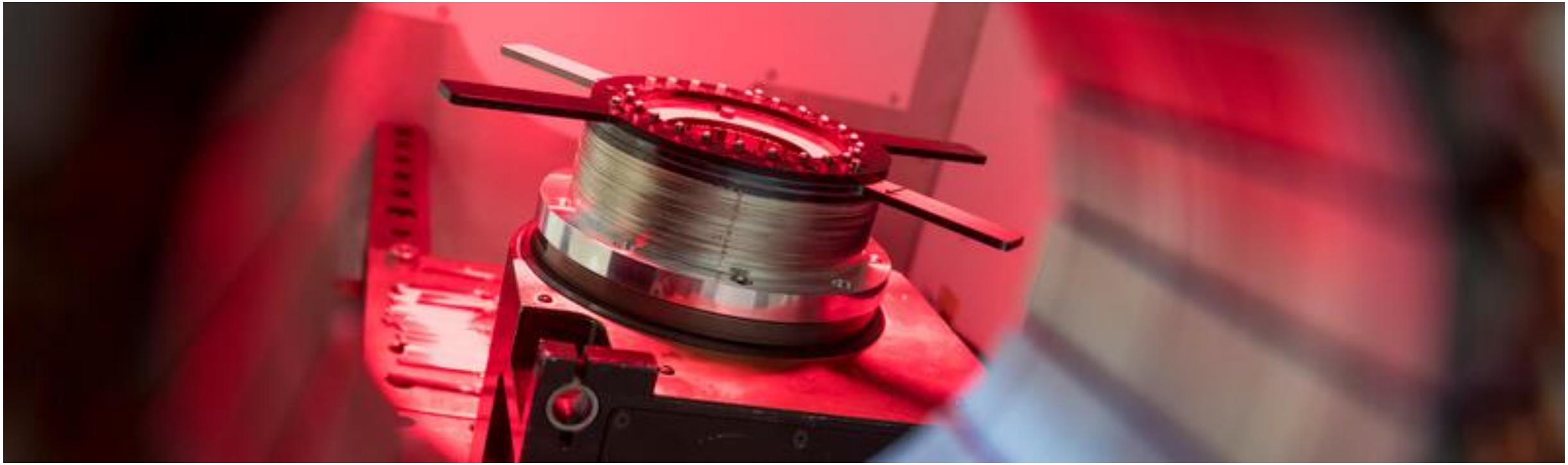


Highly Integrated Lasersystems and Innovative Welding Technologies for eMobility Manufacturing

Matthias Beranek IWE

Industry Management Mobility, Electrified Powertrain

Bologna, Italia

03/2022

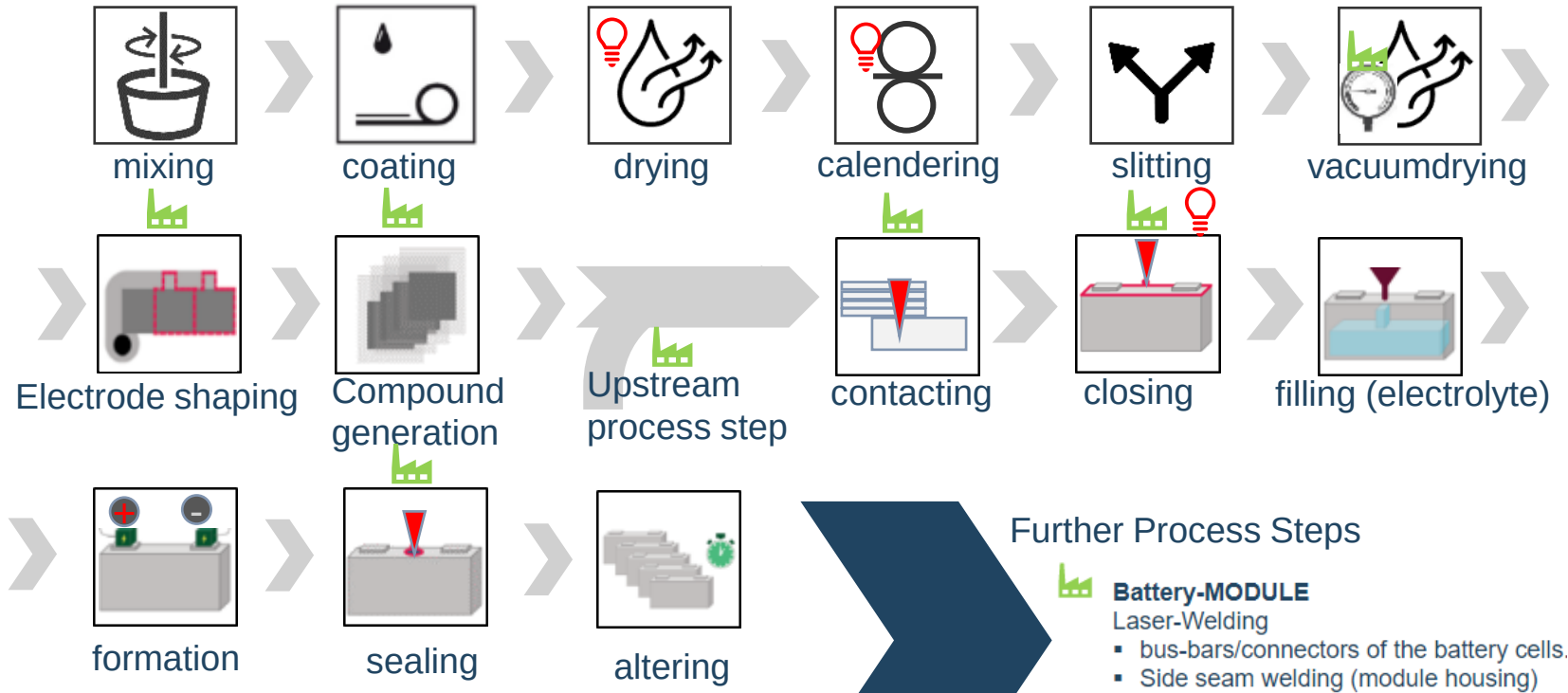
LaserEMobility *Workshop 2022*

Network and know-how for Laser based manufacturing in the EV sector

TRUMPF

Battery cell: Production process

In the electrode production and cell assembly there are many established but also new potential laser applications.



Further Process Steps

Battery-MODULE
Laser-Welding
- bus-bars/connectors of the battery cells.
- Side seam welding (module housing)
- FPC Contacting

Battery-PACK
Laser-Welding
- battery boxes/body

Battery-MANAGEMENT
Laser-Welding/-Marking
- electronic connectors.

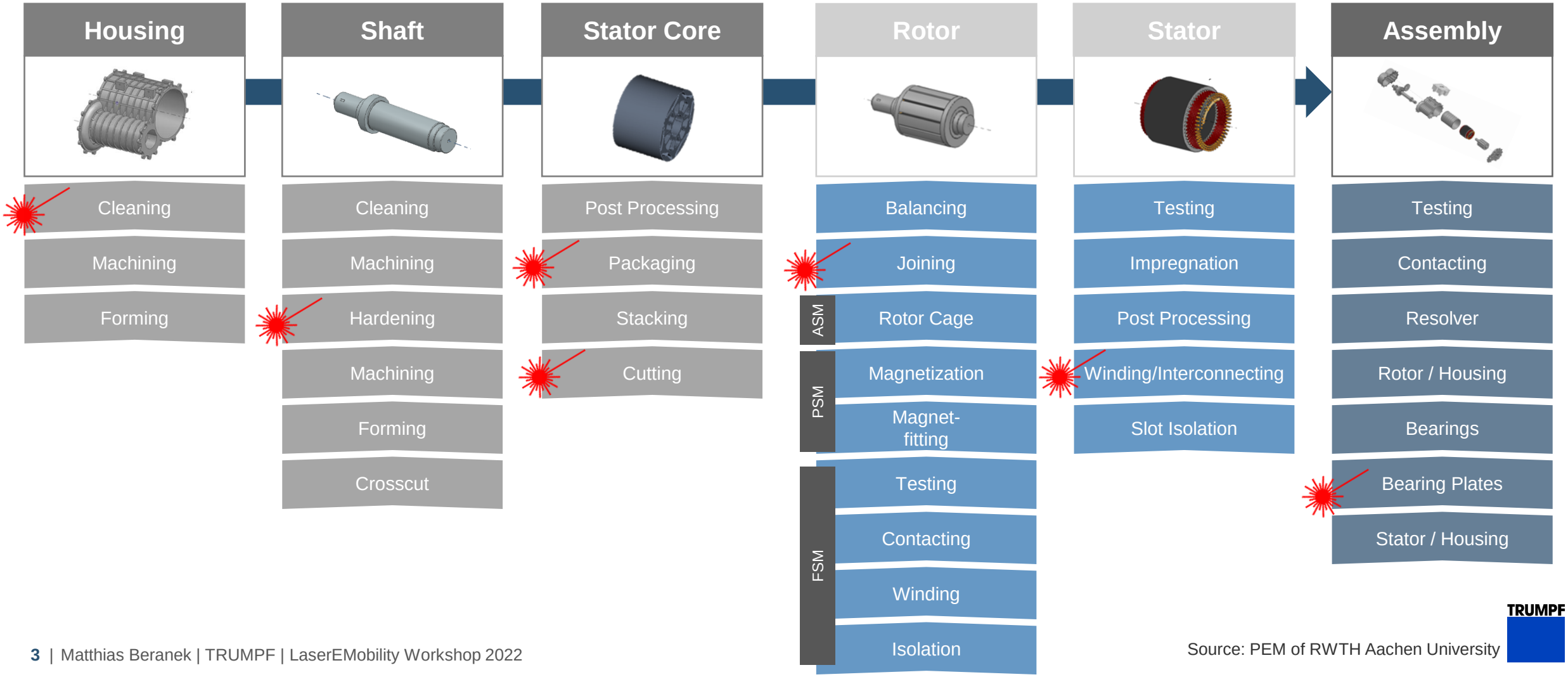
Established and industrialized laser application.

