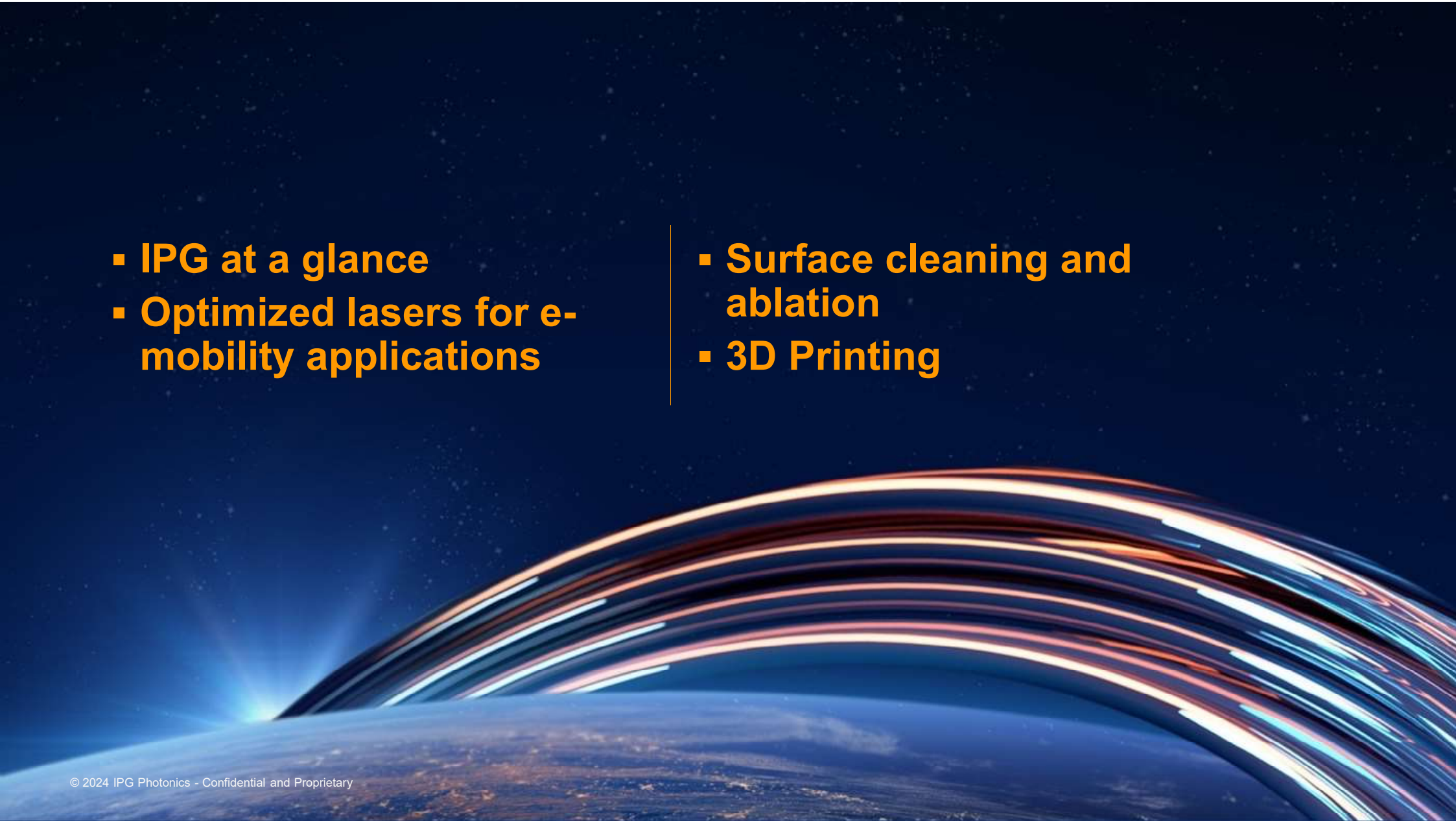
High-Efficiency Fiber Lasers – An Economic Tool for Processing Aluminum in a Wide Range of Applications

Michael Grupp
Applications Manager

23.01.25



IPG Photonics At-a-Glance

1990
FOUNDED

~6,200
EMPLOYEES

20+
COUNTRIES

$1.4B
REVENUE

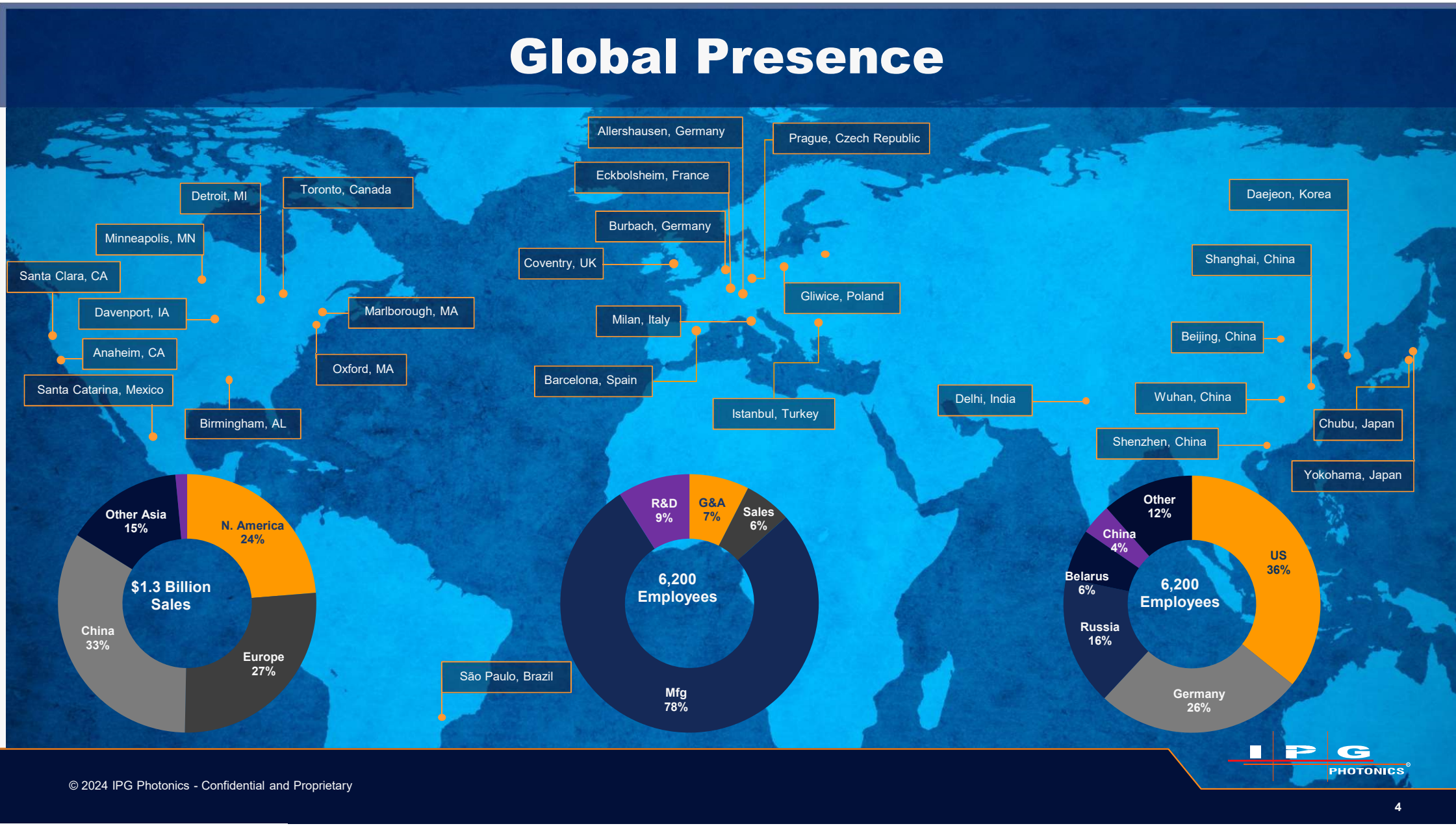
~49,000
DEVICES SHIPPED

~ 5,500
CUSTOMERS ACROSS 6 MAIN INDUSTRIES

Based on 2022 Data

- Global market leader in fiber laser technology across multiple end markets and applications
- Vertical integration, manufacturing scale and technology driving best-in-class margins
- Expanding multi-billion dollar addressable market opportunity
- Industry-leading earnings and cash flow

Global Presence



IPG | Europe

1994
Started in Europe

8
COUNTRIES

~2,100
EMPLOYEES

European Customer Center in Burbach, opened 2023

Acquisition of cleanLaser

cleanLASER
Reinigen mit Licht

IPG Laser | Technologies & Production

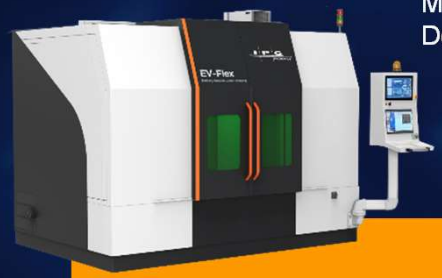
Optical Preform MfG

Silica based glass
MCVD method
Dope with rare earth ions

Fiber Draw
Active & Passive fibers

Laser Diode Packaging

PLDs



INTEGRATED SYSTEMS

DEEP IN TECHNOLOGY
DEEP IN EXPERIENCE

Components MfG

Bulk optics
Bragg Gratings
Isolators
Couplers

Industrial Lasers

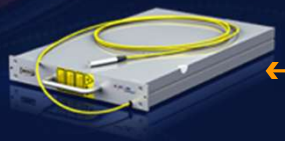
Coupling
Final burn in
Shipment

Power Supplies

Control Electronics

Laser Modules

Up to 3 kW



Fiber Blocks

Fiber Bragg Gratings
, Modulators

Revolutionizing the Laser Industry

Ultra High Power Continuous Wave (CW) Lasers

Ultra Compact Lasers

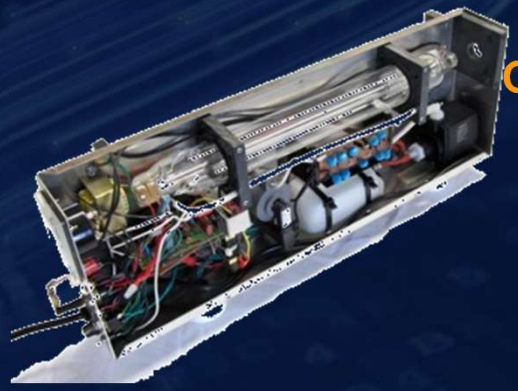
Adjustable Mode Beam and QCW Lasers

High Power Nanosecond Pulsed Pico and Femtosecond Pulsed

- Higher Productivity
- Compact
- Reliable
- Robust
- **Efficient**
- Minimal Maintenance
- No Consumables
- Scalable

