Laser Source Selection for Micro-welding Processes

Dr. Mark Boyle – America
Ing. David Van de Wall – Europe

March-2016
About us

• Manufacturers of innovative equipment for advanced processes
• Expertise in metal processing – including laser welding, resistance welding, laser cutting, and laser marking

Amada Miyachi America Corporation

• 180 employees
• HQ in Los Angeles Area
• 120+ standard and custom systems built per year
• Applications Labs in Monrovia, CA and Wixom, MI
• ISO9001, CCC, CE and CSA Certified

Amada Miyachi Europe Corporation

• 120 employees in Europe
• 2 production facilities + 7 sales offices
• 100+ standard and custom systems built per year
• Application labs in Helmond (NL) and Puchheim (DE)
• ISO 9001 and DEKRA certified
Contents presentation

- Definition of the range of Micro welding Applications
- Comparison of the Different Laser Types for Micro welding Applications
  - Laser Features
  - Welding examples
  - Laser source selection
- Summary
Definition of Micro-welding applications

- Typical penetration depth less then 0.04” (1mm)
- Typical spot sizes at the surface less then 0.04” (1mm)
- Welds can be Spot (round) and Seam (linear) types
- Typical Average Laser Power less then 1 kW

- These are found in a wide range of markets – including automotive, batteries, medical, aerospace and electronics
Depth and surface dimension range of Micro-welding applications

Micro-welding is considered any weld size in this box:
- Wide and shallow
- Wide and deep
- Small and shallow
- Small and deep

WELD SURFACE (inches) (mm)

WELD DEPTH (inches) (mm)
### Existing and Emerging Laser Welding Technologies

<table>
<thead>
<tr>
<th>Type</th>
<th>Pulsed YAG</th>
<th>CW Fiber Laser</th>
<th>QCW Fiber Laser</th>
<th>Direct Diode Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Features</strong></td>
<td>• Pulsed</td>
<td>• CW or modulated up to 100%</td>
<td>• Pulsed or CW</td>
<td>• CW or modulated</td>
</tr>
<tr>
<td></td>
<td>• High peak power</td>
<td>• Low peak power</td>
<td>• High peak power</td>
<td>• Low peak power</td>
</tr>
<tr>
<td></td>
<td>• Green wavelength option</td>
<td>• Excellent beam quality</td>
<td>• Emerging technology in welding</td>
<td>• Low beam quality</td>
</tr>
<tr>
<td></td>
<td>• Most mature technology</td>
<td>• Established technology</td>
<td></td>
<td>• New technology</td>
</tr>
</tbody>
</table>

Wide selection of source types is currently available
Select the right laser for the application
Micro Weld Considerations

- Does it need to be a Spot or Seam weld
- Type of weld
  - Lap
  - Butt
  - Fillet
- Material selection
- Part fit up
- Required weld properties
  - Strength?
  - Hermetic?
  - Cosmetic?
  - How much heat input?
Pulsed Nd:YAG Lasers

Based on Lamp pumped Solid state laser technology

The high peak power is good for significant and consistent penetration - the ratio of average to peak power can be as high as a factor of 240x!
## Pulsed Nd:YAG Laser Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Welding benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real time power feedback</td>
<td>Highly consistent welding</td>
</tr>
<tr>
<td>Free space resonator</td>
<td>No sensitivity to back reflection</td>
</tr>
<tr>
<td>Spot Size</td>
<td>0.01 – 0.04” (0.25 to 1.0mm) optical spots for fit-up accommodation</td>
</tr>
<tr>
<td>High peak power</td>
<td>Deep penetration even with low average power</td>
</tr>
<tr>
<td>Time and Energy Share</td>
<td>Multiple outputs from a single laser</td>
</tr>
<tr>
<td>Mature laser design</td>
<td>Highly reliable</td>
</tr>
</tbody>
</table>
### Application example: Spot Welding

Pulsed laser source with high peak power for penetration

**Pulsed YAG**

Material: Titanium (0.02” or 0.5mm spot size)

<table>
<thead>
<tr>
<th></th>
<th>0.25 kW</th>
<th>0.5 kW</th>
<th>0.75 kW</th>
<th>1.0 kW</th>
<th>1.25 kW</th>
<th>1.5 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2ms</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>4ms</td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
<td><img src="image9" alt="Image" /></td>
<td><img src="image10" alt="Image" /></td>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
</tr>
<tr>
<td>7ms</td>
<td><img src="image13" alt="Image" /></td>
<td><img src="image14" alt="Image" /></td>
<td><img src="image15" alt="Image" /></td>
<td><img src="image16" alt="Image" /></td>
<td><img src="image17" alt="Image" /></td>
<td><img src="image18" alt="Image" /></td>
</tr>
</tbody>
</table>

**Effect of Peak power & pulse width**

- More peak power results in a deeper weld
- Longer weldtime results in a wider weld
- Precise input of energy to get various weld profiles
Application: Seam Sealing Heat Sensitive Parts

- Heat input is linear with the average power
- Typical Applications: Sensors, Batteries, Implantable medical devices, RF/microwave devices
- Typical materials: Aluminum (3003, 1050, 1100), Titanium
Application: Seam Sealing Butt Weld with loose tolerance

- Large spot size helps bridging gaps
- The required tolerance of fit-up is reduced
- This is lowering machining costs
- And maximum yield and quality of welded part

Pulsed YAG

Before weld a 0,15mm gap

After welding a perfectly sealed part
**Application: Small conductive parts**

- A challenge for any joining technology
- Lasers offers good non contact, high speed solution
  - Inconsistent results due to high material reflectivity at 1 micron
  - Frequency doubled YAG aka “**Green Laser**” has improved results