Potential laser application, under development

TRUMPF

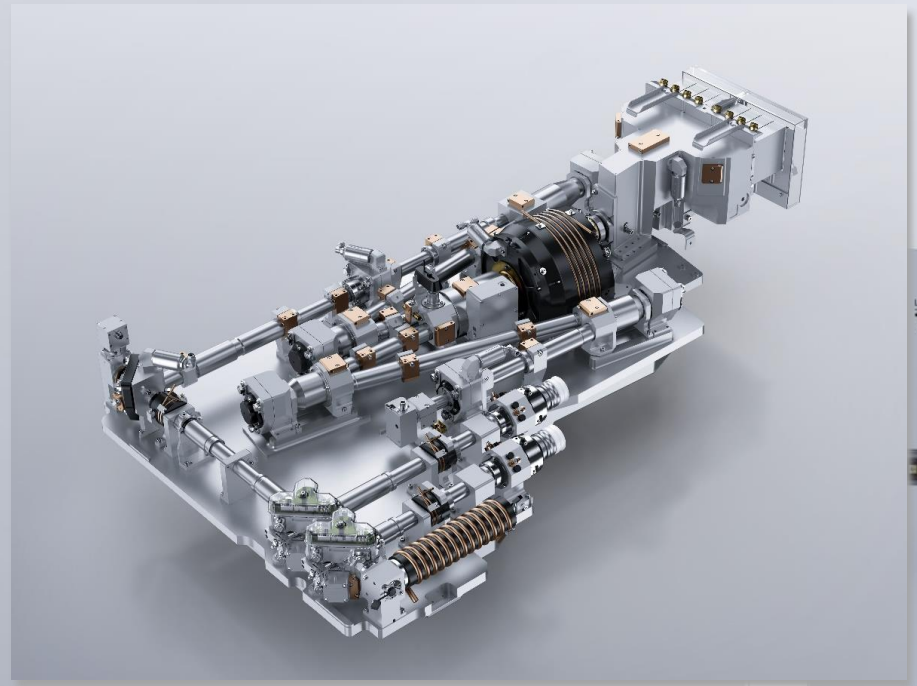
Electric Axle: Production process

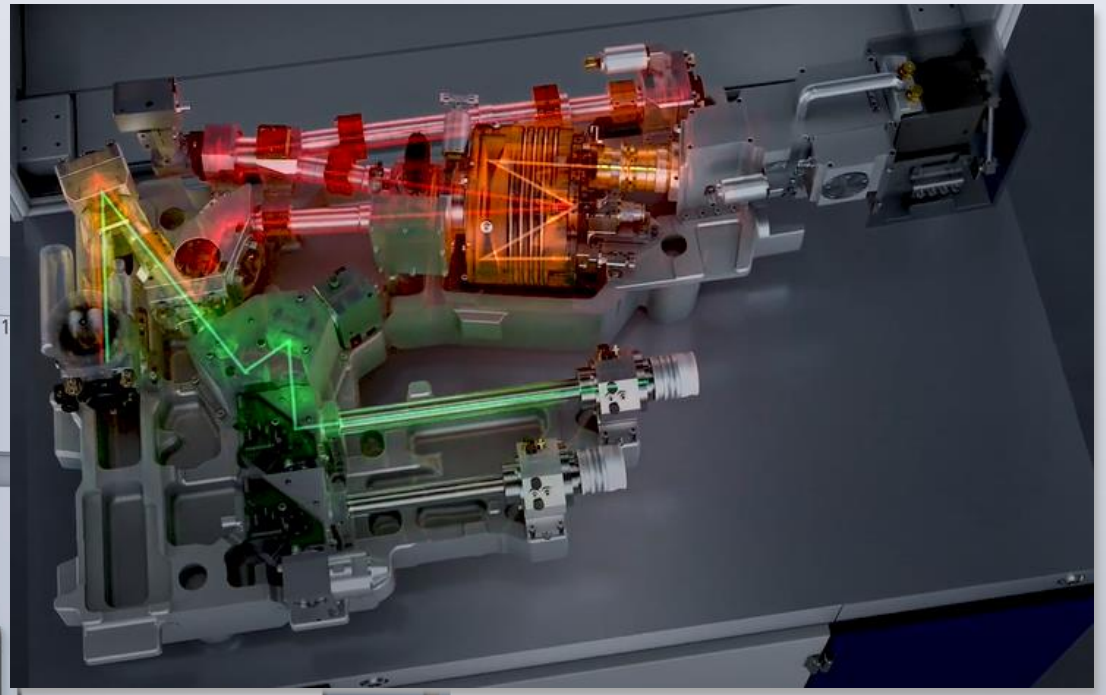
The eDrive production chain offers many possibilities of laser processing

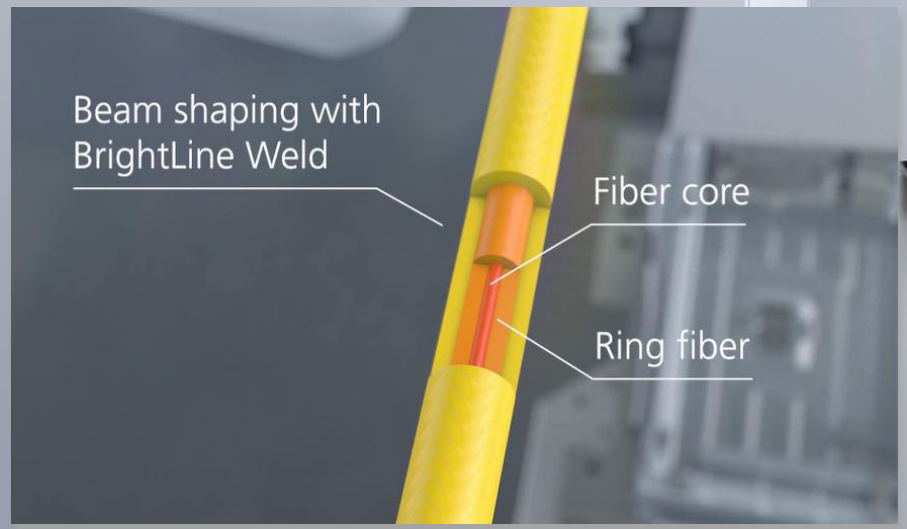


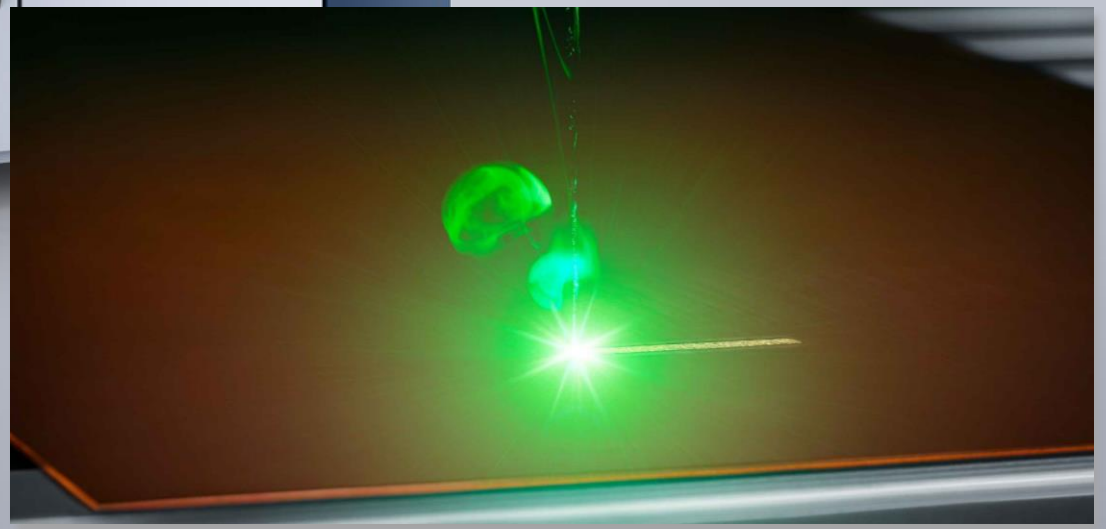
Source: PEM of RWTH Aachen University

Lasertechnologies for E-Mobility










TRUMPF
Laser Application Centers
(Picture from public event)
Ditzingen & Dunningen (GER)
Shanghai/Taicang (CN)
Detroit & Santa Clara (USA)
Yokohama (JP)
Seoul (KR)

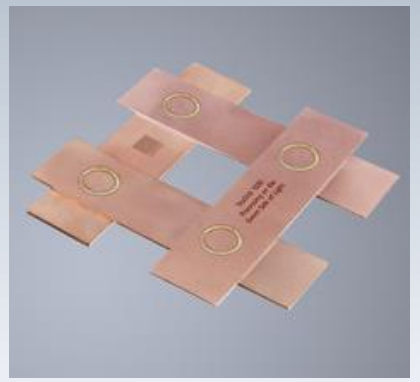
Green Wavelength Lasers utilizing the Multi Spot Technology