TRADITIONAL LASERS

Carbon Dioxide (CO_2)



Lamp-Pumped Nd: YAG

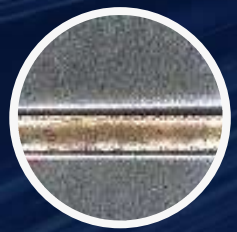
- Expensive
- Bulky
- Unreliable
- Difficult to Operate
- Inefficient
- Frequent Maintenance
- Costly Consumables
- Not Scalable

Laser Penetration in Industrial Applications

Continued adoption of laser tools in many industrial applications


CUTTING


WELDING


BRAZING

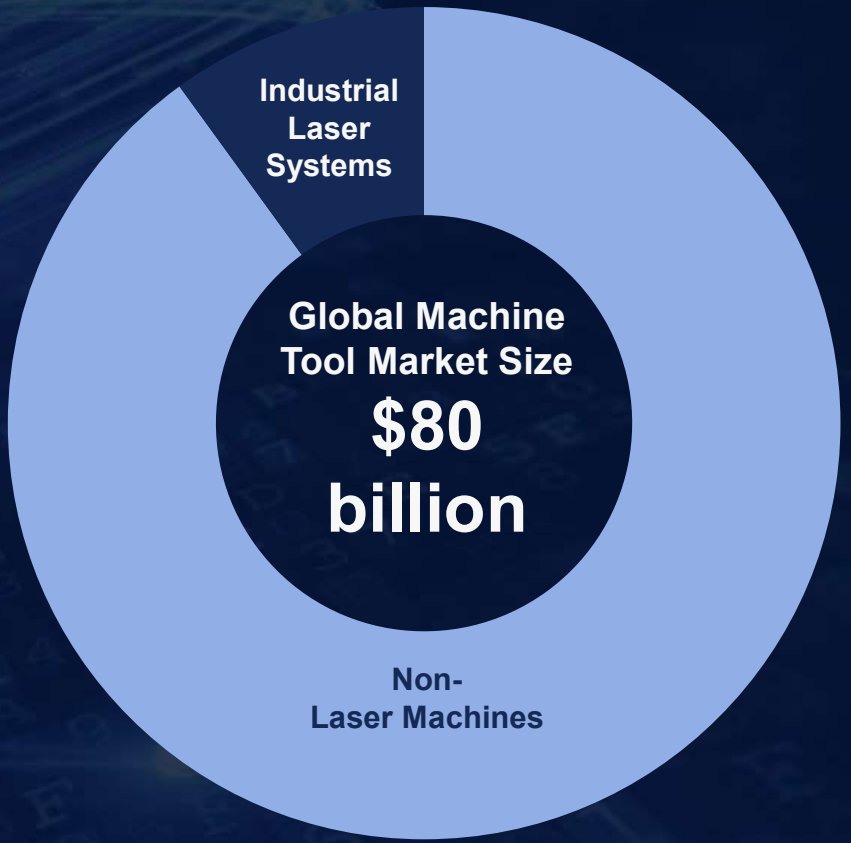

DRILLING


ABLATION


ADDITIVE MFG

MARKING

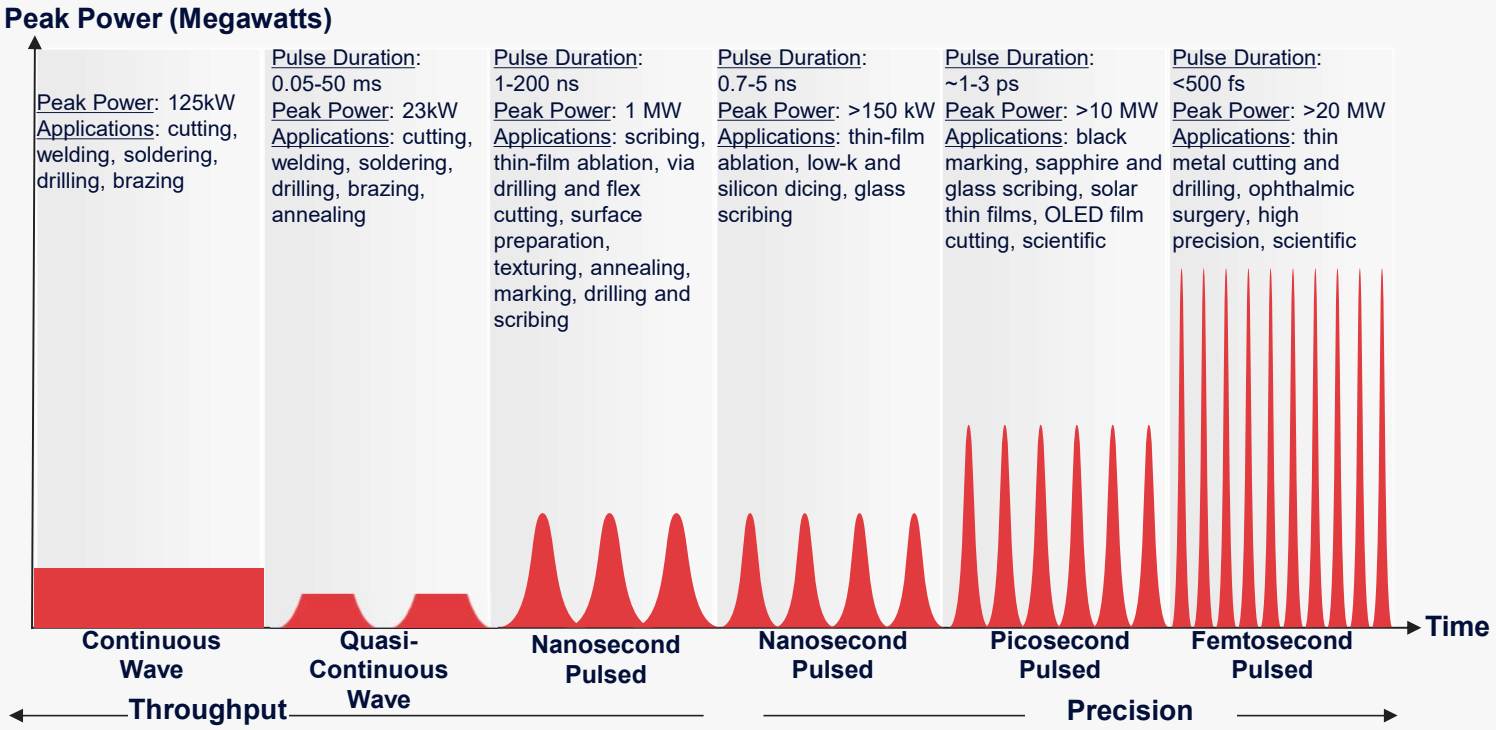

CLEANING



Source: Optech Consulting, Strategies Unlimited and IPG Photonics Corporation

Broadest Portfolio of Fiber Lasers

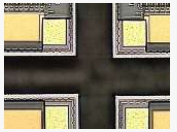
Any wavelength, mode of operation, power, beam parameters or application



