COHERENT | Solutions for E-Mobility

Webinar 18 Nov. 2020

Lavorazioni Laser nel Settore E-Mobility: Stato dell’Arte e Prospettive Future
The Anatomy of an Electric Vehicle's MP Laser Applications

- Electric Motor welding
- Track & trace laser marking throughout the vehicle
- High current device welding
- Battery cell assembly
- Battery pack welding
- Power Control Unit (PCU) assembly
CleanWeld Technology for Superior Process Results

Standard Fiber Lasers
- 1 to 10 kW CW
- Standard or Compact
- Cutting, Welding, Surface Treatment

Tailored Fiber Lasers
- Adjustable Ring Mode (ARM)
- Up to 10 kW
- Standard or Tailored
- Cutting, Welding, Microelectronics

Standard Diode Lasers
- 1 to 8 kW CW
- Standard, Compact, Rack
- Welding, Surface Treatment
ARM-FL: Adjustable Ring Mode Fiber Lasers

- INDEPENDENT kHz POWER CONTROL OF CORE AND RING MODES
- STANDARD PROCESS OPTICS and SCANNERS
- REAL-TIME CLOSED LOOP POWER MONITOR

Standard Configurations from 2 to 10kW

Combination of two beams
SmartWeld+ Beyond Wobbling

- Optimized dynamics for high speed repetition of micro patterns
- Various pre-programmed oscillation patterns, e.g. eight, spiral, ellipse, etc. – max. 15 patterns to store
- Selectable pattern size and orientation (angle) relative to feed direction
- AutoRotate function to follow a contour
- Synchronization with laser pulses
- Max. oscillation frequency - 4 kHz
- Excellent viewing quality with coaxial IR illumination, steady camera picture
- Compact, low weight

Examples for oscillation patterns
The Anatomy of an Electric Vehicle's MP Laser Applications

Battery Cell & Battery Pack

Battery cell assembly

Battery pack welding

Electric Motor welding

High current device welding

Track & trace laser marking throughout the vehicle

Power Control Unit (PCU) assembly

Battery cell assembly

Battery pack welding
Battery Cell Assembly

**Aluminium & copper processing**

- Aluminium cathode
- Copper anode
- Separator foil
- Aluminium pressure vent
- Aluminium current interrupt device
- 3000 series aluminium alloy case
- Terminal blocks copper to aluminium, aluminium to aluminium
- Electrodes copper to copper, aluminium to aluminium
- Polymer case

**Prismatic**
~20% Share

**Cylindrical**
>50% Share

**Polymer pouch**
~30% Share
### Laser Opportunities in Battery Cell & Pack Manufacturing

#### Battery Cell
- **Strucruring:** Emerging
- **Drying:** Emerging
- **Separator & Electrode Cutting:** Production
- **Foil Welding:** Emerging
- **Welding (cans, contacts, burst plates, vents):** Production

#### Battery Pack
- **Cleaning & Marking:** Production
- **Welding of bus bars & housings:** Production

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**Pre Treatment**

**Coating**

**Tailoring**

**Connecting**

**Joining**

**Assembly**
Ablation of Foil Coating with Pulsed Lasers

• To apply a continuous coating process for anode and cathode foils, it might be necessary to ablate sections for contacting afterwards.

• Coherent q-switched and ultrafast lasers enable precise ablation with very low heat affects.

• Depending on the required ablation rate and quality, pulsed (ns or ps) IR or green lasers of different power levels can be used.

Cathode foil ablated with
- 160 W average power
- ns pulsed IR fiber laser

Anode foil ablated with
- 50 W average power
- ps pulsed green laser
Laser Drying with Diode or Fiber Lasers

- Potential to substitute conventional vacuum furnace drying with inefficient energy deposition
- Direct absorption of the laser wavelength in the electrode layer
- Energy efficient due to excellent heat control.
- Reduction of energy process consumption by 50%
- Roll to roll process possible – reduction of line length

Source: Fraunhofer ILT, October 2015
Battery Cell Assembly – Separator Cutting

- Punch-press & knife cut
  - Tool wear & variable cut quality.
- Laser process
  - Scanner based high speed cutting process.
  - Speed of > 1 m/sec required.
  - CO$_2$ or CO laser wavelengths suitable for some basic materials PP or PE
- Next generation of hybrid ceramic materials, present new laser opportunity.
Battery Foil Welding

- Ultrasonic welding used today causes undesired debris.
- Depending on battery cell set-up stacks (Cu or Al) of up to 120 single foils (each 8...20 µm thick) need to be welded to a connector.
- Spattering and voids can be avoided with proper laser and process parameter selection.
- Process knowledge and dedicated laser required for stable process window with no spatter or voids.