Examples of applications areas for TruDisk 3022 Green Laser

Battery cells
foil Stack welding

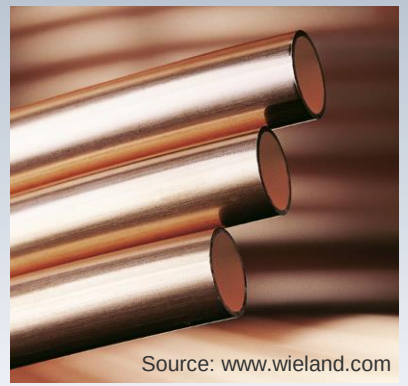
Preferred solution:
TruDisk 2021/3022

Power distribution
busbar welding

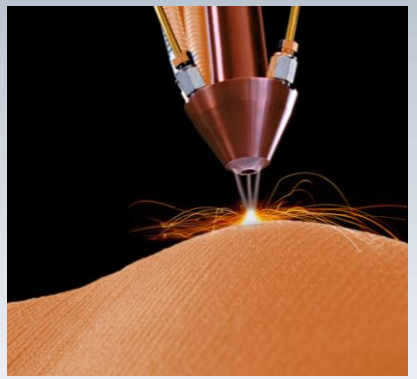


Power electronics
contact welding

General industry
high finish & tight welds



LMD
copper based alloys



Unsurpassed performance in heat conduction copper welding

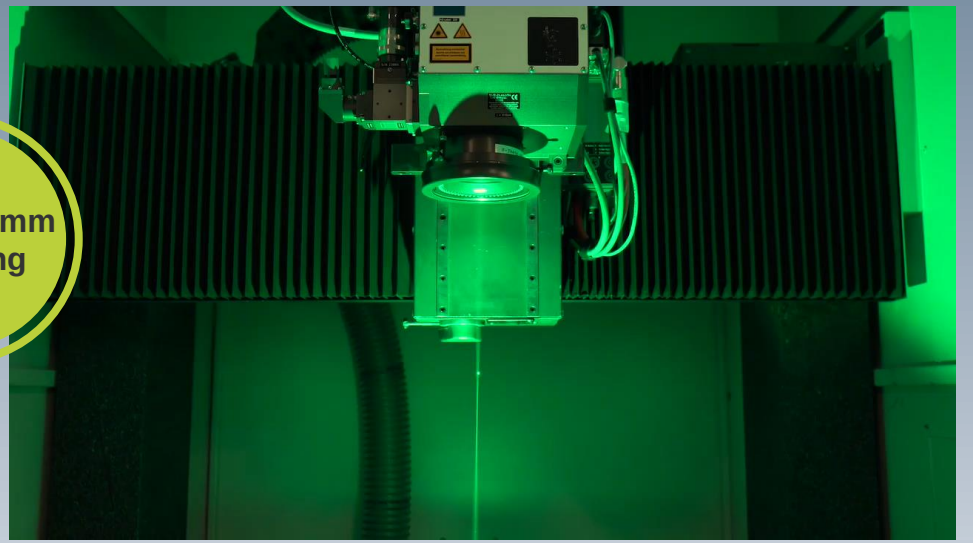
TRUMPF

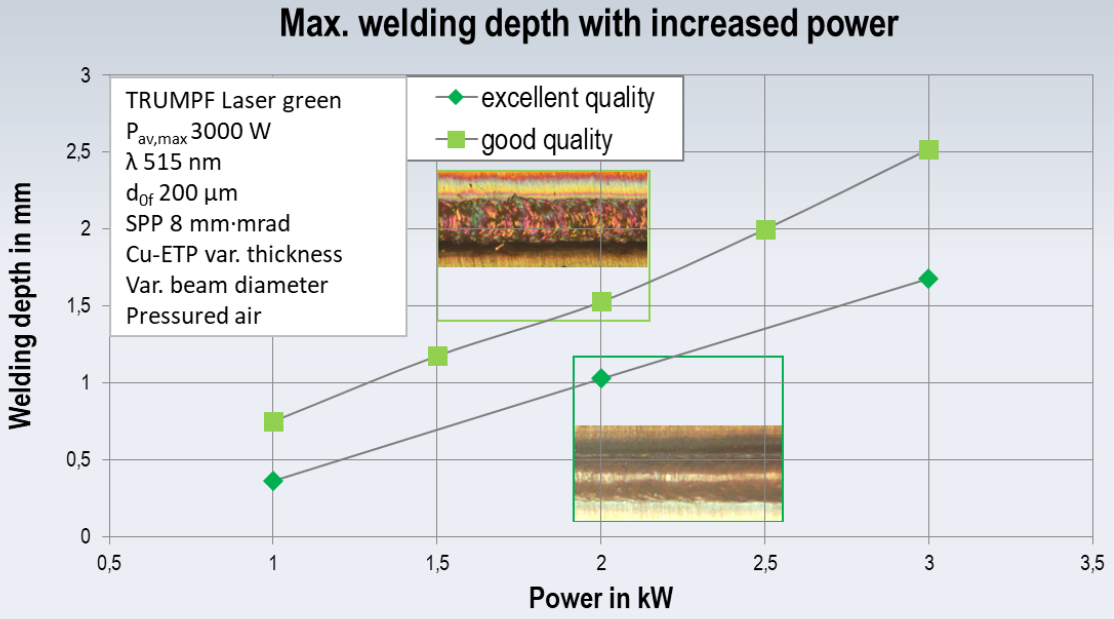
Copper welding with TruDisk 3022

High productivity
in remote welding applications

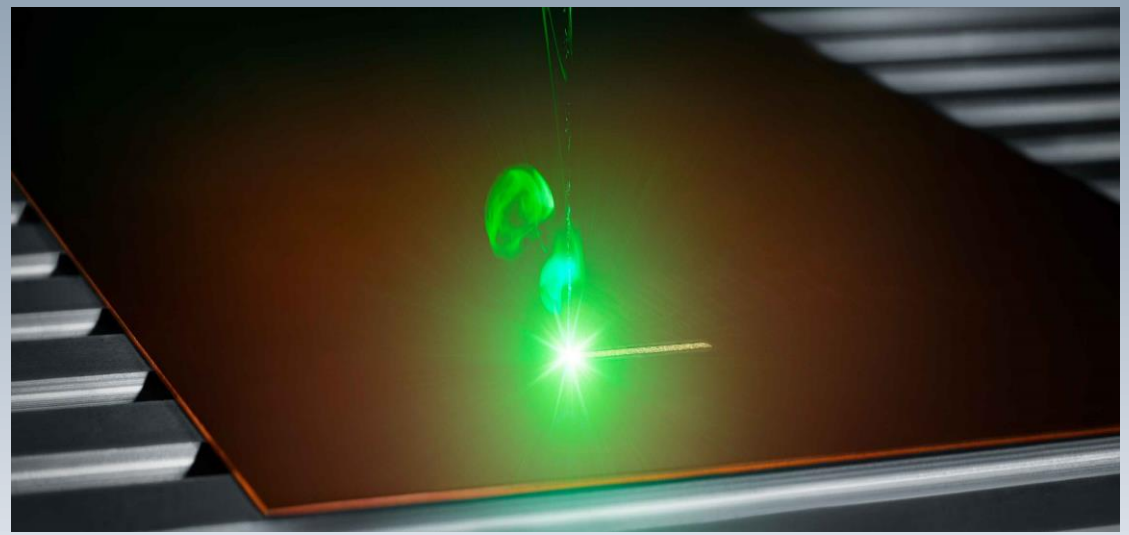
High welding depth
up to 2.5 mm in keyhole welding mode
up to 1.5mm in heat conduction welding mode

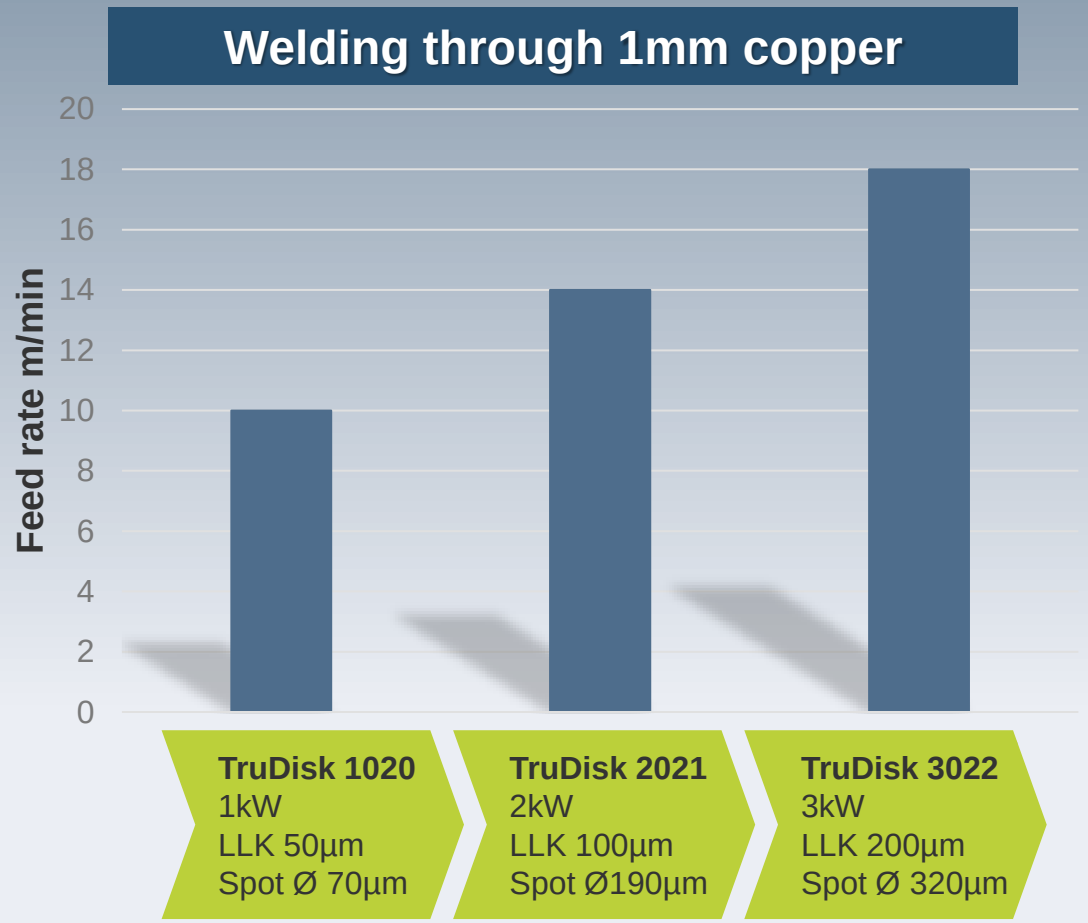
Smooth surface & accurate penetration



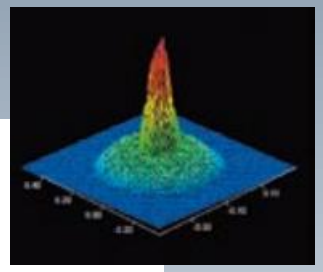


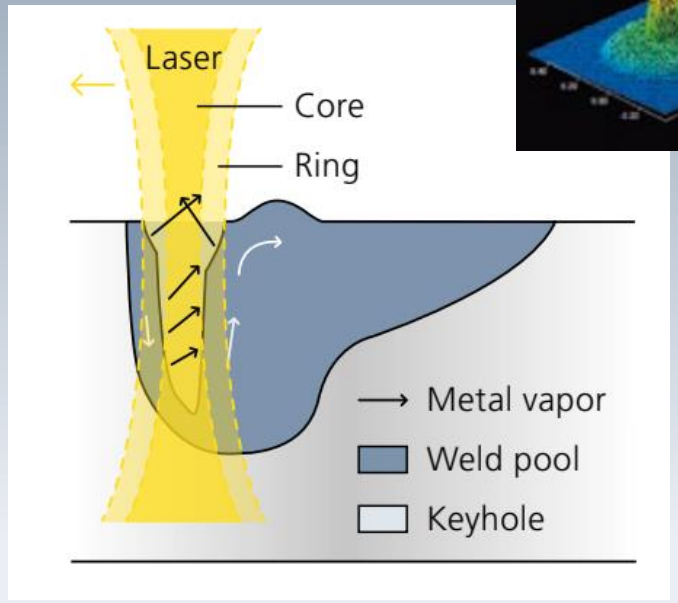
Upscaling productivity



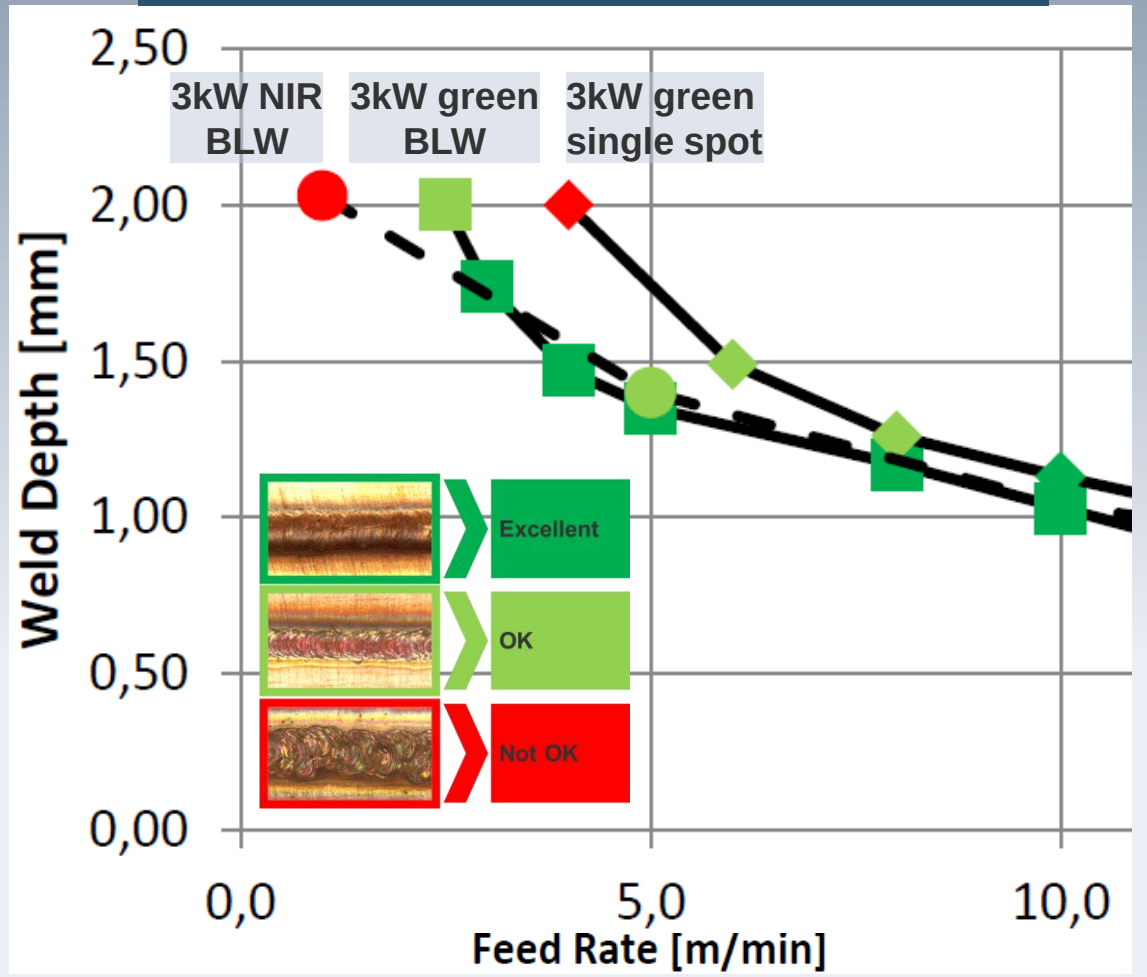


TruDisk 3022 Green with BrightLine Weld





Linear weld on 5mm copper plate



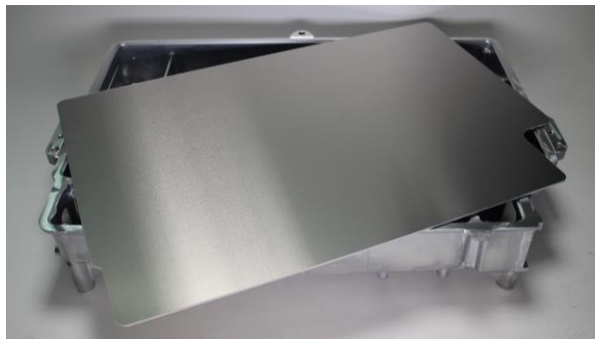
Unsurpassed seam quality

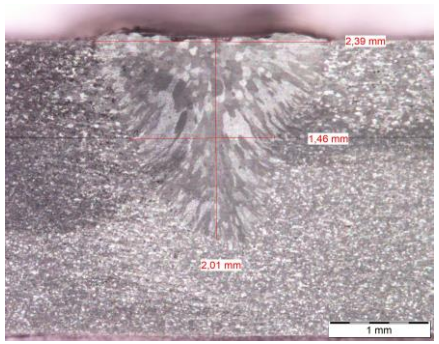
at >1.5mm welding depth in Copper

Infrared Bright Line Weld Lasers - Multispot

Innovative approach with patent pending MultiSpot Optics for tailored keyhole dynamics for high productivity and tight welds