Thick steel cut with a continuous wave laser

Drilling using a quasi-continuous wave laser

Surface Cleaning using a pulsed laser



Micromachining using an ultrafast laser

KEY REQUIREMENTS FOR EV WELDING

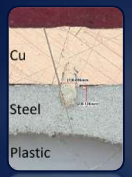
WELDING DEPTH CONSISTENCY

HIGH THROUGHPUT

SPATTER FREE PROCESS

POROSITY FREE WELD

EXTREMELY LOW HEAT INPUT



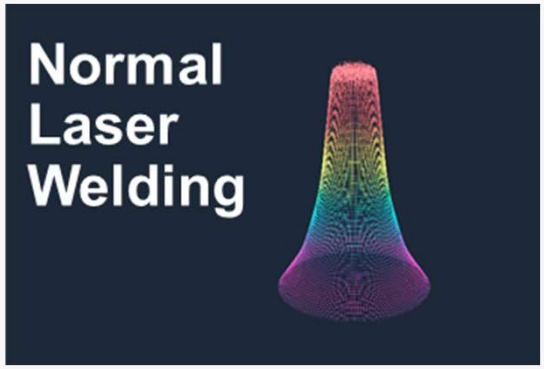
LARGE FIELD OF VIEW

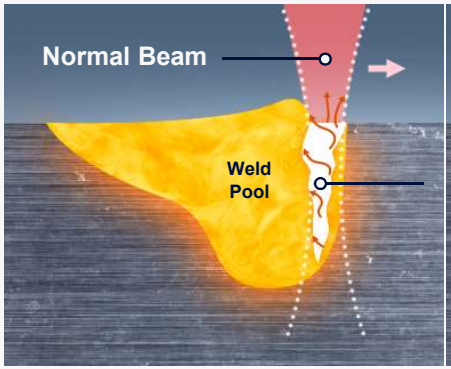
100% QUALITY CONTROL

EASE OF SYSTEM INTEGRATION

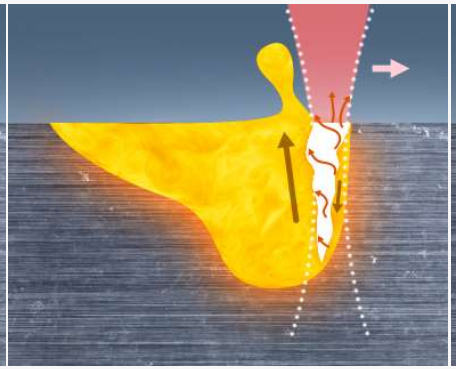
MEETING WELDING REQUIREMENTS ENSURES
SAFE & RELIABLE COMPONENTS

AMB STABILIZED KEYHOLE WELDING PROCESS ELIMINATES SPATTER & INCREASES QUALITY

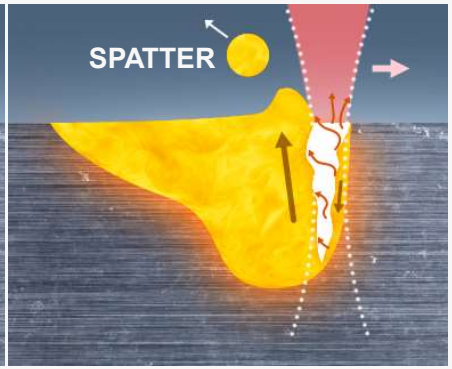




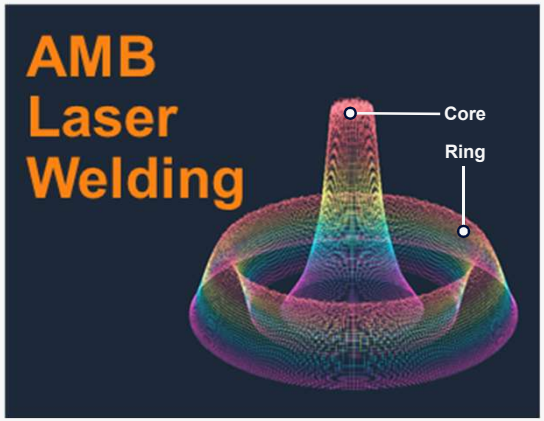
Normal laser welding continuously lases the material until it is vaporized and exits the keyhole quickly

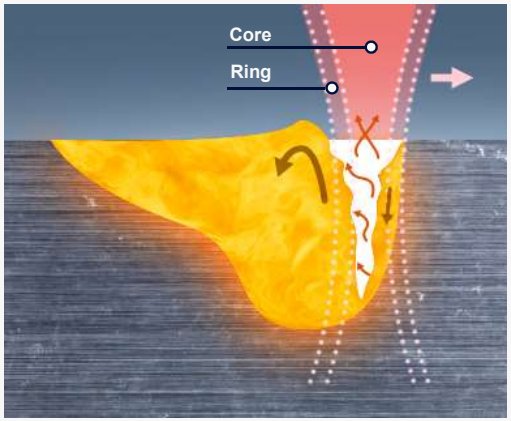


The high pressure from the metal vapor escaping pushes material toward to the top of the keyhole



Spatter is propelled out the top of the keyhole and becomes fused to the surface





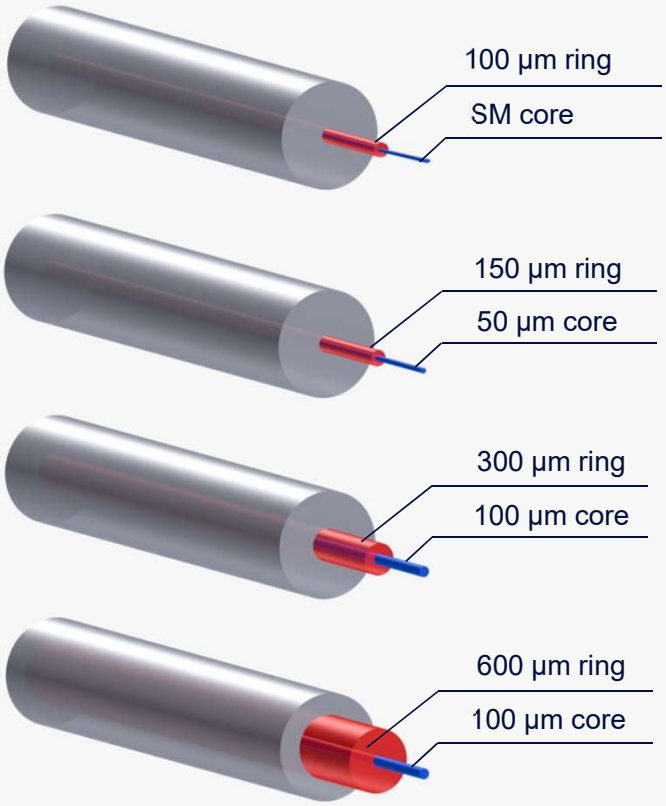
KEYHOLE STABILIZATION

- **AMB creates a larger and more stable keyhole** allowing metal vapor to escape more easily
- The ring beam minimizes the kinetic energy of the escaping vapor **minimizing spatter**

WELD POOL STABILIZATION

- **AMB stabilizes the weld pool** and there is no further melting behind the more stable keyhole
- The ring beam softens and deflects material towards the bottom of the weld pool which **significantly reduces spatter**

