Photonics 4 Precision Manufacturing

Industrial Micro-materials Processing Applications with Fiber Lasers

Wednesday, 15.06.2016, Palexpo Genève

The Power to Transform®

Tim Westphäling

IPG Laser, Burbach Germany

Copyright IPG Photonics
IPG Overview

Single Mode

QCW

Short pulse Laser

Outlook & Conclusion
General data IPG Photonics

- 3800 employee world wide
- Development and Production of Fiber Laser
- Service and Sales Department
- Application lab

Vertically Integrated Production

- Final Assembly
- Modules
- Process Heads
- Active Fiber Block
- Beam Switches
- Collimators
- Fiber Beam Delivery
- Optical Components
- Fiber Draw
- Optical Preform
- Fab Operation
- Diode Assembly
General data IPG Photonics

- Founded in 1991
- 17% year-over-year increase
- 800 employees more in 2015
- Total net sales 901 million $

2015 Sales by Geography and End-Use

- Asia (54%)
- Europe, CIS (31%)
- Americas (15%)
- Materials Processing (94%)

High Power Laser Sales
(in millions)

- 2011: $222.1
- 2012: $263.4
- 2013: $344.1
- 2014: $426.1
- 2015: $499.6

Source: IPG Photonics Annual Report 2015
Application Field of Fiber Laser

Overview

- Photovoltaics
- Advanced and Scientific
- Medical Procedures
- Power Plant
- Medical Device
- Rapid Manufacturing
- Heavy Industry and Transport
- Entertainment & Projection Display
- Oil & Gas
- Consumer and Appliances
- Aerospace
- Automotive
- Semiconductor & Electronics
- Telecommunications
IPG Product line

Overview Laser

- Low Power CW Fiber Lasers
- Mid Power CW Fiber Lasers
- High Power CW Fiber Lasers
- Quasi-CW Fiber Lasers
- Nanosecond Fiber Lasers
- Pico & Femtosecond Fiber Lasers
- Mid-IR Hybrid Lasers
- CW Fiber Amplifiers
- Diode Lasers
Single Mode Laser in Micromachining

Single Mode Fiber Laser (CW)

- Precision Cutting
- Remote Applications
- Accurate Welding

High Power 1 kW – 20 kW

Mid-low Power < 1 kW
Single Mode Laser in Micromachining

Single Mode Fiber Laser(CW)

Application Example

Accurate Welding

Foil Welding

© BIAS, Deutschland
Spot welding of watch parts
Seam welding of Batteries
Fine Cutting with 100 – 300 Watt

YLR 300 SM

Cutting Speed m/min

Thickness mm

Stainless steel
f = 50 mm
Nitrogen
Single Mode Laser in Micromachining

Single Mode Fiber Laser (CW)

Application Example

Fine Cutting

Nitinol

Steel
Remote Cutting Metals
Remote Cutting Metals - Examples

Micro punching applications:
- automotive
- electronics
- medical industry
- precision mechanics
- gaskets
- etc.
Remote Cutting Speeds

![Graph showing cutting speed vs. sheet thickness for 1 kW and 3 kW singlemode fiber lasers on stainless steel (1.4301) without cutting gas.]

Source: IWS
Pulsed Fiber Laser in Micromachining

**QCW Laser**

- Drilling
- Cutting
- Spot Welding
- Batteries
- Seam Welding
- Medical Devices
- Micro welding
- Computer Components
- Deep Engraving

<table>
<thead>
<tr>
<th>Average Power</th>
<th>Peak Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 W</td>
<td>1500 W</td>
</tr>
<tr>
<td>300 W</td>
<td>3000 W</td>
</tr>
<tr>
<td>450 W</td>
<td>4500 W</td>
</tr>
<tr>
<td>600 W</td>
<td>6000 W</td>
</tr>
<tr>
<td>900 W</td>
<td>9000 W</td>
</tr>
<tr>
<td>1200 W</td>
<td>12000 W</td>
</tr>
<tr>
<td>1500 W</td>
<td>15000 W</td>
</tr>
<tr>
<td>1800 W</td>
<td>18000 W</td>
</tr>
<tr>
<td>2000 W</td>
<td>20000 W</td>
</tr>
<tr>
<td>2300 W</td>
<td>23000 W</td>
</tr>
</tbody>
</table>
Beamshaping Software
Pulsed Fiber Laser in Micromachining

**QCW Laser**

**Application Example**

**Pulsed Welding**
- Sealed welding
- Pulse shaping
- Low HAZ

**Grid Welding**

**Membrane**

**Thermosta**

**Decorative**

Application Example:
- Gold
- Brass
- Stainless Steel
- Pacemaker
- Titanium

© Medtronic, Schweiz
Spot welding of watch wheels
Seam Welding of pressure sensors (diameter 12 mm)

Laser: YLR-150-1500-QCW-AC
Material: stainless steel, 20 µm
Parameter: 50 µm fiber
200 mm/min
Pulsed Fiber Laser in Micromachining

QCW Laser

Application Example

Pulsed Cutting
• Accurate Cutting
• Pulse shaping
• Low HAZ
• Cutting of different material

© ACSYS, Germany
CW and Pulsed with One Device

YLR-150/750-QCW-AC

Cutting speed [m/min] vs. Thickness [mm]

- Stainless steel 1.4301
- Collimator: 100 mm
- Focal length: 125 mm
- Fiber: 50 µm
- Spot: 60 µm
- P_avg: 150W
- Duty cycle: 20%

- 2 mm stainless steel
- 3 mm stainless steel
- 4 mm stainless steel
Pulsed Fiber Laser in Micromachining

QCW Laser

Application Example

Deep Engraving

Drilling

---

Graph showing the relationship between peak power and depth for micromachining applications.