Microsections of Overlap Joints





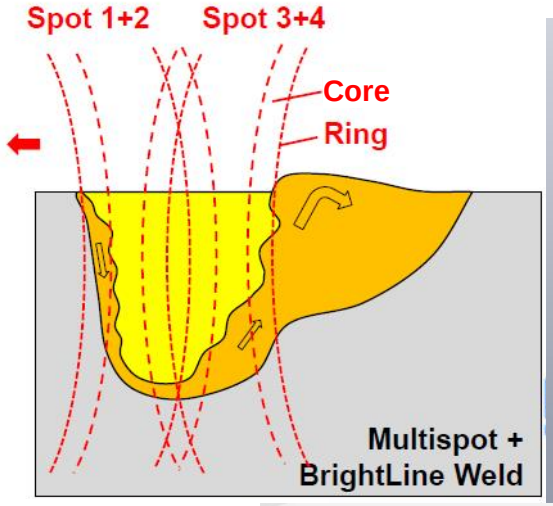
Upper sheet metal 1 mm

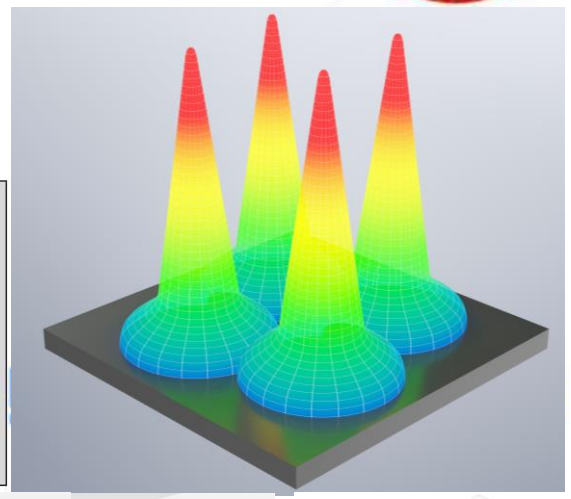
Overlap laser weld seam

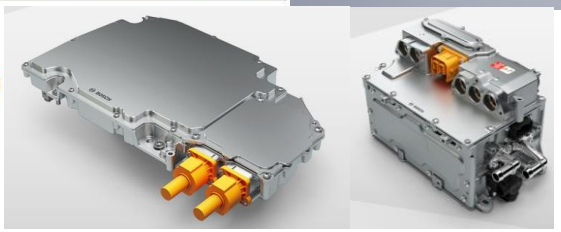
Lower sheet metal t = 2 mr

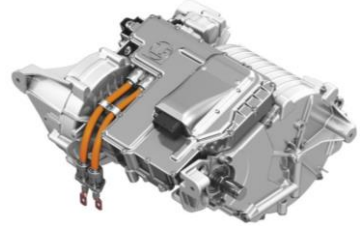
PASSED

Helium Tightness test









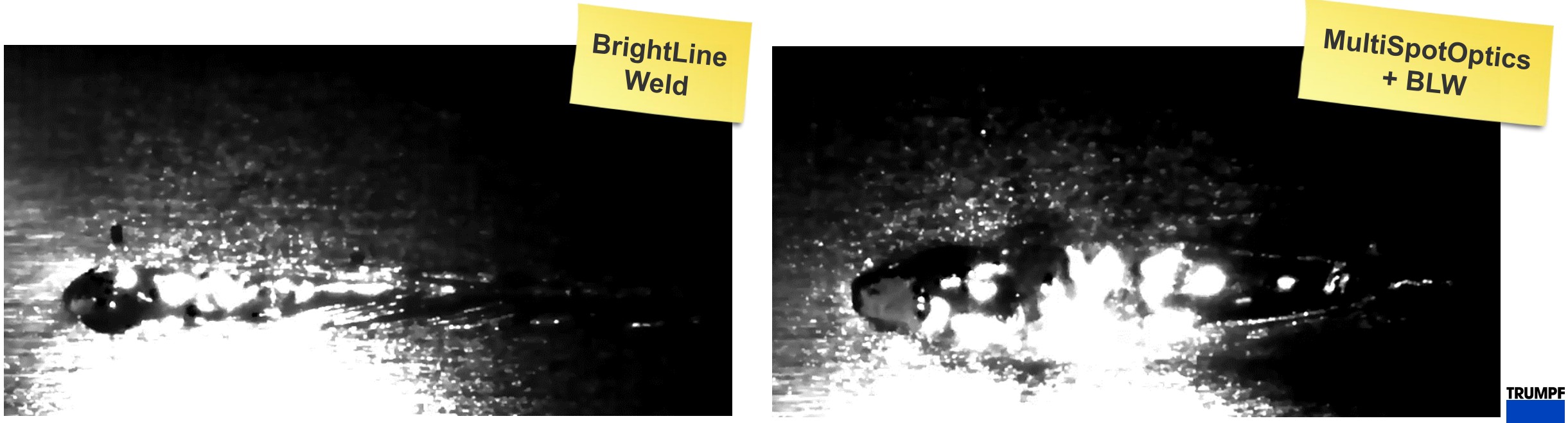
TRUMPF

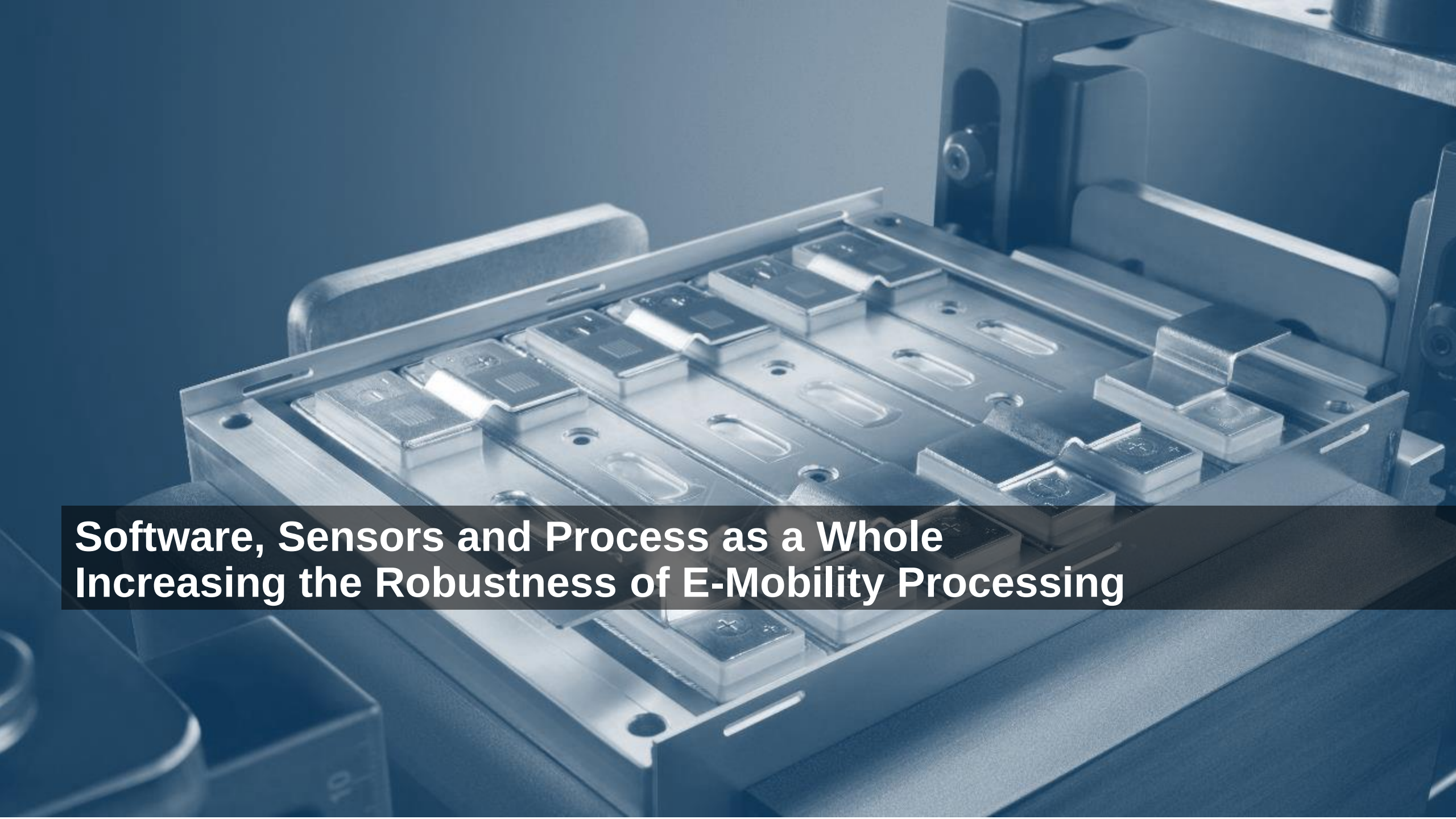
MultiSpotOptics for realization of gastight weld seams by stabilization of the keyholes

- **Higher process stability**
  - Less process pores
  - Less spatters
  - Mitigation of crack formation