ADJUSTABLE MODE BEAM
CORE & RING BEAM FIBER OPTIONS

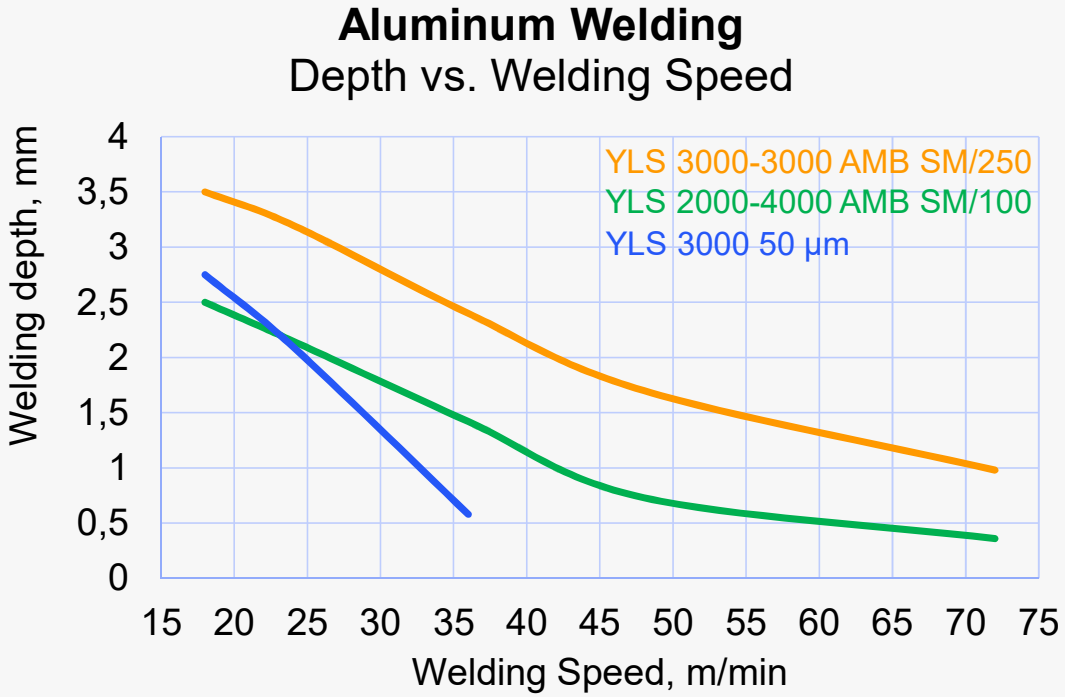


Up to **4 kW in Single-mode Core**

Up to 30 kW in Multi-mode Core

***Custom orders for >100 kW total power are possible by request**

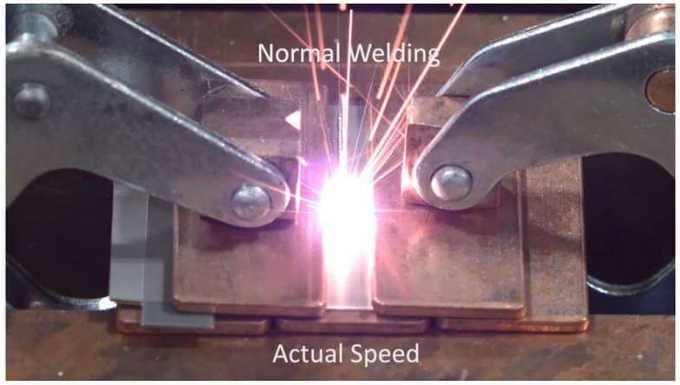
AMB TECHNOLOGY ENABLES STABLE ULTRA-FAST WELDING

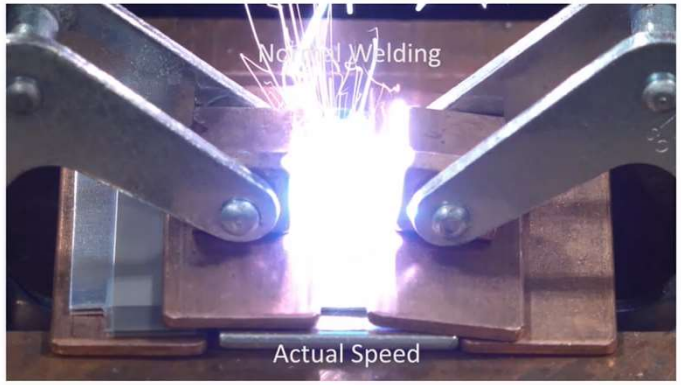


Spatter-Free Welding of
1.30 mm at **>1 m/s**

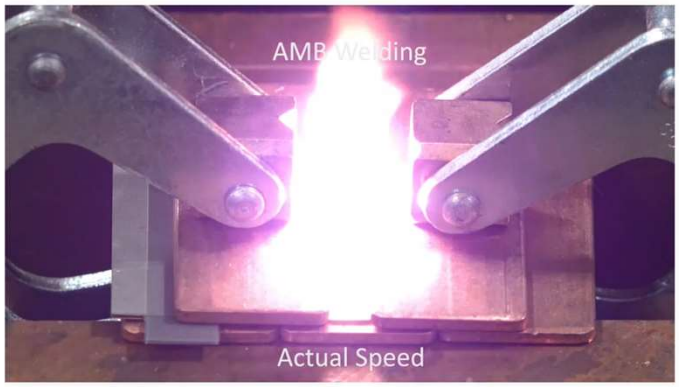
AMB LASERS ENABLE SPATTER-FREE WELDING

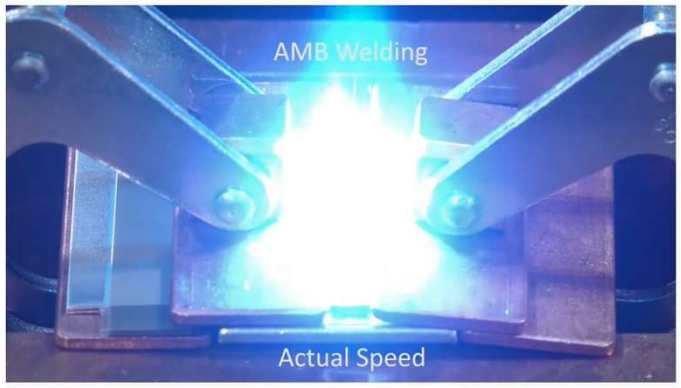
Regular Laser: SPATTER





AMB Laser: SPATTER FREE





COPPER WELDING

3.4 mm Lap joint

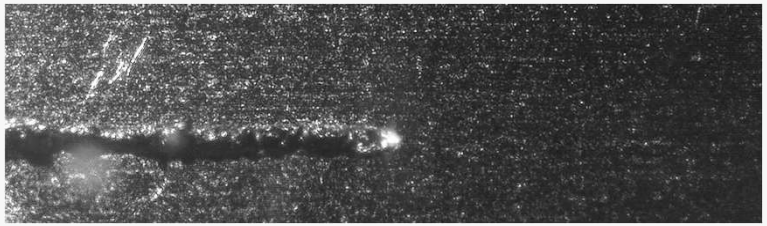
Material: 0.2 mm **Ni coated Copper** + 0.2 mm **Ni coated Copper** + 3.0 mm **Copper**

DISSIMILAR WELDING

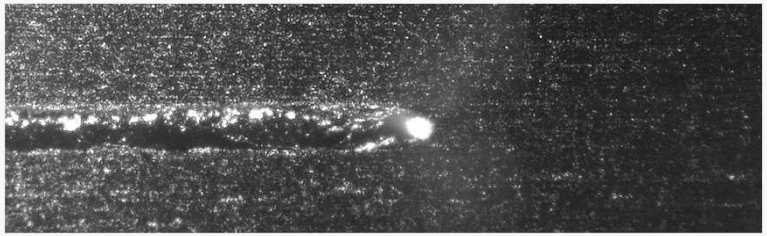
3.4 mm Lap joint

Material: 0.2 mm **Aluminum** + 0.2 mm **Aluminum** + 3.0 mm **Ni coated Copper**

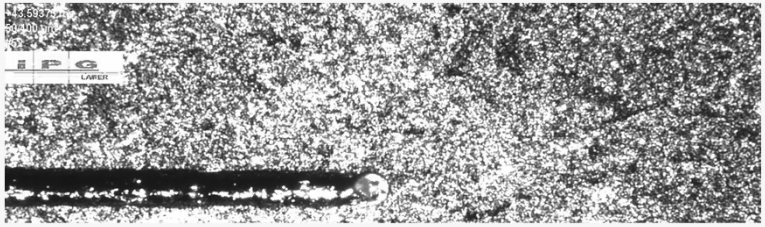
Spatter Reduction by AMB Technology



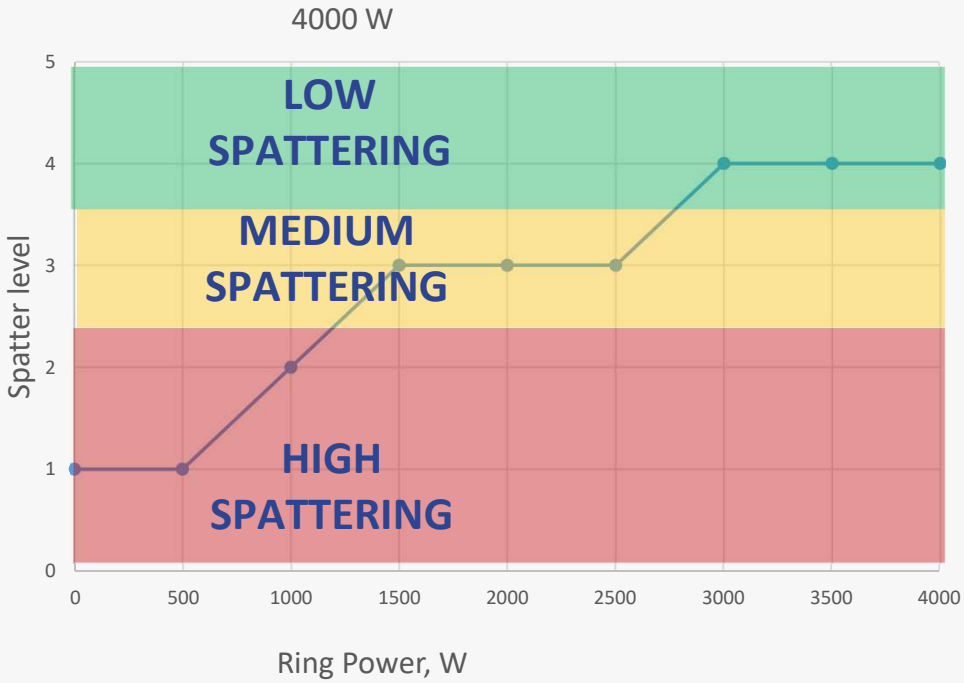
4000/0W



4000/1500W



4000/3000W



HIGH-SPEED VIDEO ANALYSIS ON ALUMINUM
REGULAR VS. AMB WELDING

Al 1.5 mm + Al 3.5 mm Lap joint (Prismatic Batteries: Busbar to Terminal welding)

