beam divergence

T x H x D = 60 x 33 x 4.7 cm
Efficiency (DC) > 35%

Building blocks (modules) for HPFLs
**IPG Fiber Lasers**

High power multi-mode fiber lasers

Modular multi-kW fiber laser

High beam quality
IPG Fiber Lasers

High Power Fiber Laser

HPFL Layout

Power 1 – 50 kW
**IPG Fiber Lasers**

![Graph showing BPP For Industrial Lasers](image)

Ref. published information: [www.trumpf-laser.com](http://www.trumpf-laser.com); [www.rofin-sinar.com](http://www.rofin-sinar.com); [www.ipgphotonics.com](http://www.ipgphotonics.com)
IPG Fiber Lasers

Feed Fiber Power Density - MM
(1:1 spot size reproduction)

Ref. published information: www.trumpf-laser.com; www.rofin-sinar.com; www.ipgphotonics.com
**IPG Fiber Lasers**

**IPG Product Line:**

- CW Single Mode fiber lasers from 5 – 5000 watts (10,000 watts under final development)
- 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 10-milli-joules
IPG Fiber Lasers

New products for materials processing (2009):

• 15 Watt CW Single Mode green operating at 535 nanometers, narrow line width

• Pulsed Green at 535 nm 10 watts 1 ns pulse duration 50-300 kilohertz (scalable to 100 watts, conversion from 1070 to 535 nm @ greater than 84%)

• 2 new pulsed MOPA models operating at 1070 nm, peak power >50 kW variable pulse duration 1 ns-100 ns frequency to 500 kHz

• 3 & 4 kW fiber laser designed exclusively for cladding, annealing and brazing applications
Advantages over previous technologies:

- Long diode life > 100,000 hrs
- High electrical efficiency 30%
- Compact size
- Mobile
- Highest beam quality at all power levels
- Large dynamic power range
- Rapid installation (hours not days)
- No resonator alignment
- Maintenance free
- Single mode - pure Gaussian
- Multi-mode - near top hat
- Consistent spot size over complete dynamic range
- Air cooled to 300 watts
- No warm up, on demand power
- Modules can be added for future power upgrades
**Fiber Laser Adoption and Growth**

**Plant floor space is manufacturing real estate.** Fiber lasers free up manufacturing capacity. (Ref. 2007)

**4kW Nd:YAG**
- <4% efficient
- <2000 hrs lamp life
- 92KW consumption
- 3200 x 1700 x 1250
- 3000 lbs
- $600-700K USD

**8kW CO2**
- <12% efficient
- Uses laser & process gas
- 84KW consumption
- 1665 x 1524 x 1100
- 3241 lbs
- $450-500K USD

**4kW Fiber Laser**
- ~25% efficient
- 100,000 hrs diode life
- 16KW consumption
- 860 x 810 x 1500
- 500 lbs
- $350-$450K USD
Key market drivers for fiber laser utilization:

- Utilization of high strength steels in automotive production (hot stamped steels requiring laser trimming)
- Increased utilization of remote welding applications
- Electron beam quality welds possible with fiber Lasers
- Energy related automotive applications - fuel cells, batteries
- Extensive use of pulsed lasers in the manufacture of silicon based and photo-voltaic solar cells
- Enabling of new manufacturing processes that improve quality and reduce the total cost of manufacturing
  
  Reduced cost to manufacture is always the driver
Military applications & objectives:

- Efficiency, effectiveness and mobility of defense services rendered
- Tactical High Energy Laser (THEL) program
- Advanced Tactical Laser (ATL) program
- Airborne Laser (ABL) program
- Joint High Power Solid State Laser (JHPSSL) program
- Seeking 10kW SM laser as a module for 100kW + units
- “Lasers will challenge the primacy of projectile weapons”

Lasers for Security, Northrop Grumman, Case #07-0573
Military applications & objectives:
- Feb 25, 2009
- IPG Photonics wields high-power laser weapon
  - The fiber-laser maker's diodes are shooting down both the competition and, thanks to a Boeing demonstration, unmanned aircraft.
  - Laser Avenger
Fiber Laser Power Sources

Single Mode versus Multi-Mode

- **Single Mode**
  - Near “Gaussian” Power Density Profile
  - ~7 - 20 um feed fiber optic cable dia.
  - mW to 5 kW