Successfully welded stack of 100 Cu foils (8 µm each) with ARM laser.
Copper Foil-to-Tab Welding by ARM Laser

ARM: No Spatter and No Voids

- Ultrasonic welding used today causes undesired debris.
- >50 foils, each 5 µm thick, need to be welded to a connector
Aluminum Foil-to-Tab Welding by ARM Laser

ARM: No Spatter and No Voids

• Ultrasonic welding used today causes undesired debris.
• >50 foils, each 5-30 µm thick, need to be welded to a connector

[Images of welding process]
Single Mode ARM - Foil to Tab Welding

• **Material**
  - Foils: Cu, 30 pcs
  - Tab: Cu (Ni-plated)

• **Setup**
  - FL-ARM single-mode laser
  - Optics: HighYag RLSK magn. 3x

• **Welding pattern**
  - 42 points (21 points in 2 lines)
    - Distance between points in line 1.5mm
    - Distance between lines 1.3 mm or 2.0 mm
  - Weld duration 9 ms/point

• **Summary**
  - All the spots welded, without punctures
High Speed Video: Single Mode ARM Welding
Fiber Laser Scanner Welding of CID on 18650 Cells...

Process control for required welding depth... no weld through

- 3 segments
- Aluminum 0.25 mm thick
- Stainless 0.5 mm thick (coated)
- < 0.8 sec. cycle time for 9 parts
- No effect on backside

18650 battery cell, sectional side view  
Source: www.batteryuniversity.eu

Laser power: 900 W  
Welding speed: 300 mm/s
Surface Treatment for Joining Metal and Plastics

(PowerLine F 50 varia)

S-CID (Slim Current Interrupt Device): Detachable Type/Integrated Type

Using short pulsed micro laser to make pockets on metal surface.
Battery Cell Assembly – Prismatic Cell Assembly

Materials
- Aluminum (typically 3000 series)
- Copper

Laser process
- Legacy pulsed Nd:YAG process.
- QCW fibre laser as direct replacement for pulsed Nd:YAG lasers on existing lines.
- Currently - Disk, fibre & ARM fibre, hybrid diode laser.
- High speed contour typical for lid - can weld
- Scanner welding possible for electrodes, CID, and overpressure protection
Battery Lid Welding <1mm Weld Depth

Welding of CID and safety vent – 3000 series aluminum

Requirements:
• Smooth and shiny weld seam surface
• No pores or cracks

Achievements:
• Welding speed up to 400 mm/sec
• up to 1,0 mm penetration
• up to 1,0 mm seam width
• 1,5 kW laser power

Premier weld results with standard fiber lasers @ weld depth <1mm
Battery Tab Welding

Requirements:
• No pores or cracks
• Controlled inter-metallics

Achievements:
• Welding speed up to 250 mm/sec
• About 1.0 mm penetration
• Up to 1.0 mm seam width
• 1.5 kW laser power

Precise welding of dissimilar materials enabled by superior beam quality and application experience.
Single Mode ARM - Aluminum Tab to Bus Bar

• Material
  • Tab: Al
  • Plate: Cu

• Setup
  • FL-ARM single-mode laser
  • Optics: HighYag RLSK magn. 3x

• Welding pattern
  • Linear
  • Linear with wobble
  • Snake with wobble

• Summary
  • Customer very positive, low spatter, good results.
## High Speed Video - Single Mode ARM Welding

<table>
<thead>
<tr>
<th>Mode</th>
<th>Velocity</th>
<th>Power</th>
<th>Duration</th>
<th>Shield Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>10mm/s</td>
<td>C700W/ R1200W</td>
<td>0.180s</td>
<td>N2 20 l/min</td>
</tr>
<tr>
<td>Linear with wobble</td>
<td>60mm/s</td>
<td>C700W/ R1000W</td>
<td>0.300s</td>
<td>N2 20 l/min</td>
</tr>
<tr>
<td>Snake with wobble</td>
<td>45mm/s</td>
<td>C700W/ R1000W</td>
<td>0.302s</td>
<td>N2 20 l/min</td>
</tr>
</tbody>
</table>
SmartWeld+ Application Examples

- Market: Battery manufacturing
- Material: 3 x 0.2mm Ni plated Cu to Al
- Application: Busbar welding
- Sub-system: FL 010, SmartWeld+

- Rectangular, homogenous cross section
- Very low porosity, minimum pores
- No impact visible on back side

- Length / width: 20mm / 1.4mm
- $T_{cycle}$: 0.6 s
- Welding depth: ~1 mm
- Shear strength: > 1740 N
- $P_{avg}$: 500 W
SmartWeld+ Application Examples