Weld Depth 2.101 mm, Line Weld at 200 mm/sec

Regular Welding

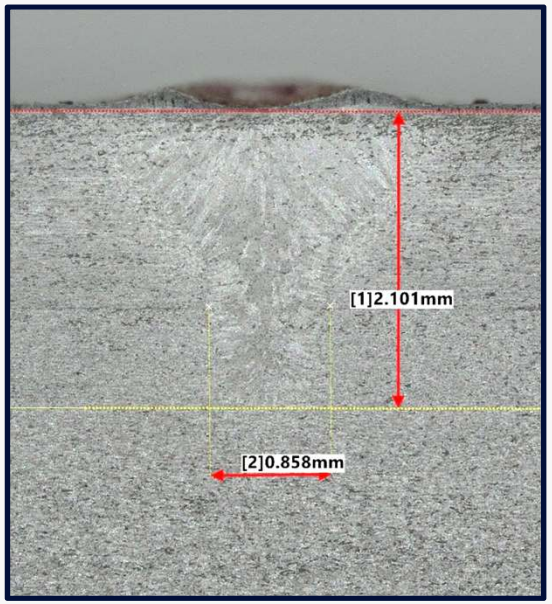
5000 W

HIGH SPATTER

AMB Welding

4000/4000 W

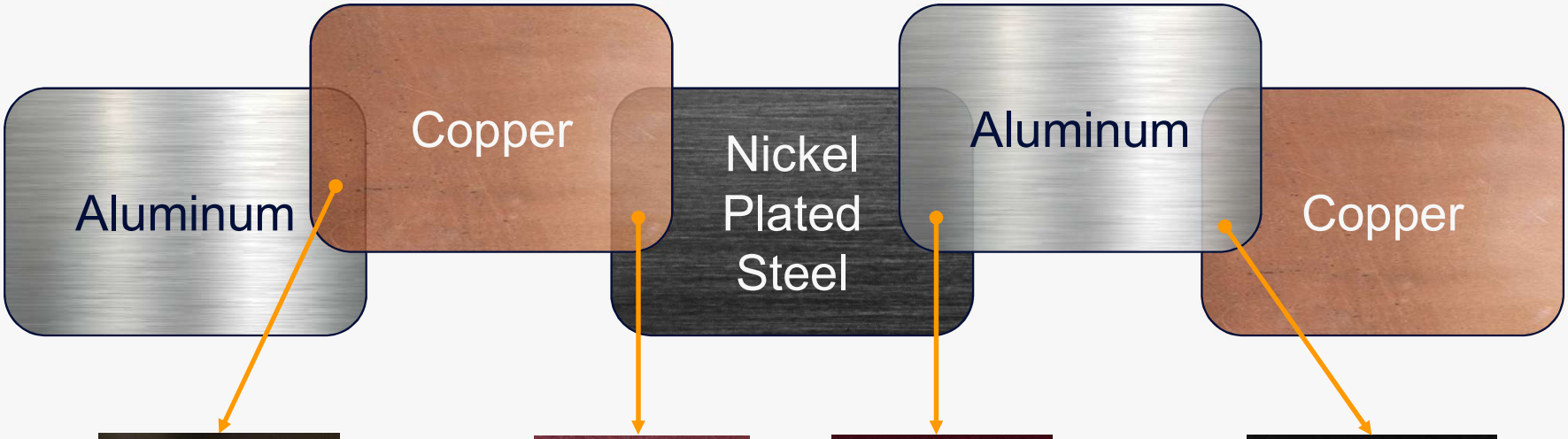
SPATTER-FREE



AMB Welding

HIGH-QUALITY FINISH

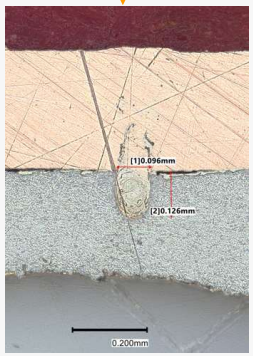
AMB LASERS ENABLE WELDING A WIDE RANGE OF DISSIMILAR MATERIAL COMBINATIONS

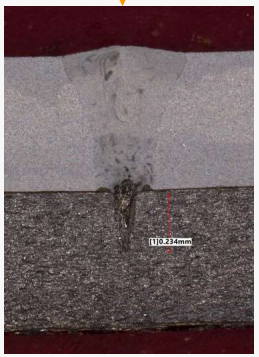


0.2 mm Copper + 1.0 mm Aluminum

0.4 mm Copper + 0.3 mm Ni-Plated Steel

No Plastic Melting





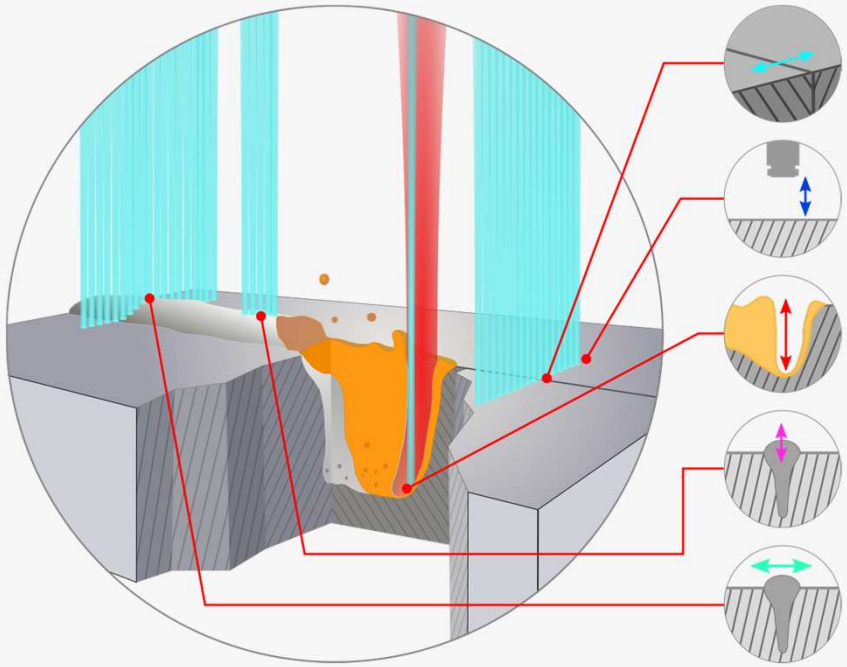
0.5 mm Aluminum + 0.5 mm Ni-Plated Steel

0.3 mm Aluminum + 0.3 mm Copper

Process Monitoring

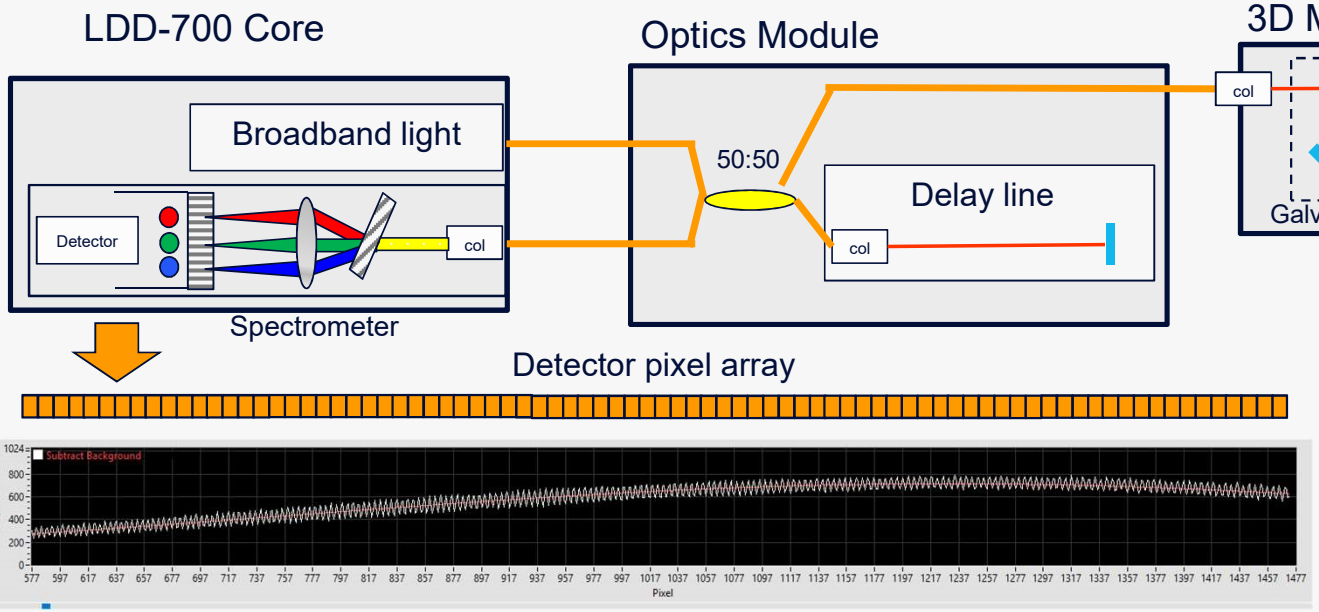
- **LDD is the ONLY technology that is capable of performing multi-factor, integrated quality assurance measurements of:**
  - Seam Position
  - Workpiece Height
  - **Keyhole Depth**
  - Finished Weld Surface
  - Transverse Profile

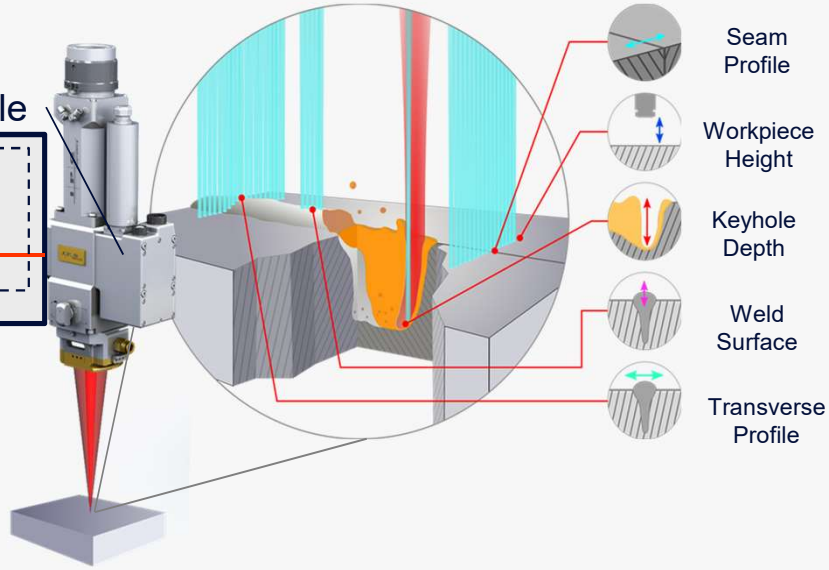
LDD Technology Overview—Multi-factor QA



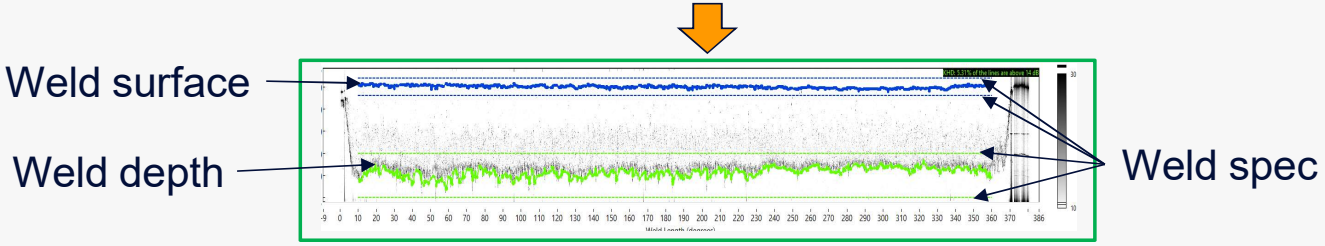
OCT (Optical coherence tomography)

LDD 700





Signal processing & multiple acquisitions

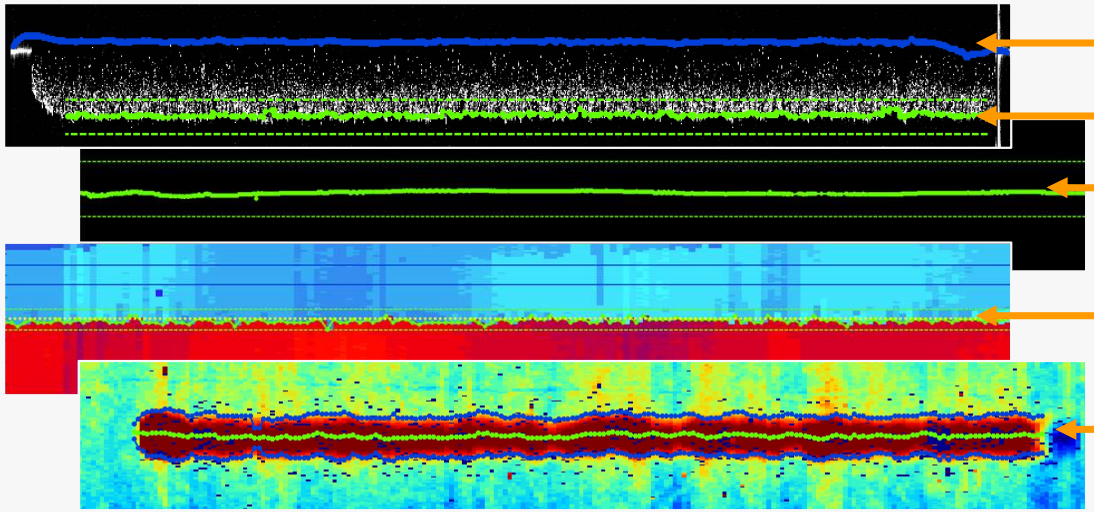


The LDD Difference

- Quality **measuring**, not just monitoring.
- High Speed (250 kHz), High precision (<20 µm)
- Resistant to blinding by process emissions
- Scanning technology is flexible for high speeds and curvature of linear welds
- IP protected ultraprecise alignment capabilities support single-mode AMB welding in serial production.