- **Multi-Mode**
  - Lower mode order (quasi-Gaussian)
  - 50 – 100 um feed fiber optic cable dia.
  - 100 W to +20 kW (and greater)
# Cutting with Fiber Lasers

## Process parameters for comparative tests of fiber- and CO₂-laser cutting

<table>
<thead>
<tr>
<th>Parameter</th>
<th>YLR1000</th>
<th>DC025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser</td>
<td>YLR1000</td>
<td>DC025</td>
</tr>
<tr>
<td>Handling system</td>
<td>KuKa</td>
<td>Arnold</td>
</tr>
<tr>
<td>Focal length</td>
<td>120 mm</td>
<td>127 mm</td>
</tr>
<tr>
<td>Collimation</td>
<td>120 mm</td>
<td>-</td>
</tr>
<tr>
<td>Focus diameter</td>
<td>15 μm</td>
<td>140 μm</td>
</tr>
<tr>
<td>Focus position</td>
<td>0 - -1 mm</td>
<td>0 - -1 mm</td>
</tr>
<tr>
<td>Distance nozzle-workpiece surface</td>
<td>1 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cutting gas</td>
<td>N₂</td>
<td>N₂</td>
</tr>
<tr>
<td>Gas pressure</td>
<td>10 bar</td>
<td>10 bar</td>
</tr>
<tr>
<td>Nozzle diameter</td>
<td>1,5 mm</td>
<td>1,5 mm</td>
</tr>
</tbody>
</table>

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*Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005*
Cutting results St1203 (AISI CRS 1005, 1008, 1010)

- Fiber laser YLR 1000
- CO₂ laser DC025

Cutting gap:
- YLR1000: 100 µm
- DC025: 120 µm

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005
Cutting results on AlMg3 (AISI 5XXX, Aluminum)

- Fiber laser YLR 1000
- CO2 laser DC025

Cutting gap:
- YLR1000: 125 μm
- DC025: 200 μm
Cutting with Fiber Lasers

Cutting results an V330-50A

(AISI M22, Electrical Steel)

fiber laser YLR 1000

CO₂ laser DC025

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005
Cutting with Fiber Lasers

Comparison of the cutting edges

(AISI CRS) St1203
(AISI 5XXX) AIMg3
(AISI M22) V330-50A

YLR 1000 SM

DC025

Ref: Schneiden mit Faserlasern_01.ppt 23.11.2005
Cutting with Fiber Lasers

CRS (1mm) Cutting Speed Versus Power Requirements

- FL Cut Power
- FL Power Draw
- DC Cut Power
- DC Power Draw

Power Requirements (Watts):

Cutting Speed (m/min):

Ref: SM FL Conversion Efficiency 25%, DC Conversion Efficiency 12%.
# Cutting with Fiber Lasers

New process regime…

Thick section cutting with NIR lasers

High power and beam quality are making this possible

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Power (Watts)</th>
<th>Speed (m/min)</th>
<th>Gas (type) &amp; pressure</th>
<th>Focal Position</th>
<th>Tip Dia. &amp; Offset</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>16mm</td>
<td>4000</td>
<td>0.5</td>
<td>O² (2.5bar)</td>
<td>+3.0</td>
<td>Ø1.0 @ 0.5mm</td>
<td>30º</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>16mm</td>
<td>5800</td>
<td>0.5</td>
<td>N² (20bar)</td>
<td>-12.5</td>
<td>Ø1.8 @ 0.4mm</td>
<td>30º</td>
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</tr>
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Single Mode (SM) fiber laser applications:

- Stent cutting
- Cutting surgical blades
- Cutting solder-masks
- Welding of razor blades
- Silicon cutting (solar panels)
- Adjustment of disc drive flexures (bending)
- Laser engraving (rolls and flat plate)
- Welding of medical devices
- Laser sintering
- Soldering
- Laser marking
- Remote cutting
Scanner welding of copper contacts

YLR-200-SM
f = 100 mm (~25 µm spot size)

Overlap welding E-Cu58
0.3 + 0.3 mm
Fiber Laser Applications - SM

Micro welding of fuel cell components

Laser: YLR-500-SM

v= 80 m/min

v= 40 m/min
There is now the power and beam quality to achieve “excessively” high power density and/or a wide spectrum of caustic beam profiles to examine the boundaries of existing processes and explore new process regimes.