Stabilized Keyhole by MultiSpotOptics-Technology

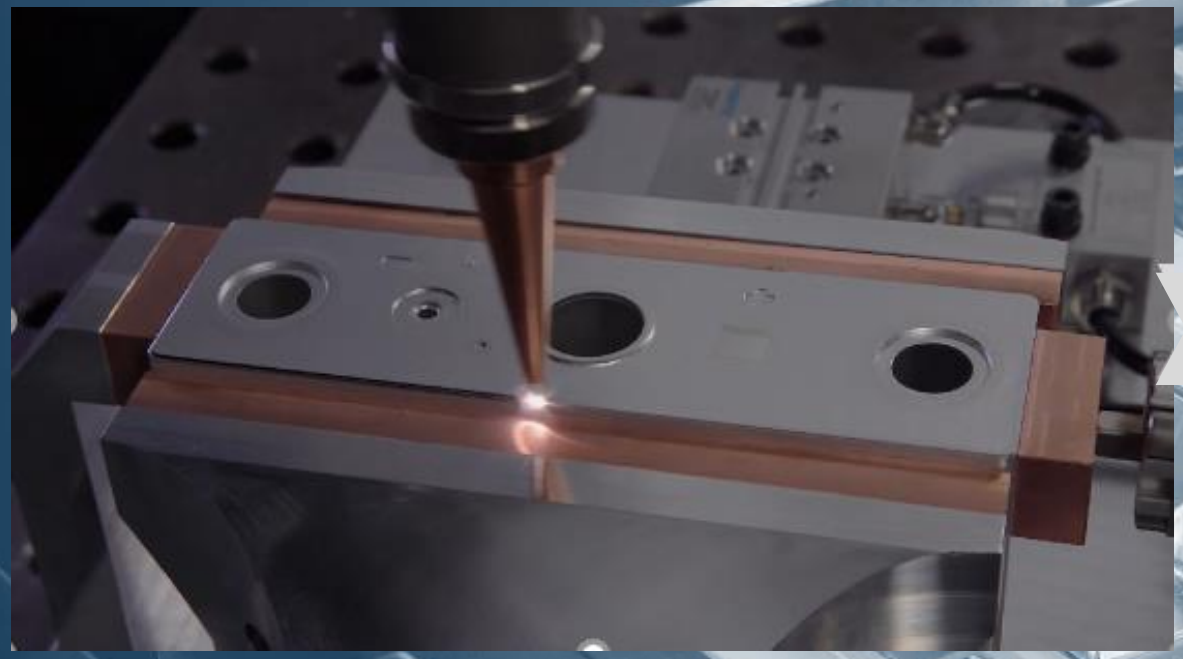
→ Realization of gastight weld seams





Software, Sensors and Process as a Whole Increasing the Robustness of E-Mobility Processing

Can-Cap Welding



Weld Speed 150 mm/s
Recent Approach

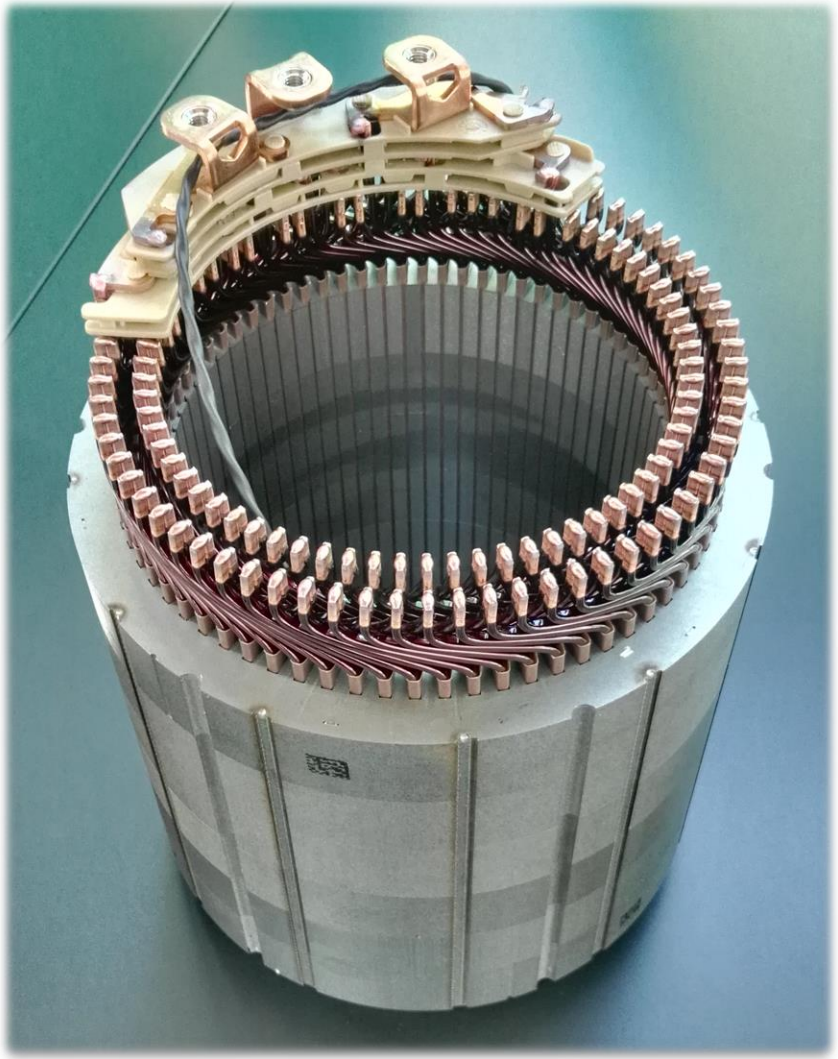
Weld Speed >450 mm/s
Next Generation

Same Weld Depth

HAIRPIN CONTACTING

LASER WELDING with Bright Line Weld Multi-Spot Technology

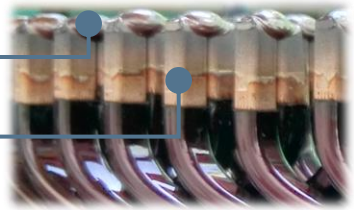
Overview of eDrive Laser Applications



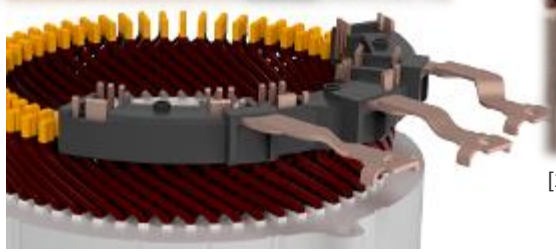
Hairpin Contacting

Hairpin Welding

Hairpin Decoating



Phase Connectors / Busbars

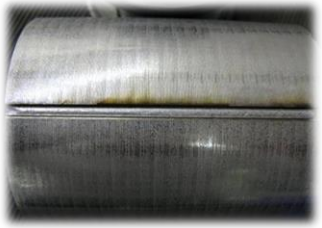


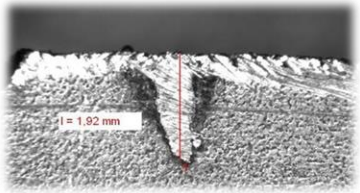
[2]

[1]

Wide Range of Connection Designs
Point-to-Point
Rail Systems

Stator Core



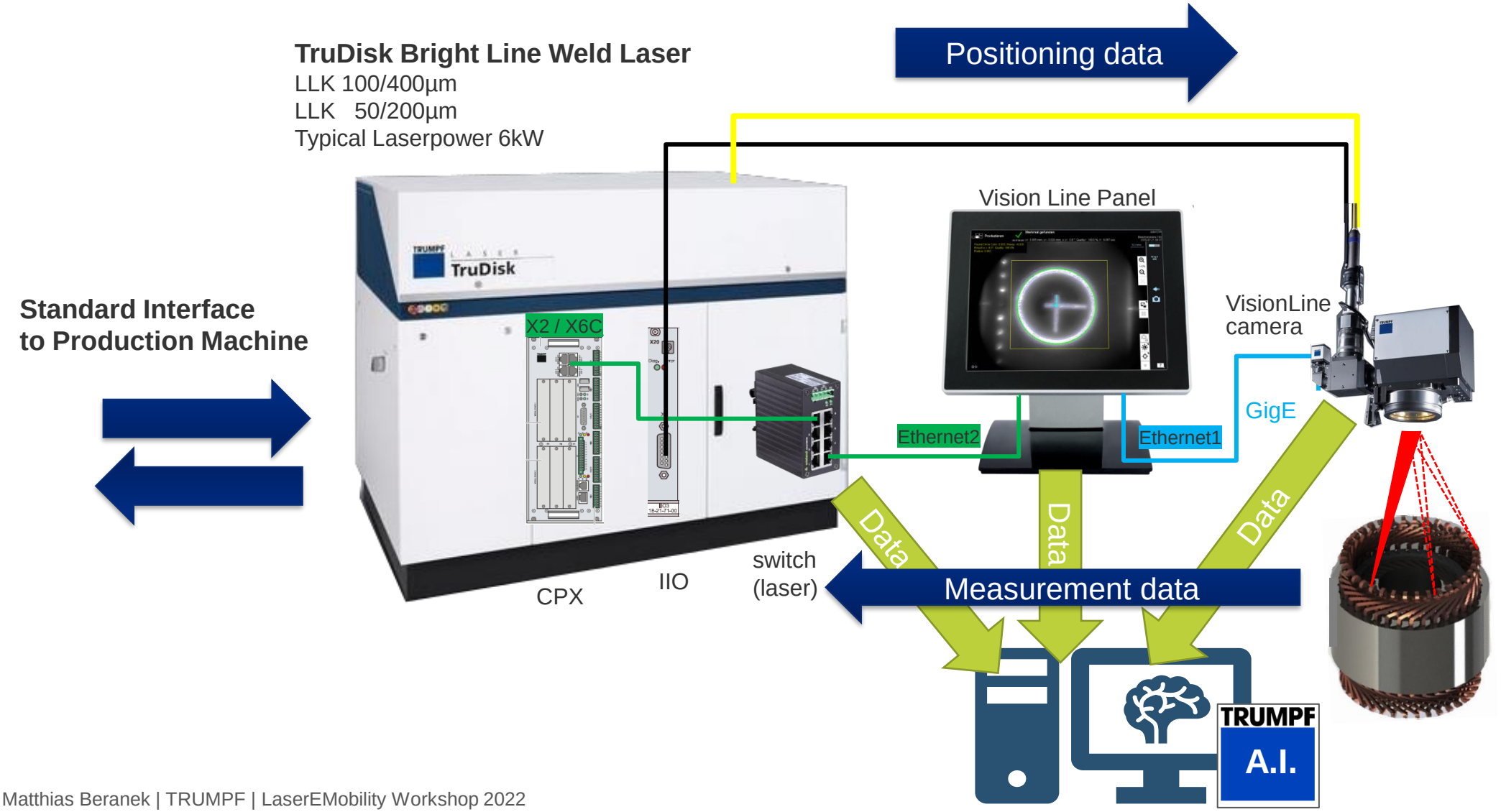


Position Seam Welding

[1] https://www.electricmotorengineering.com/files/2021/07/zeiss.jpg
[2] New-Generation E-Mobility Traction Motor Stators are Enabled by Advanced Busbar Technologies – Power by Interplex

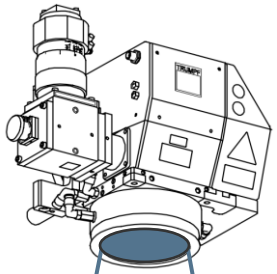
Solution Bundle for Hairpin Laserwelding

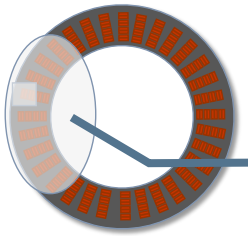
State of the Art Process Control



Basic Aspects of different Setups for Hairpin Welding

Welding Setup Scalability





Elliptical Working Field
of Optics in a static position

Spotsize Core	**95µm**
Weld Intensity*	**up to 100 MW/cm²**

Shortest Welding Times

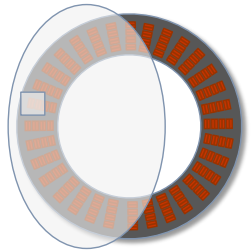
Lowest Energy input and Heat generation

4-10mm²
Fusion Area

50µm/200µm

50µm-Lasers
1kW - 8kW

F=265



Larger working area
- Enables optimized processing sequences
- Mechanical positioning operations can be reduced