OmniWELD Data

- **Simultaneous Measurements**



- **20+ Weld Metrics**

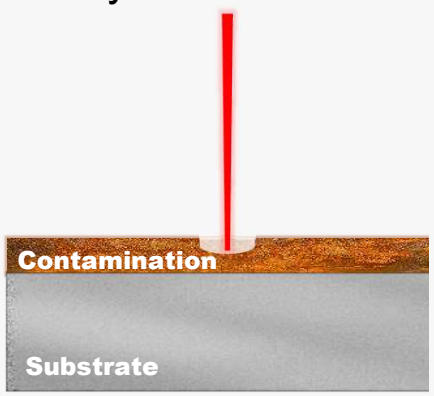
Joint Position **Gap Width** **Distances in Range** **Weld Penetration** **and more…**

Min/Max Ranges **Step Height** **Process Stability** **Lateral Weld Profiles**

Laser Cleaning Process

Absorbing layers

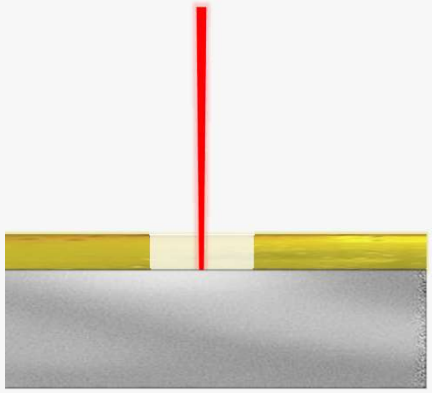
- Like:
  - Rust; Oxide layer…



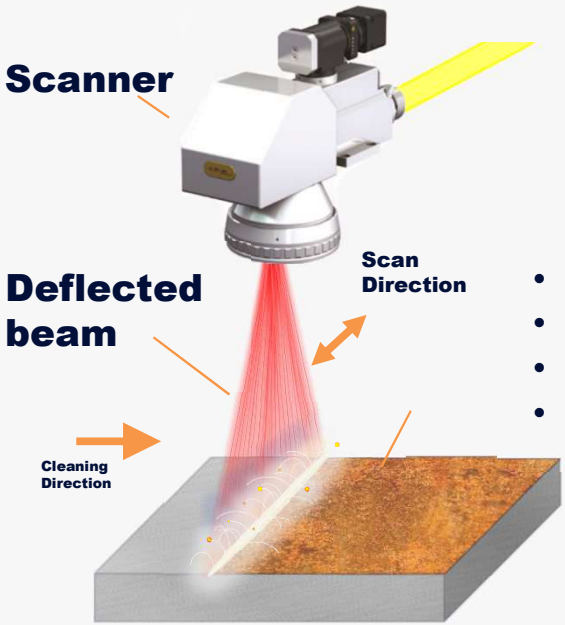
Absorbtion in Top Layer

Transparent layers

- Like:
  - Oil, Silicates…



Absorbtion in Substrate



- Rust
- Dust
- Oil
- Coatings

Laser Cleaning:

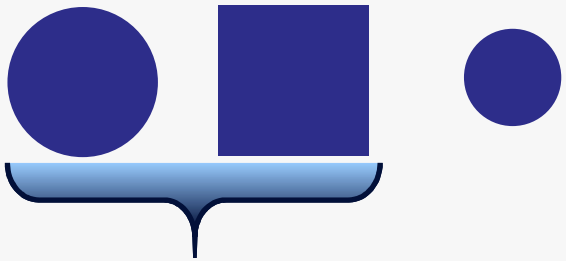
- No solvents
- No consumables (sand blasting, glass blasting, dry ice)
- Low energy consuption

Laser Cleaning

Requirements Process

- Accurate ablation without destroying substrate
- High Speed

Spot properties for Laser cleaning



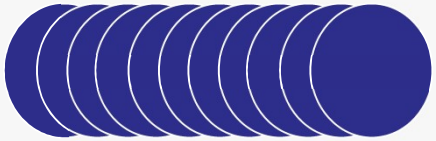
Large Spot size

Large spot size for higher ablation rate

Important Requirements Laser

- High frequency > kHz
- High pulse energy > mJ

High overlap

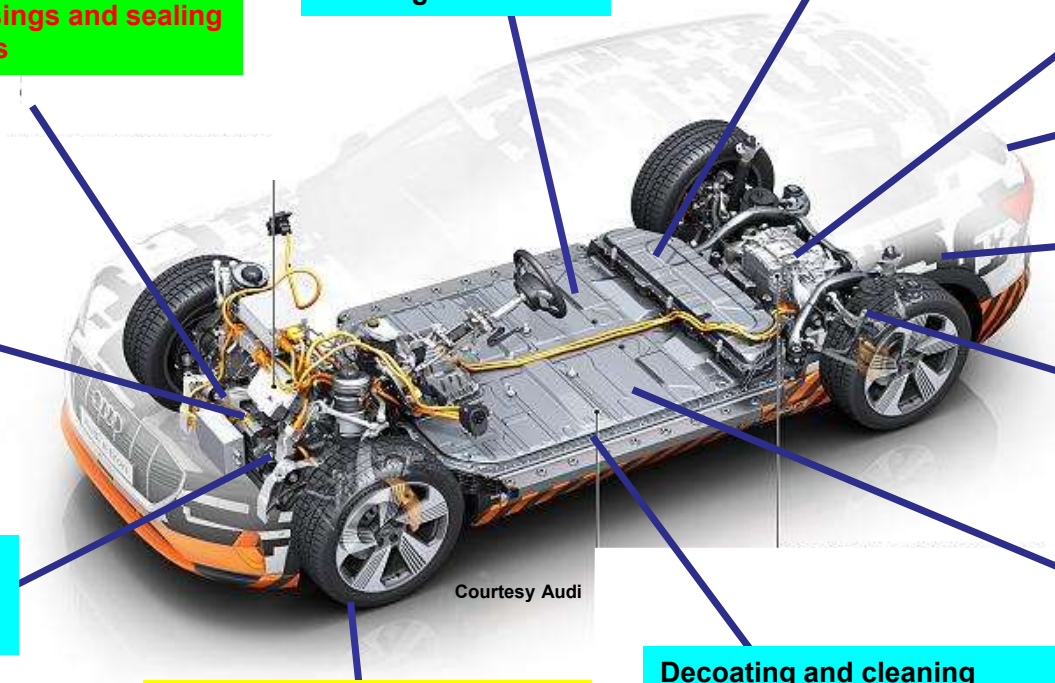


Low overlap

Square spot size for higher ablation rate

OVERVIEW APPLICATIONS - E-MOBILITY - ADHESIVE APPLICATIONS

- Batterie and control
- Power train
- Body in white & others



Adhesive pre-treatment of E-Drive housings and sealing areas

Cleaning of battery and cell connectors, e.g. for wire bonding

Pre-treatment and flux removal on the cooling system

Decoating of copper hairpins

Weld pretreatmnt (BIW)

Bonding pre-treatment for structural adhesive (BIW)

Resin removal from e-stator parts

Decoating/pre-treatment of housing sealing surfaces

Pre-treatment for the bonding of control units and sealing areas

Adhesive or coating pre-treatment of battery cells, modules and battery housings/frames

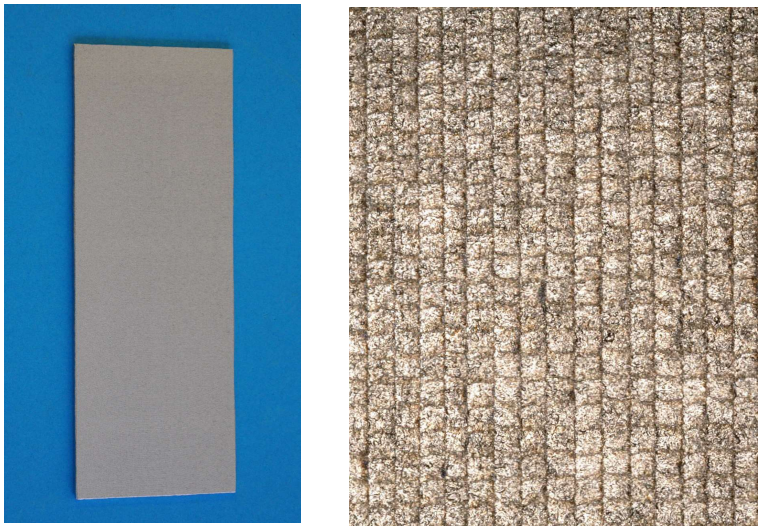
Pre-treatment of tyres for bonding sensors or 'run flat' parts