- Market: Battery manufacturing
- Material: 2 x 0.3 mm Sigmaclad and 1 x 0.3 mm to 1 mm Cu (composite of Ni-SS-Cu)
- Application: Busbar welding
- Sub-system: SF600, SmartWeld+
- Rectangular, homogenous cross section
- No impact visible on back side
- Length / width: spot weld, Ø 1 mm
- Tcycle.: 0.04 s
- Welding depth: ~ 400 µm
- Pavg.: 250/350 W
Battery Track and Traceability

• Track & Traceability mandatory for safety relevant parts
• Battery individual serial data coded in machine-readable datamatrix codes
• Direct part marking requires necessary contrast ratio for good readability, even by hand held devices
• DPSS or fiber laser are a common choice for the marking onto aluminum material
• DM2 code 5x5mm in less than 3 secs
Battery Housing Cleaning

• Contamination by electrolyte remains on the exterior face of the battery housing

• Laser cleaning of aluminum pocket to maintain adhesive forces of spray paint layer at all environmental conditions

• Sub-ns / ns laser for minimal abrasive process, no change in material properties, wall thickness, no smoke residue and minimal particle contamination

• Cleaning performance up to 80cm²/sec
Welding of Connectors/Busbars

- Bus bars connect various cell terminals.
- Consists of either Aluminum, Copper or Ni-plated steel.
- Flexible high-speed welding process with 2D Scanner.
- High Power cw Fiber Laser (e.g. 2 kW for 2 mm penetration in Al at 4 m/min)
- Mixed metal welding requires process knowledge and dedicated laser sources for a stable window.

Source: Amada Miyachi
SmartWeld+ Application Examples

- Market: Battery manufacturing
- Material: 0.2 mm Cu to 0.3 mm SS
- Application: Busbar welding
- Sub-system: SF150P, SmartWeld+

- Rectangular, homogenous cross section
- No impact visible on inner side

- Length / width: spot weld, Ø 1 mm
- Tcycle.: 0.026 s
- Welding depth: ~ 300 µm
- Yield strength: 150 N / spot
SmartWeld+ Application Examples

- Market: Battery manufacturing
- Material: 2 mm Al to 1 mm steel
- Application: Busbar welding
- Sub-system: SF150P, SmartWeld+

- Large contact area
- Homogenous penetration depth
- Bridging large gap and misalignment
Welding Copper with ARM

- 4 kW, 5m/min
- 4 kW, 5m/min; optimized beam profile
- Power modulation for copper foil (100 x 10µm) welding
Lap Welding  Cu1020P 0.8mm Speed 12m/min

Center 3kw  

Ring 4kw  

Center 3kw+Ring 4Kw
The Anatomy of an Electric Vehicle's MP Laser Applications

Electric Motor Welding

1. Cu Pin stripping

2. Cu Pin welding

3. Cutting and welding of stators (prototypes)

Source: Polaris LLC
Electric Powertrain: 1. Cu Pin Stripping

- Copper wire has lacquer layer, polyamide-imide PAI, for protection.
- Residual lacquer layer has a significant impact on welding process.
- Complete removal of lacquer layer necessary for consistent welding process, quality and cleanliness by 2-step approach.
- Step 1: CO₂ laser to remove lacquer layer without structuring surface.
- Step 2: Small remaining lacquer spots are removed by F100 IR ns fibre laser or Pico 50, to provide a clean and structured surface, which is beneficial for subsequent welding process.
Stripping of conductor rails or hairpins. Special designed process chamber is available.
Electric Powertrain: 2. Cu Pin Welding

• The stripped Cu Pins are welded in the stator

• Proper alignment of the pins and a weld without any defects (inclusions) are essential for the motor performance
Hair Pin Welding: Fiber Laser Comparison

Three Approaches
- Multimode fiber laser
- Single Mode fiber laser
- ARM fiber laser

Single Spot MM Fiber Laser with Scanner
0.25 seconds

SM Fiber with Wobble
0.25 seconds

Stationary Beam with ARM Fiber Laser
0.1 seconds
Hair Pin Welding: ARM

Realtime

![Image of hair pin welding setup]
Lasers for Lithium-Ion Battery Cell Assembly

Slurry Drying
HighLight DL Series

Surface Structuring
HyperRapid NX Series

Electrode Foil Cutting
Avia NX Series

Electrode Tab Welding
HighLight FL ARM

Lithium-Ion Battery Pack Assembly

Terminal Welding  Surface Cleaning  Bus Bar Welding  Track & Trace

HighLight FL Series  PowerLine Pico Series  HighLight FL Series  PowerLine F Series

Foto LP rail
Products for Electric Motor Assembly

- Lamination Welding
- Wire Stripping
- Hair Pin Welding
- Track & Trace

- HighLight FL Series
- PowerLine Pico Series
- HighLight FL Series Starshape
- PowerLine F Series
Thank you for your Attention

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