<table>
<thead>
<tr>
<th>Material - Copper</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength</strong></td>
<td>1064nm</td>
</tr>
<tr>
<td><strong>Spot Weld results</strong></td>
<td><img src="image1.png" alt="Spot Weld result 1064nm" /></td>
</tr>
</tbody>
</table>
Application: Small Scale Electrical Interconnects

Pulsed YAG

4000 Individual Welds – all must be successful
0.003” Phosphor Bronze to 0.003” Cu - Epoxy below
Penetration depth controlled within 10 um
**CW/Modulated Fiber Lasers**

Based on CW fiber laser technology

**Power**

- **Average power** – 500W
- **Peak power** – 500W

**CW or modulated output**

**Average CW power and Peak power are the same**
## CW/Modulated Fiber Laser Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Welding benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>High beam brightness (high beam quality)</td>
<td>Optical spot sizes can be as small as &lt; 30mm (~0.001”) for welding the finest parts</td>
</tr>
<tr>
<td>Selectable beam brightness</td>
<td>Weld performance can be tuned to fit the joint geometry &amp; fit-up</td>
</tr>
<tr>
<td>Continuous Beam</td>
<td>Good for seam sealing at high speeds</td>
</tr>
<tr>
<td>Efficient laser generation</td>
<td>Small &amp; compact, electrically efficient</td>
</tr>
<tr>
<td>Single emitter pump diodes</td>
<td>No laser consumables</td>
</tr>
</tbody>
</table>
Application: Very Small Spot Welds

- Thin materials require small spot size
  - Single mode laser provides sub 0.001" (25 um) spot
  - Laser power requirement < 100W

Fiber Laser

**Wide and shallow (multimode laser)**
- 0.003" (75 um) diameter
- 0.0025 (60 um) deep
- 430 SS, 100W fiber laser

**Small and deep (singlemode laser)**
- 0.001" (25 um) diameter
- 0.008" (200 um) deep
- 304L, 50W fiber Laser

- 0.001" (25 um) diameter
- 0.0005" (10 um) deep
- Titanium, 20 W, SM laser
Applications: High Speed Seam Welding

- Hermetic Sealing of 0.02” (0.5mm) and thicker lids
  - Larger packages can take this larger thermal loading
  - 500W, SM, 0.04” (1.0mm) penetration at 1.5”/s (40mm/sec)
  - Weld type: Lap weld

Fiber Laser

6061 base to 4047 lid
**Application: High Speed Seam Welding**

<table>
<thead>
<tr>
<th><strong>Weld Parameters</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Automotive</td>
</tr>
<tr>
<td>Part</td>
<td>Airbag Initiator</td>
</tr>
<tr>
<td>Material</td>
<td>Steel</td>
</tr>
<tr>
<td>Equipment</td>
<td>500W, MM Laser</td>
</tr>
<tr>
<td>Speed</td>
<td>1250° /s</td>
</tr>
<tr>
<td>Comments</td>
<td>0.02” (~0.5mm) penetration</td>
</tr>
</tbody>
</table>

*Fiber Laser*
Case study - Fiber Laser and Nd:YAG laser
For this product the Fiber Laser is 10x faster

<table>
<thead>
<tr>
<th>Process Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Lighting</td>
</tr>
<tr>
<td>Part</td>
<td>Bulb</td>
</tr>
<tr>
<td>Material</td>
<td>A380 / 5082 aluminum</td>
</tr>
</tbody>
</table>

500W Nd:YAG laser
30s weld time

500W, SM fiber laser
3s weld time
Based on fiber laser technology, but with a Pulsed output, as opposed to a CW output.

Average CW power and Peak power are not the same. Ratio can be up to 1:10.
## QCW Laser Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Welding benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selectable brightness</td>
<td>Welding of conductive metals</td>
</tr>
<tr>
<td>Small Spot Size</td>
<td>Small welds</td>
</tr>
<tr>
<td>High peak power</td>
<td>Deep penetration even with low average power</td>
</tr>
<tr>
<td>Continuous Beam</td>
<td>High speed seam welding</td>
</tr>
<tr>
<td>Air cooled up to high powers</td>
<td>Independence from facility water</td>
</tr>
</tbody>
</table>
QCW Application: Spot Welds

430 Stainless steel PV Substrate to Sn coated Cu Bus bar

**Process Parameters**

- 600μm spot size, 0.9kW
- 7.5J, 6ms pulse

0.004” (0.1mm) thick SS
Sn coating helps, but still copper
QCW Application: Seam Weld

Process Parameters

17-4 SS to 304L hex nut

600um Spot size, 220W, 4J, 2kW, 55pps
Comparison between QCW and Nd:YAG

Similar pulse energy, peak power, average power, pulse duration and spot size
Summary

- Spot Welds
- Seam welds of heat sensitive parts
- Weld Reflective material use green (532nm) laser
- Large gap butt welding

**Pulsed Nd:YAG**

- High speed seam welds
- Thin material spot welding
- SM lasers offer very interesting welding properties

**CW/Modulated Fiber Laser**

- Seam Welds
- Spot welds
- Similar to pulsed Nd:YAG

**QCW Laser**

These are some basic guidelines, in the end, you should qualify process by testing!
Summary

• A number of sources exist in the micro welding laser toolbox
• Pulsed lasers for spot welding and low heat input seams
• CW Fiber lasers offer excellent seam welding capabilities
• QCW is the latest technology, and deliver similar welding to pulsed Nd:YAG
Further Information

For further information on Amada Miyachi laser welding products, please contact:

Mark Boyle – mark.boyle@amadamiyachi.com
David Van de Wall – david.van.de.wall@amadamiyachi.eu

Or visit our websites:

http://www.amadamiyachi.com/
http://www.amadamiyachieurope.com/