Decoating and cleaning electrical connections before welding

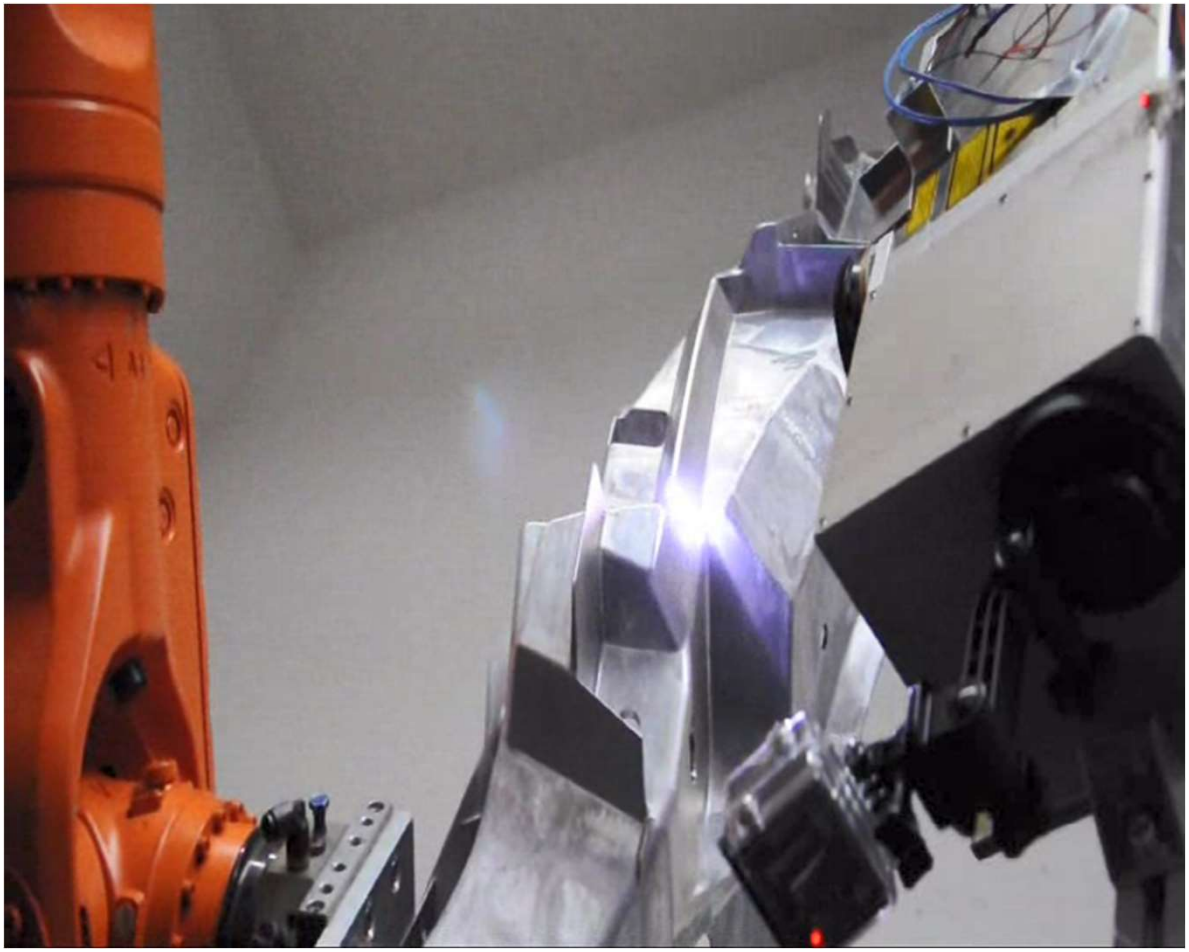
PREPARATION OF THE STRUCTURAL BONDING OF STRUCTURAL COMPONENTS

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

- Area rate of 10-30 cm²/s
- Up to 100cm² with reduced corrosive demand
- Long-term corrosion resistance
- ‘Survives’ common accelerated ageing tests without degradation
- No creep corrosion
- Direct epoxy, hotmelt and PU bonding is possible

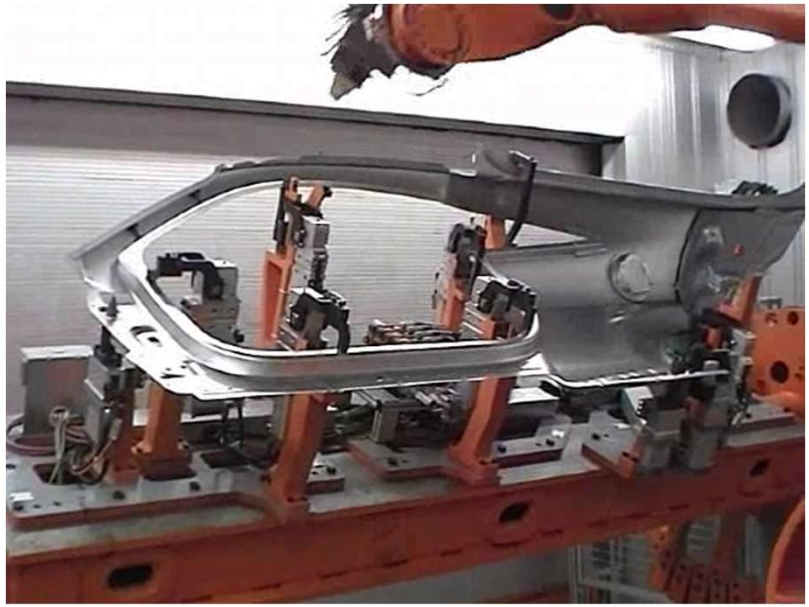


Typical specimen/pattern after laser treatment

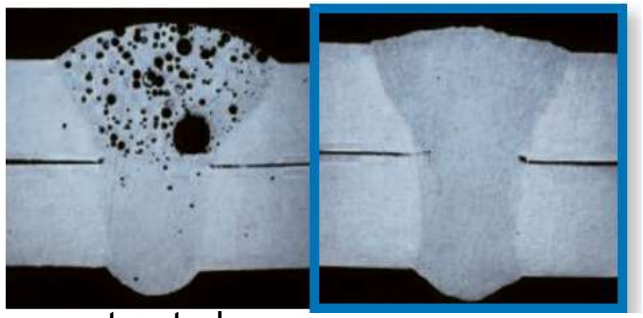


Weld Pre-Treatment with CLEANLASER-TECHNOLOGY

Aluminum BIW applications

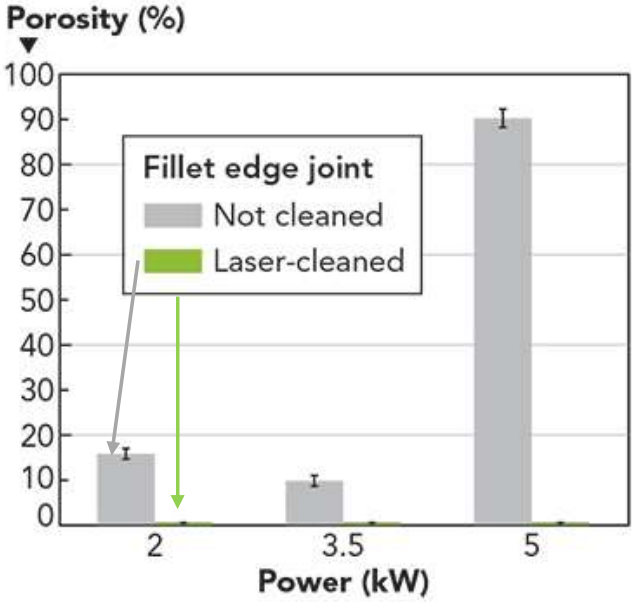


- Treatment with mid-power laser
- Removal of oxidation and grease layers
- Welding pre-treatment of sheet metal with Al 6000 alloys
- Localised surface cleaning at up to 12 m/min
- Consistent surface quality for welding
- Comparable results to chemical cleaning
- Direct and in-line, mainly for sheet metal and extruded material
- Status: in series production at several OEMs (> 130 systems)



untreated

Advantage LASER! – Reduction of Weld Porosity below 1%



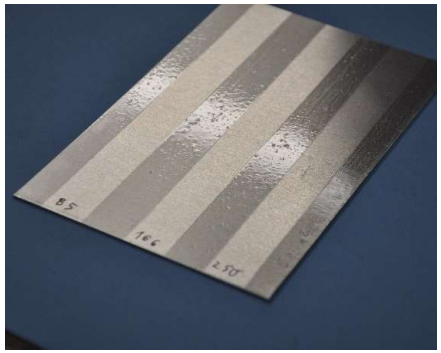
Investigations on weld seam porosity at an OEM:

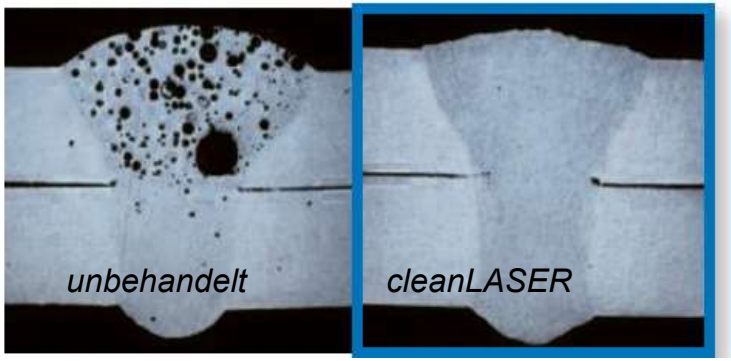
- Different welding powers and with/without cleanLASER pre-treatment
- For all three laser welding parameters, laser cleaning significantly reduced the porosity and achieved less than 1 % porosity in all case

Process release (OEM):