Welding Time
25 to 200ms

Function of Weld Volume, Wire Section

F=450

Spotsize Core	**161µm**
Weld Intensity*	**up to 35 MW/cm²**

>10mm²
Fusion Area

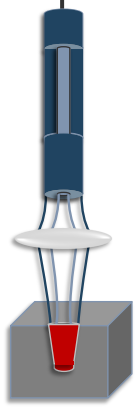
Schematic not to scale

F - Focusing Length [mm]

***Example P=8kW, BrightLine Mode**

Benefits of Bright Line Weld | All Copper Grades

Enables significant Spatter & Porosity Reduction



Powershare Core [%]

EST= Welding Depth

100 %	90 %	80%	70%

Maximum value pictures from highspeed videos show ‘spatter traces’

Weld process zone (plasma)

Radiograph (Weld)

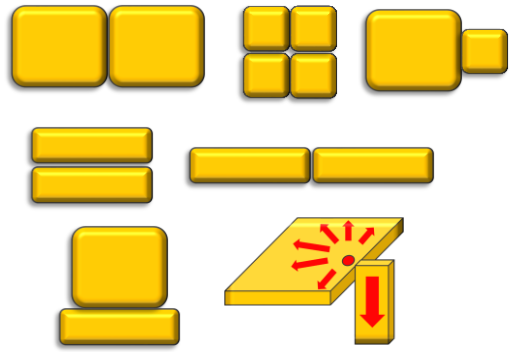
60%	50 %	40 %	30 %	20 %

Identical Melting Volume at all welds

Selection Criteria for different Setups for Hairpin Welding

Multiple boundary condition influences need to be covered

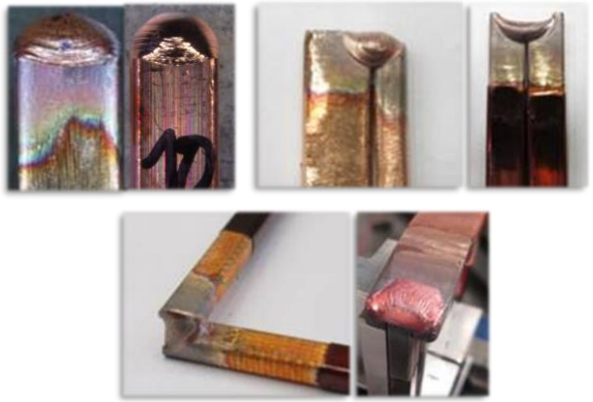
Wire Arrangement



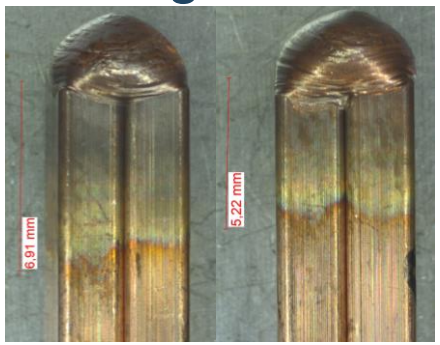
Expected Heat and Melt flow

Welding Setup

Weld Localization

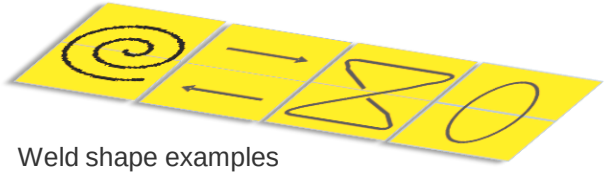


Decoating Limitations

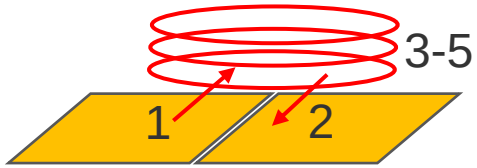


Decoated length and winding head height

Welding Strategy

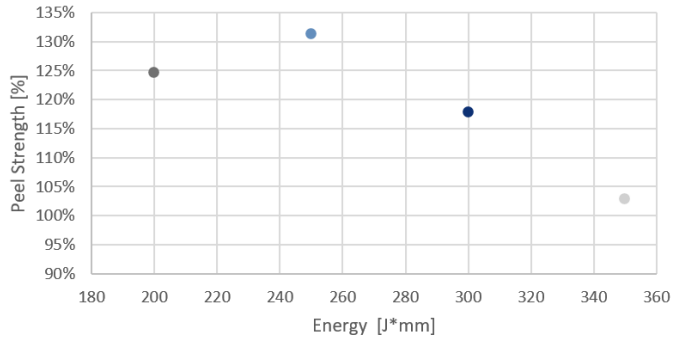