Consider the advent of remote cutting…

Task: 100 Holes in stainless steel
Thickness to cut: 50, 100 and 200 μm

<table>
<thead>
<tr>
<th>Thickness [μm]</th>
<th>Time [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1.17</td>
</tr>
<tr>
<td>100</td>
<td>1.92</td>
</tr>
<tr>
<td>200</td>
<td>2.55</td>
</tr>
</tbody>
</table>
Fiber Laser Applications - SM

Comparison: Remote Cutting - Linear Drive Machine

Cutting time: 1,17 s 19 s
Fiber Laser Applications - MM

High power, low-mode order fiber laser applications:
- Cutting of hydro-formed automotive frames
- Blank welding for automotive industry
- Titanium welding of aircraft skins and structures
- Laser cladding for Aerospace and Oil industries
- Battery welding for automotive and medical device industry
- Pacemaker welding for medical device industry
- Transmission welding for Automotive Industry
- Sheet metal cutting and welding
Fiber Laser Applications - LAM

Laser Additive Manufacturing:

- Low volume manufacturing
  - Medical devices
  - Defense components
  - Space components
  - Functional prototypes
- Surface modification and repair
  - Gas turbine engines
  - Tools and dies
  - Heavy equipment
    - Shafts
    - Bearings
    - Other wear surfaces
**Fiber Laser Applications - LAM**

**Laser Additive Manufacturing:**

- Advantages over existing technologies
  - Metallurgical bond versus mechanical bond
  - Very low and controllable heat input with minimum dilution and heat affected zones
  - Minimal stress and distortion created by deposits
  - Rapid cooling rates
  - Cost effective for repairs and manufacturing
  - Ability to add a high abrasion resistant wear surface(s)
- Ref. LAM Workshop March 3-4, 2009, San Antonio, Texas
- RPM & Associates Inc., Rapid City, SD
- Optomec, Albuquerque, NM
Fiber Laser Applications - LAM

850-R Utilizing 3 KW IPG Fiber Laser

- Controlled chamber – less than 10ppm O2
- Motion controlled to +/- 0.001"
- Travel: “X” – 3’, “Y” – 5’, “Z” – 3’, with tilt and rotate table
- Large Front Door: 73.5” Tall x 45” Wide
- Small Rear Door/Window: 42” Tall x 42” Wide
- Approximate Glove Box: 94” Length x 75” Wide x 89” Tall
**Fiber Laser Applications - LAM**

**Laser Clad Male and Female Bearing Adapters**

- Developed WC overlay process for Male and Female Bearing Adapters.

- Laser Clad proprietary WC on 4340 bearing adapters, which increases wear area.

![Female Bearing Adapter ID cladding](image1)

![Final Grinding – Female Bearing Adapter](image2)

![Laser Deposit – Male Bearing Adapter](image3)

![Final Grinding – Male Bearing Adapter](image4)
Laser Repair of 4340 Atomizer Shaft Used in Electric Power Generation

- This atomizer shaft is a high speed (8800 rpm) precision shaft used to drive a rotary spray head typically used in “Flue Gas Desulfurization” (FGD) scrubber systems in Coal Fired Power Plants and Incinerators.
- Developed Repair Process for tapered fit section and seal surface of 4340 Atomizer Shaft utilizing 420 SS.
- Shafts were previously repaired by a Spray Process featuring a “Mechanical Bond.” The LCT Process utilizes a “Metallurgical Bond” that generates a high quality permanent repair, which saves over $14,000.00 over purchase of a new shaft.
- Repeat customers; several parts have been repaired.
Fiber Laser Applications - LAM

• Beam switchable for multi-cell production.

• Plug and play fiber sizes and geometries

3 & 4 kW Power Supplies
(Others available upon request)
Fiber Laser Applications – Welding

• Autogenous laser welding
  – Remote (thin sheet)
  – Close coupled (thin & thick)
• Cold wire (filler wire)
• Hybrid (Laser + MIG)
• Hybrid (Laser + TIG)
• Hybrid (Laser + TIG + Wire)
• Hybrid (Laser + Plasma)
• Hybrid (Laser + Plasma + Wire)
Fiber Laser Applications – Remote Welding

Scannerfree Remote Processing

Working Distances
1000-1500 mm

Scanner Remote Processing

Working Distances
~ 500 mm
Fiber Laser Applications – Remote Welding
Fiber Laser Applications - Welding