Copyright IPG Photonics
Percussion drilling

Laser: YLR-150-1500-SM-AC
Optic: 73:100 mm
Material: Stainless Steel, 4 mm
Parameter: 500 Hz, 0.3 J, 200 μs
Avr. Power: 150 W
Hole size: 250 μm entrance
200 μm exit
Drilling time: 1-10 s

Aspect ratio > 20
Pulsed Fiber Laser in Micromachining

YLP-V2/V3 series overview

- Average power: 10/20/30/50/100 W
- Pulse energy: 1 mJ
- Pulse repetition rate: 2…200 kHz
- Pulse duration: 100 ns
- Beam diameter: 7.5 mm
- Beam quality M2: <2
- Delivery fiber length: 3 m
- Operating wavelength: 1064 nm

- Bitstream 1 operating mode (instant emission ON/OFF)
- Built-in RS232C interface
- Extended PRR down to 2 kHz
- Full factory pre-calibrated
YLP-V2/V3

Application Example

Marking

Grayscale marking

Color marking

Marking of different Material
Pulsed Fiber Laser in Micromachining

YLP-V2/V3
Application Example

Drilling

Dust cleaning

© LZH, Germany

Structure

Surface finish

© LZH, Germany

Steel

Silicon

Stainless Steel

Aluminum
# Pulsed Fiber Laser in Micromachining

## MOPA (Master Oscillator Power Amplifier) Series Overview

<table>
<thead>
<tr>
<th>Feature</th>
<th>YLPN-1-4x200</th>
<th>YLPN-1-1x120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average power</td>
<td>10/20/30 W</td>
<td>30/50/100 W</td>
</tr>
<tr>
<td>Pulse energy</td>
<td>0.5/1 mJ</td>
<td>1 mJ</td>
</tr>
<tr>
<td>Pulse repetition rate</td>
<td>1.6...1000 kHz</td>
<td>2...12000 kHz</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>4-200 ns, adjustable</td>
<td>1-120 ns, adjustable</td>
</tr>
<tr>
<td>Beam diameter</td>
<td>7.5 mm</td>
<td>7.5 mm</td>
</tr>
<tr>
<td>Beam quality M2</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Delivery fiber length</td>
<td>2 m</td>
<td>2 m</td>
</tr>
<tr>
<td>Operating wavelength</td>
<td>1064 nm</td>
<td>1064 nm</td>
</tr>
</tbody>
</table>

![Image of MOPA series lasers](image-url)
Pulsed Fiber Laser in Micromachining

MOPA (Master Oscillator Power Amplifier)

Application Example

Precise Ablations

Patterning

Scale: 200um

Gold on PET

Steel
Pulsed Fiber Laser in Micromachining

MOPA (Master Oscillator Power Amplifier)

Application Example

Scribing

Silicon

Resistance trimming

Solar Industry

- Open of Passivation - Layer
- Scribing
- Drilling
Pulsed Fiber Laser in Micromachining

Pico Second Fiber Laser

- Fine Ablation
- Dark Marking
- Scribing
- Precision Hole Drilling

- Peak power up to 330 kW
- Average power 30 W
- Pulse energy up to 1 mJ
- Pulse repetition rate 2...1000 kHz
- Pulse duration 0.15...5 ns
- Beam diameter 7.5 mm
- Beam quality M2 <2
- Delivery fiber length 5 m
- Operating wavelength 1064 nm
- Size module (WxHxL) 215x95x286 mm
- Size head (WxHxL) 162x70x320 mm
Pulsed Fiber Laser in Micromachining

Pico Second Fiber Laser

Application Example

Cutting of PCD (PolyCrystalline Diamond) and Tungsten-Carbide (WC)
Pulsed Fiber Laser in Micromachining

Pico Second Fiber Laser

Application Example

Cutting of PCD (Poly Crystalline Diamond) and Tungsten-Carbide (WC)

Process Results:
- less roughness on cut edge wall (Ra = 0.2 – 0.3µm)
- less chipping (<8µm)
- no heat affected zone
- ablation rate ~ 1mm³/min
- 2 step process:
  5ns/1mJ for deep engraving
  150ps/50µJ for fine finish
Pico Second Fiber Laser

Application Example

Drilling

- Less heat input
- Constant holes in ceramic
- High aspect ratio
Pulsed Fiber Laser in Micromachining

Pico Second Fiber Laser

Application Example

Dark marking of different Material

- Copper
- Aluminum
- Steel
- Brass
- Coated Material
- Synthetic Material
- ...

Copyright IPG Photonics
Pulsed Fiber Laser in Micromachining

Pico Second Fiber Laser

Application Example

Example c-Si PV Selective Removal of Backside Passivation
  • no melting with 150ps
  • no heat affected zone

Thin Layer Technology

• Solar cells (c-si)
• Molybdenum layer
• CIGS (copper-indium-gallium-selenide)
• ITO (indium tin oxide)
• PEDOT (Poly(3,4-ethylenedioxythiophene))
• …

Example P1 on flexible substrate
Outlook & Conclusion

- IPG is market leader for fiber lasers
- Single mode lasers for fine cutting and micro welding applications
- QCW lasers to replace lamp pumped Nd:YAG lasers
- Pulsed lasers in ns range for a broad range of micromachining applications
- Sub ns fiber lasers are a cost efficient alternative for ultra short pulse lasers for many applications
Thank you for your attention!

Tim Westphäling
twestphaeling@ipgphotonics.com

IPG Laser, Burbach
Germany
www.ipgphotonics.com