Weld shape examples



Weld sequence example

Joint Strength Strength

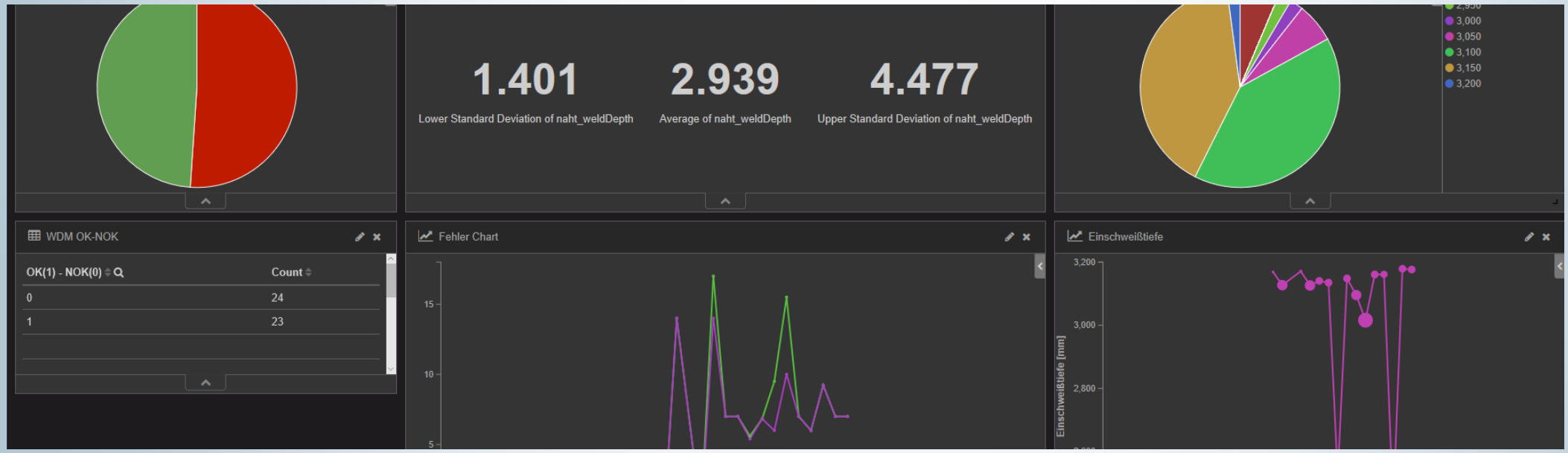


Joint volume determines Energy input

TRUMPF

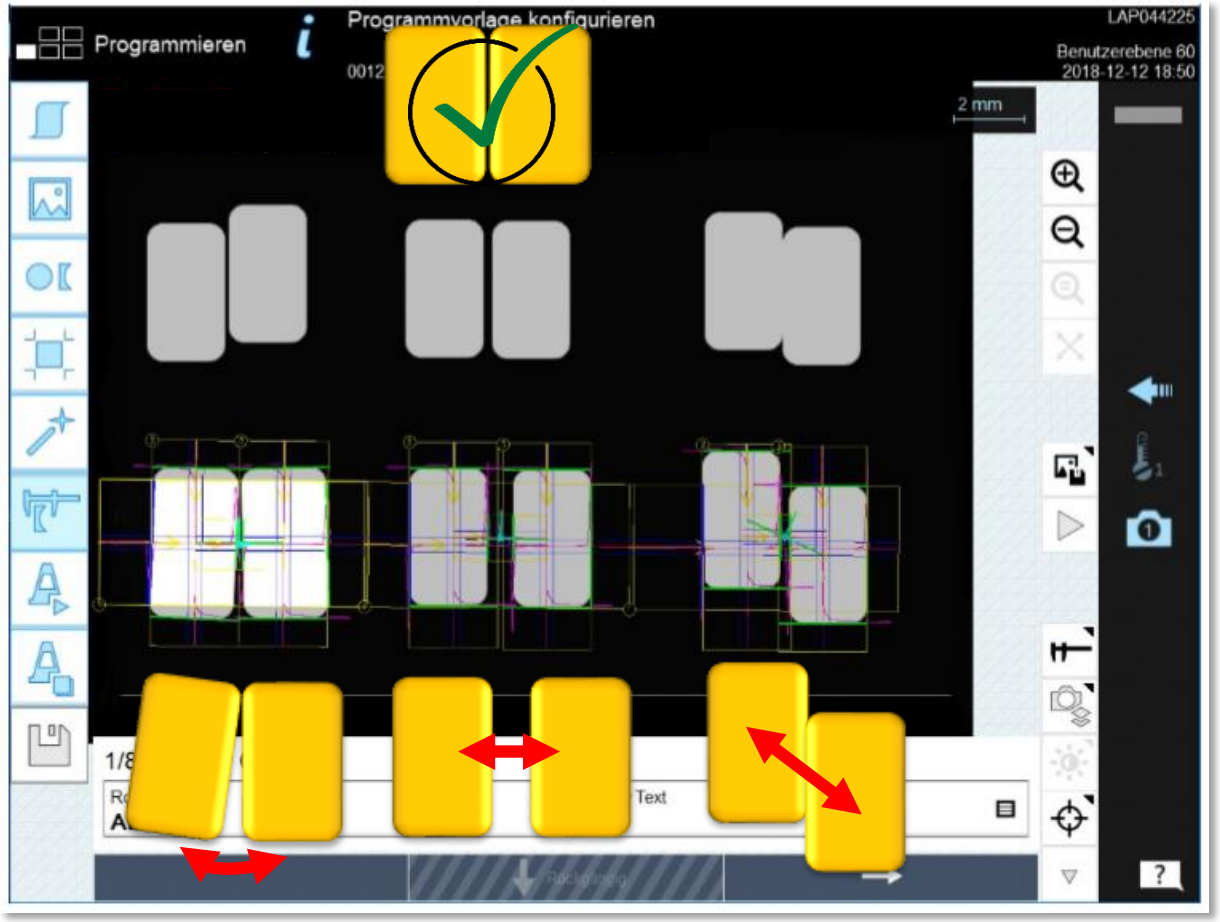
CONTACTING TECHNOLOGY
HAIRPIN DECOATING & WELDING

INTEGRATED SENSOR TECHNOLOGY FOR HAIRPIN WELDING

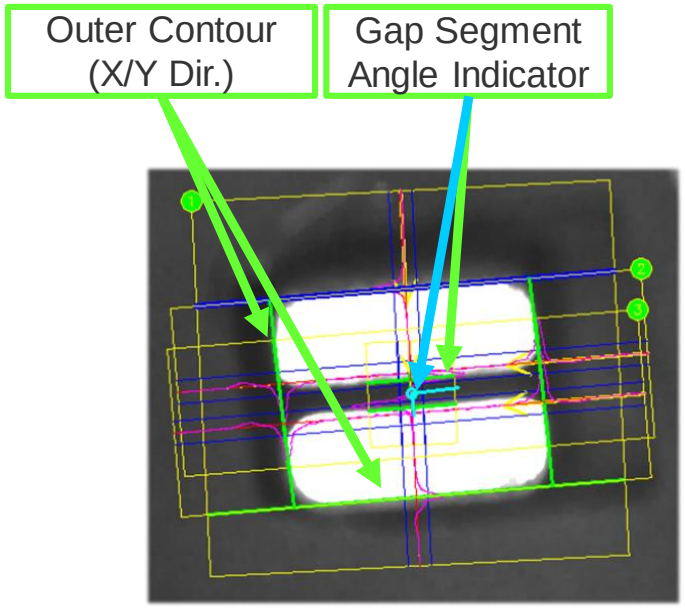


Vision Line for Hairpin Welding

Implemented Measurements

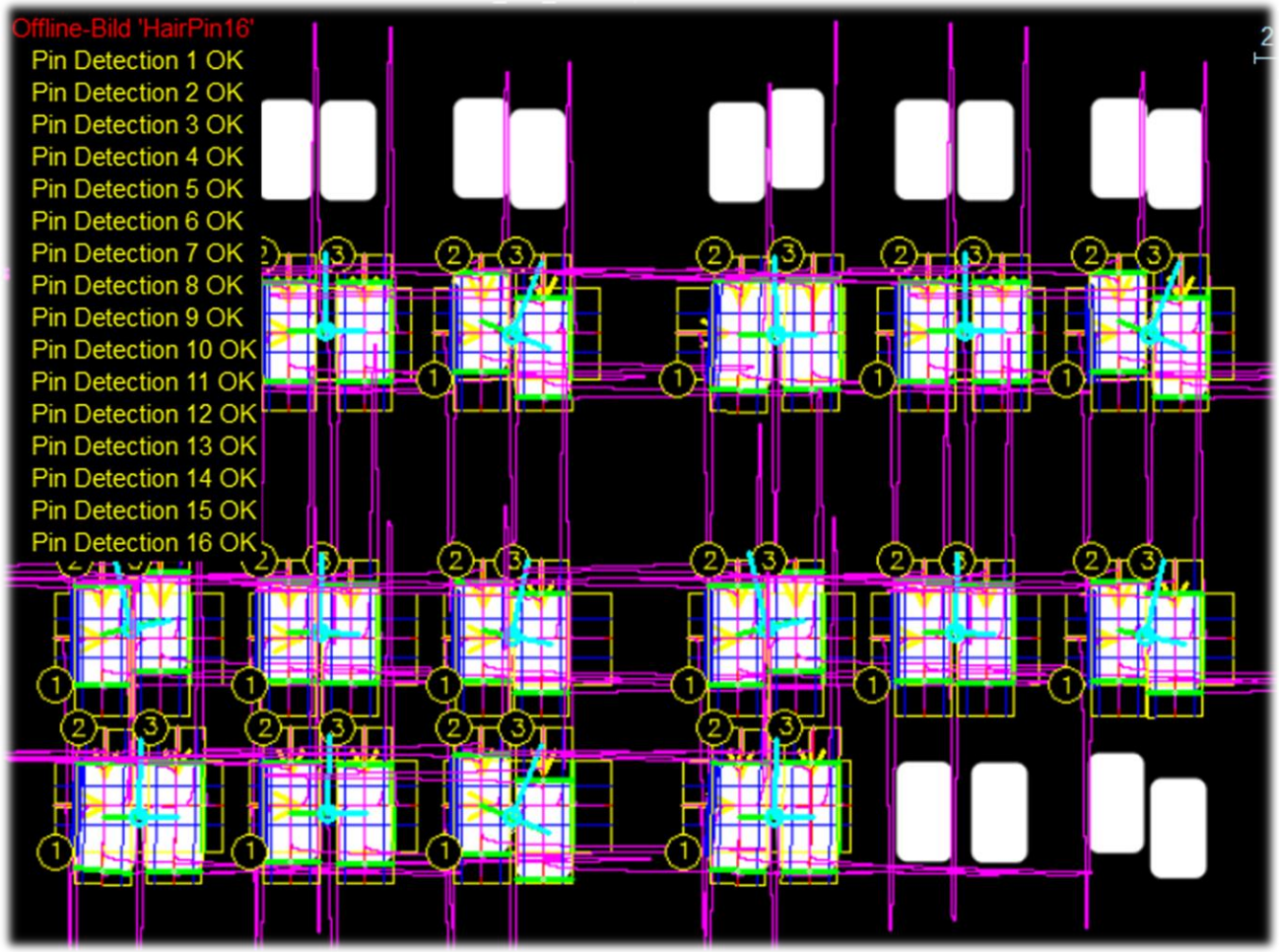


Angle Gap Lateral Offset



Vision Line for Hairpin Welding

Project Layout (Example)



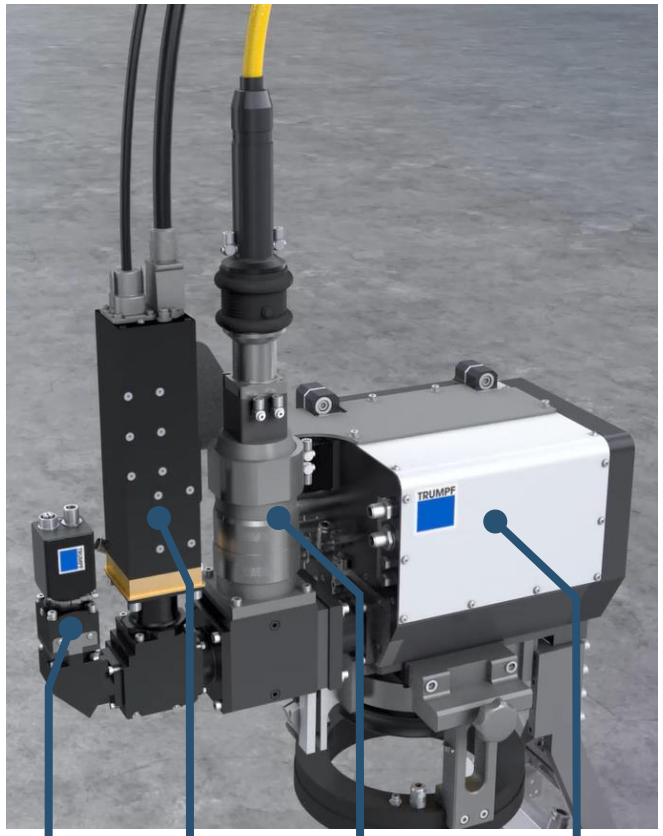
- (Pin-) Group Measurement Strategies
- Boundary- and Cancellation limits adjustable
- Integrated measure quality monitoring
- Database Interface

- Measurement & Processing typ.30-50ms (per Pinpair)

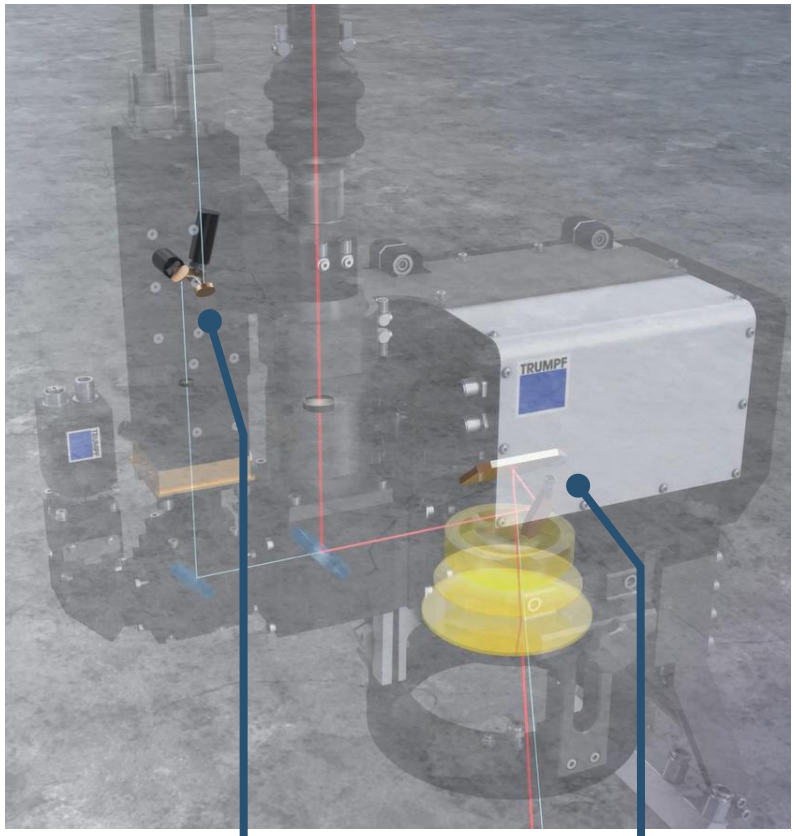
Optical Coherence Tomography 3D Feature Detection

OCT Hardware integrated to Standard Welding Setup

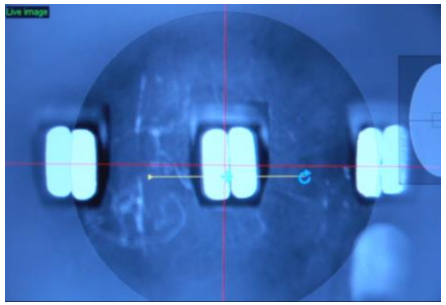
System Components



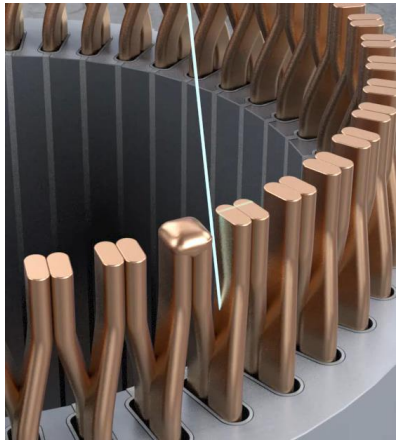
Scanner-in-Scanner Measuring

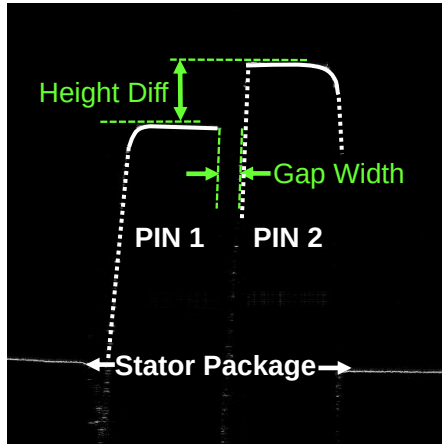


2D Teaching



3D Measurement and result (computed)