Hybrid Laser Welding – Examples & Candidates
- Ship building
- Pipeline welding
- Tube welding
- Off-Shore-Industry
- Railcars

Laser-Hybrid X70
$t = 12 \text{ mm}$
$P_L = 10.5 \text{ kW}$
$v_S = 2.2 \text{ m/min}$

Quelle: BIAS
Fiber Laser Applications - Welding

Hybrid Laser Welding – Examples & Candidates

- Laser GMA hybrid welding tractor (fibre laser version)

- T-joint welding at Navantia, Spain
- 10 mm stiffener thickness
- 1.5 m/min welding speed
Monfalcone, Italy

The first outfitting of a welding gantry with a 10 kW fibre laser source for hybrid welding in production at Fincantieri Shipyard in Monfalcone in 2007.
New Process Regimes for Fiber Lasers

The limitation is no longer the power source, but how it is applied and the physics of the process application itself:

- Extreme narrow gap welding
- Hybrid thick section welding
- Remote welding
  - Fixed optic
  - Scanner optic
  - Flying scanner optic
- Remote cutting
- Thick section cutting
- Fixed cutting head (no capacitive height sensing)
New Process Regimes for Fiber Lasers

Saw Blade Welding

- Laser power: 1.0 kW
- Electron beam: 0.37 mm, \( v_s = 8 \text{ m/min} \)
- Fiber laser: 0.18 mm, \( v_s = 10 \text{ m/min} \)
- Fiber laser: 1.6 mm, \( v_s = 30 \text{ m/min} \)

Fraunhofer Institut Werkstoff- und Strahntechnik

Fraunhofer IWS
New Process Regimes for Fiber Lasers

Welding copper

Conclusions
- fiber lasers are definitely able to weld copper under certain precautions (angle of incidence, fiber diameter, focal position)
- wide range of parameters to meet the requirement of different applications
- with 4 kW laser power, penetration depth of 4 mm possible
- use of shielding gas and cross jets increases welding depth
- mixed alloy joints (copper/brass/Manganin) possible
- the excellent beam quality of fiber laser opens new application areas in copper welding
New Process Regimes for Fiber Lasers

Cutting with QCW Lasers

10 mm Stainless Steel
$P_{av} = 2 \text{ kW}$

CW: dross $\sim 1\text{ mm}$

QCW: dross $< 0.3 \text{ mm}$

$v = 0.3 \text{ m/min}$

$v = 0.4 \text{ m/min}$
**New Process Regimes for Fiber Lasers**

**Orthotropic bridge construction:**

New core and sandwich solutions for structural panels enabled by laser welding, thick section blind welds of 3/8” – 1” thick deck plate to ribs and webs beneath.

[Image: Sandwich panel and bridge construction](http://sandwich.ballport.com/public_downloa ds/public-project-summary.pdf)

Stiff, lightweight metallic sandwich panels offer the potential for significant weight and cost reductions.

*Image courtesy of: Applied Thermal Sciences Inc., and Naval Metalworking Center*
New Process Regimes for Fiber Lasers

YLR 20000

- Welding Speed m/min
- Penetration mm

Stainless Steel (1.4301/SUS 304)
Spot size 420 µm

Overlap joint 2x 15 mm
Stainless steel 1.4301, 1 m/min.
Future

Outgrowth of continuous improvements at IPG:

• Increase in SM power (near future target of 10kW)
• Diode coupled fiber delivery (e.g. for brazing applications)
• Increased beam quality and power from single element diodes
• QCW fiber lasers
• Increased modulation capability of pulsed fiber lasers
Fiber Laser Summary

Conclusions:

• Fiber lasers have made a major impact in the worldwide material processing market
• Fiber lasers have expanded the material processing market
• 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 can compete, on a cost basis, with other technologies such as Plasma, EDM and Electron Beam
Fiber Laser Summary

IPG is committed to:

• Continuing improvement and expansion of product offerings
• Continuing reduction in the cost of ownership
• Expansion of the market through application development
• Our mission is to make Fiber Lasers the preferred choice for manufacturing technology
• Commitment to support of our customers
THANK YOU FOR YOUR ATTENTION

rpaura@ipgphotonics.com
Please consider joining the LIA & FMA

• Great networks of knowledge
• Training seminars, webinars…
• Conferences (ALAW, ICALEO, ILSC, etc.)