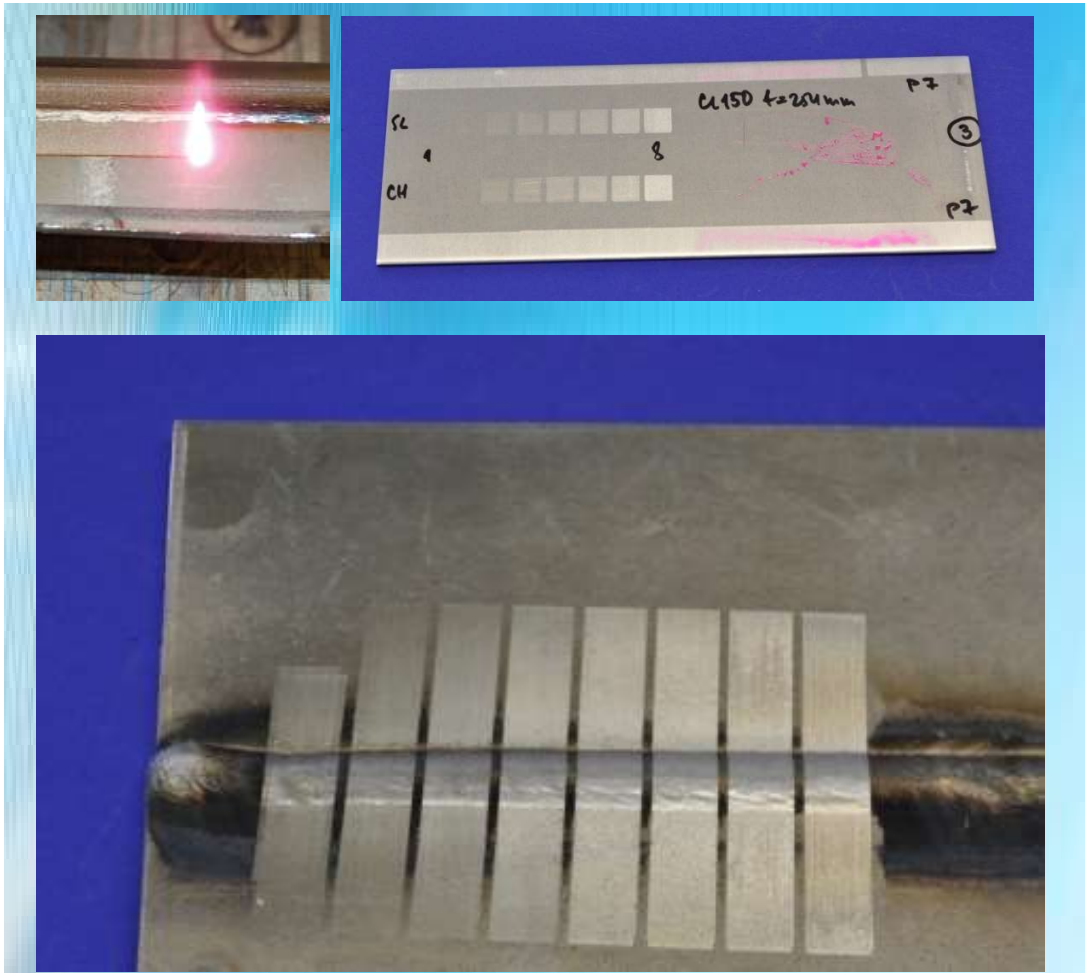
The process is **approved** by the OEM as follows

- Cleaning with initial oiling of up to 4g/m² (series specification approx. 2g/m²) permitted
- Feed rate with complete cleaning validated up to 15m/minThe machined components can be stored for several hours until rewetting





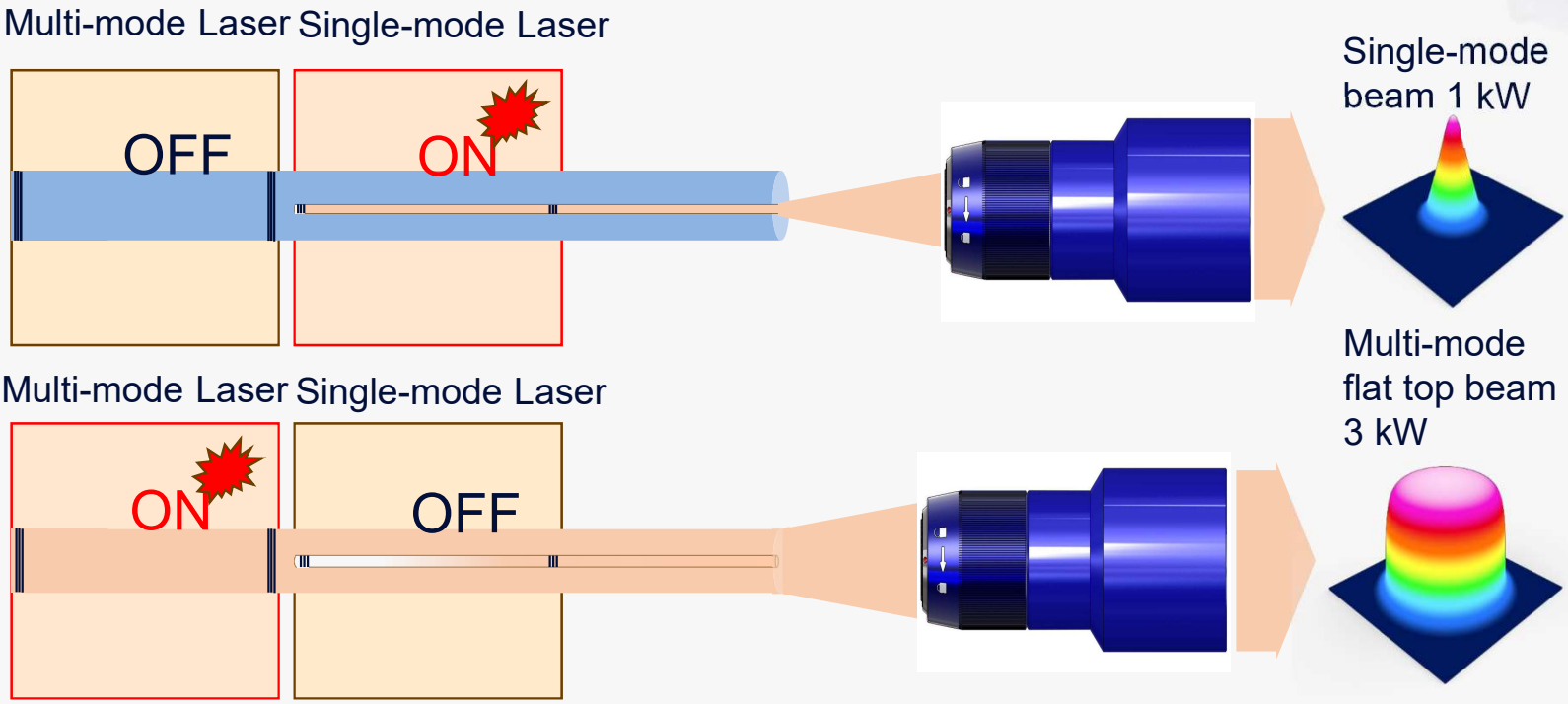
POST-TREATMENT OF ALUMINIUM WELD SEAMS



- Removal of fumes and oxide layers
- Surface activation
- Process monitoring possible
- Surface tension >56mN/m (paint adhesion optimisation)
- Surface modification (adjustment of roughness) possible and also avoidable
- Replacement for brushing and particle blasting processes
- Suitable for aluminium and steel
- Typically approx. 4-10m/min feed rate with 20mm track width (CL 500)

Tailored Laser Sources for 3D Printing

YLR-3000-1000-AM: Single-mode or Multi-mode Output from One Fiber



AlSi10Mg

Comparison

- High performance gaussian parameters
  - Layer size 120 µm
  - Build rate 152 cm³/h
  - Density >99.9%
- YLR 3000/1000-AM Parameters
  - Layer size **240 µm**
  - Build Rate up to **432 cm³/h**
  - Density >99.7 %

➡ A multiple of the highest build rate available on the market!

Production Example - Aconity*SCAN*

Key Data

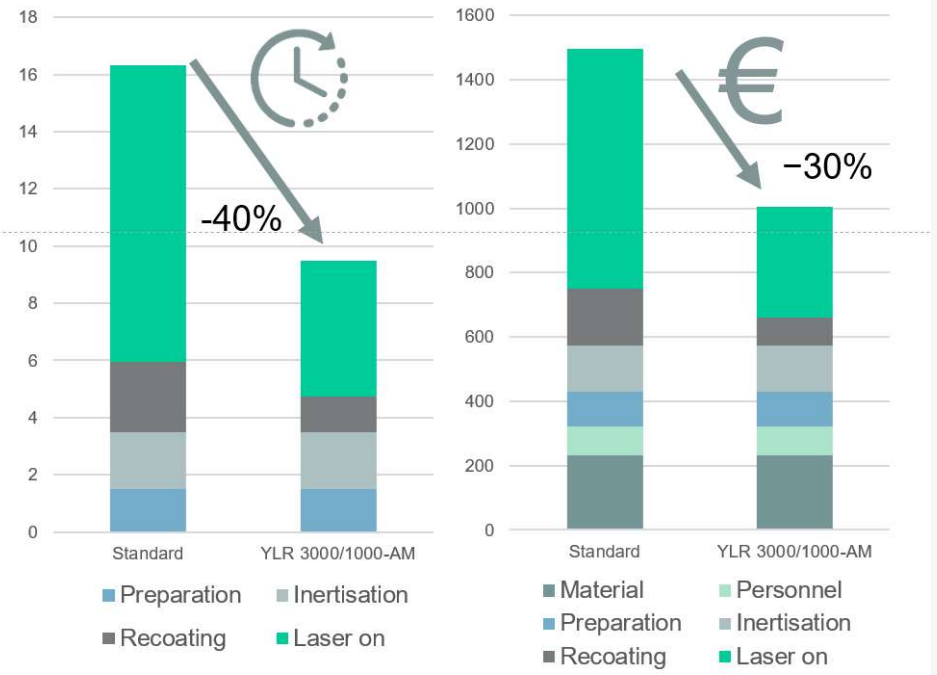
- 162 x 126 x 110 mm³ (LxWxH)
- Integrated water and air channels for cooling
- Machining allowance < 0.5 mm
- Build on preform:
  - faster set-up times
  - referencing for postprocessing

➡ Optimized design reduces process downtimes to a minimum

Production Example - Aconity*SCAN*

Key Data

- 162 x 126 x 110 mm³ (LxWxH)
- Integrated water and air channels for cooling
- Machining allowance < 0.5 mm
- Build on preform:
  - faster set-up times
  - referencing for postprocessing



➡ Optimized design reduces process downtimes to a minimum

Summary

- There is not the ONE laser source which can achieve the best process quality over a wide range of application.
- BUT: With improved technologies we are able to adress the charcteristics of the laser for best performance and quality
- New challenging applications drive the development of new equipment in terms of laser – optics – process monitoring
- These new technologies enables us to expand the acceptance of laser processes in formerly non-laser applications