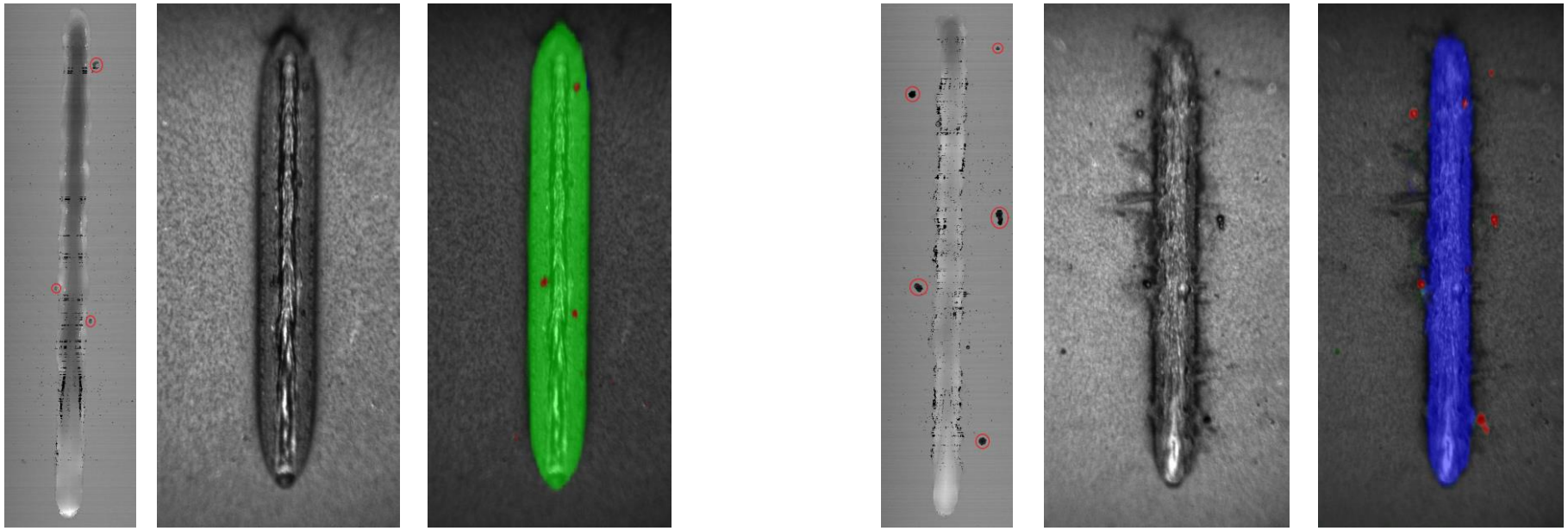




Use of A.I. enables new evaluations

Detection of spatter in e-mobility welding

- **Heat mark measurement**
- **Detection of spatters on the workpiece**
- **Comparison: 2D plus AI VS. 3D (OCT)**

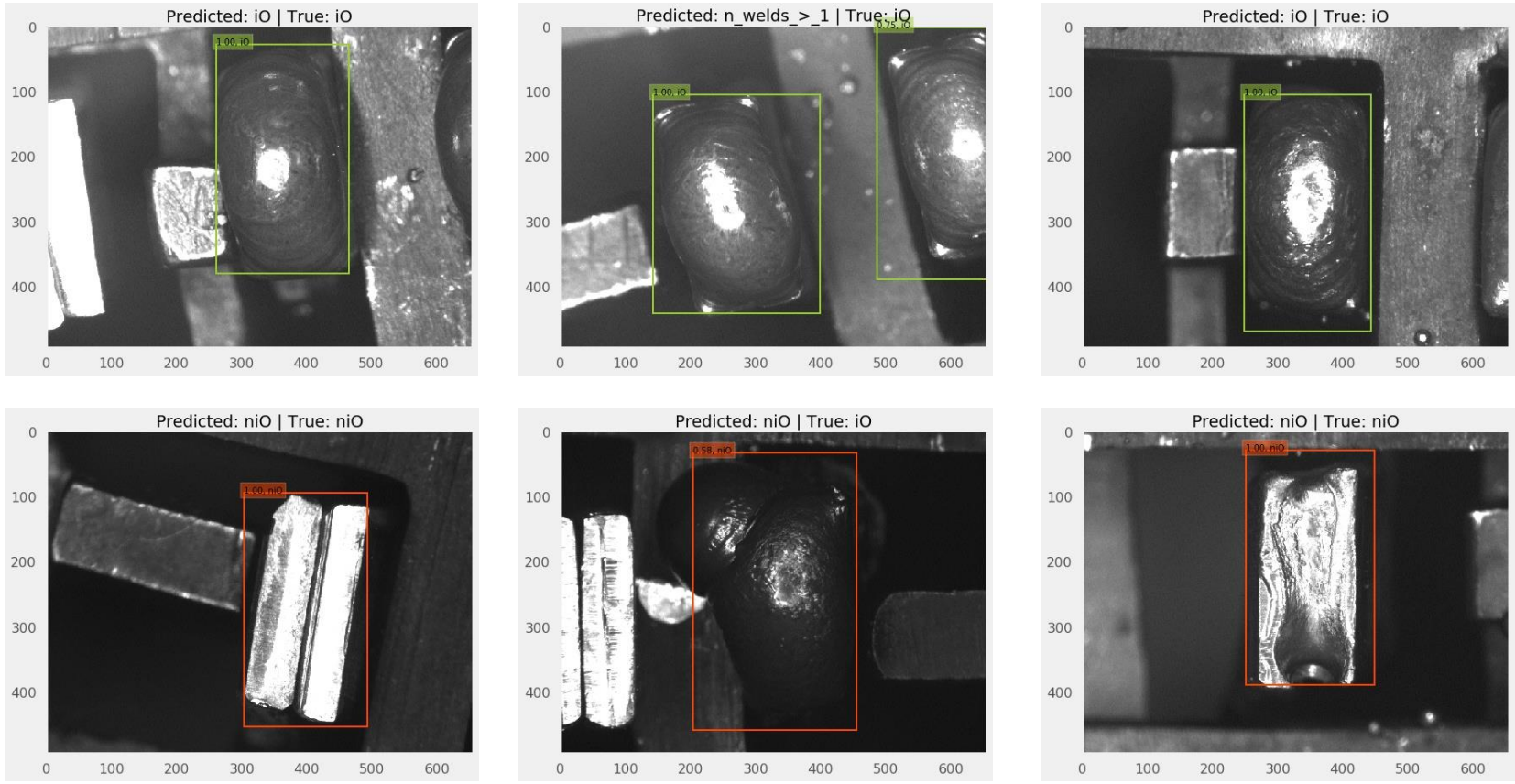


3D 2D Plus AI 3D 2D Plus AI

Use of A.I. enables new evaluations

Hairpin

- **Evaluation**



Active Process Logic: Attach the welding parameters to the measurements

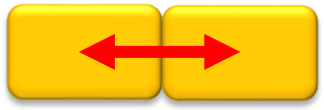
Automated Welding Path Adjustment

Measured Features

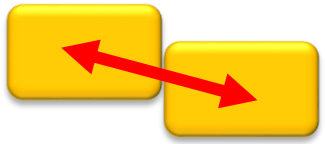
Automated Welding Strategy Adjustment

Part of TruDisk / PFO architecture

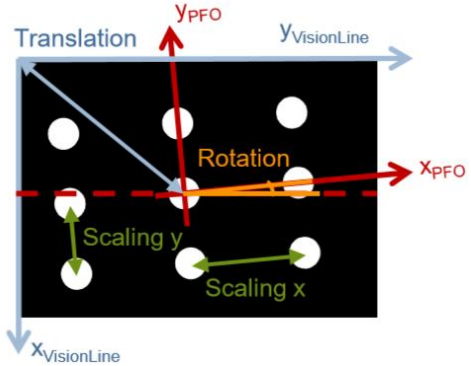
Optimum Welding Path

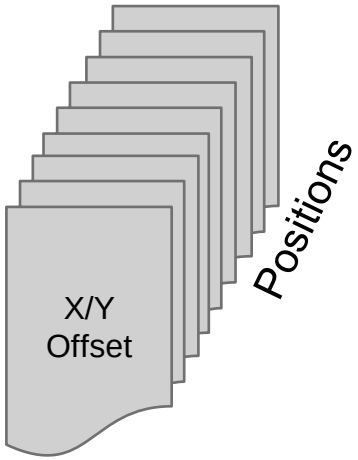


Adjusted Welding Path



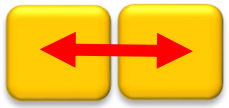
Automated Vector Calculation



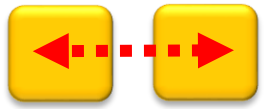


Gap Bridging Strategy

Optimum



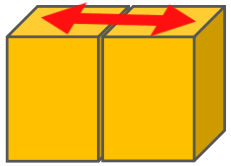
Gap Situation



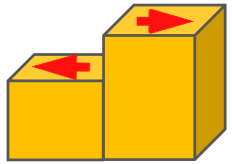
Adapt the welding strategy to bridge gaps
Avoid enamel damage

Levelling of Height Differences

Optimum



Difference in height



Adapt the welding strategy to level height differences
Use extended system hardware OCT and PFO3D optics

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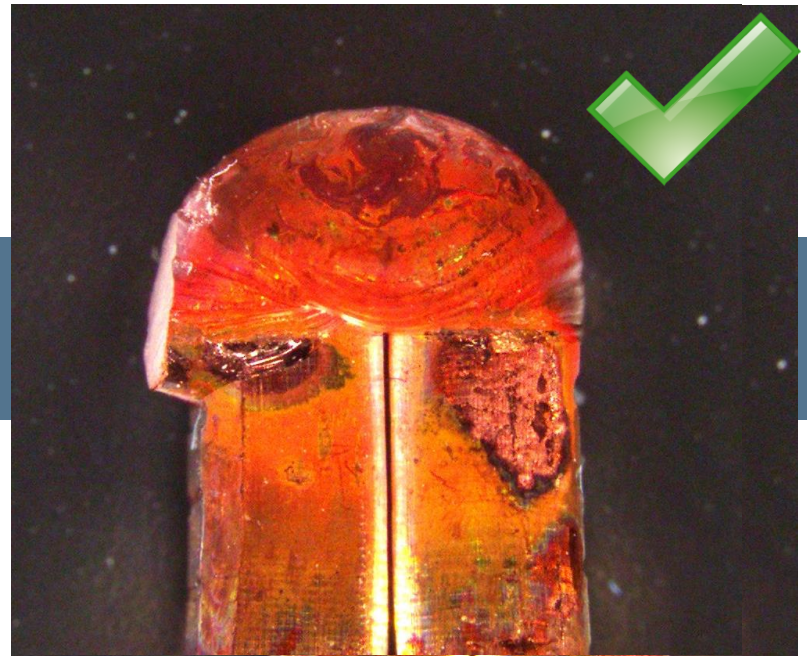
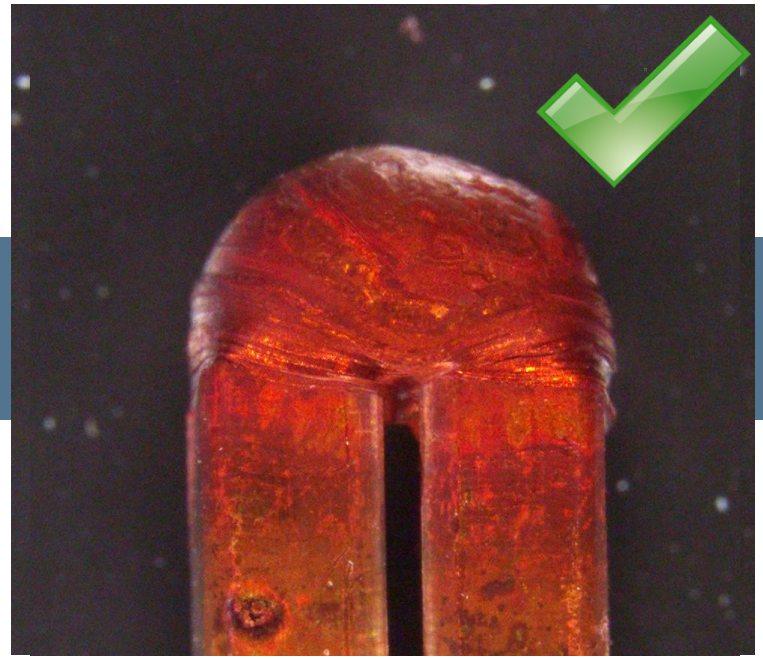
Example: Automated Welding Strategy Adjustment

Zero Gap Condition - Reference



0.5 Gap, no compensation

0.5 Gap, compensated



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