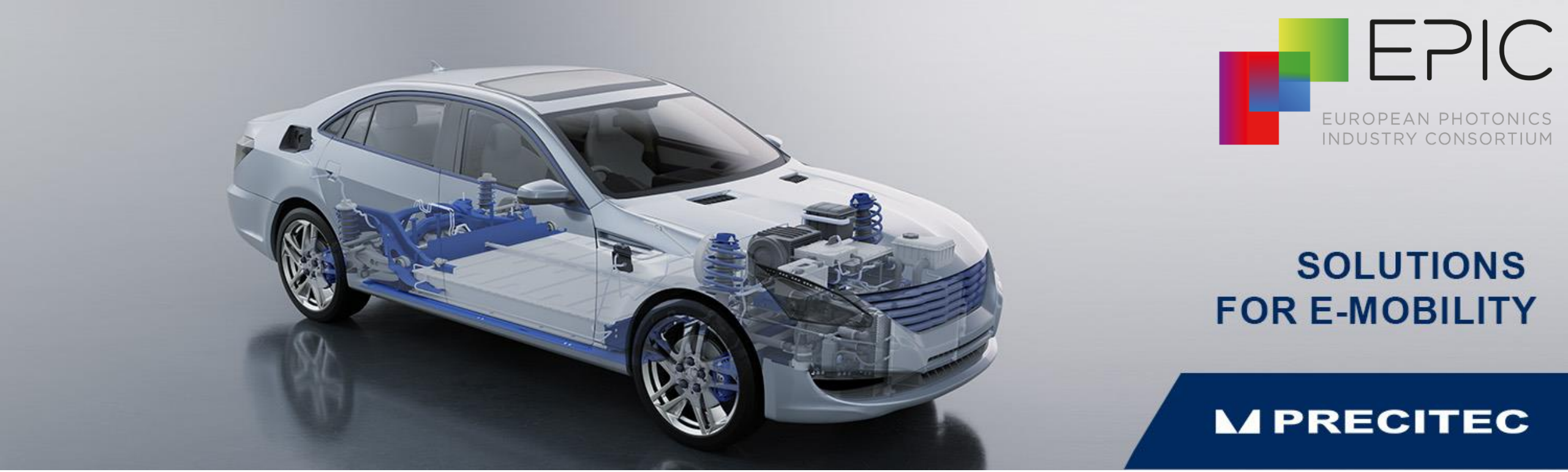


BEAM SHAPING, PROCESS MONITORING AND AI – SUCCESSFUL TEAMWORK FOR LASER BEAM WELDING IN E-MOBILITY

EPIC Online Technology Meeting on Industrial Laser Processes for Automotive and Electro Mobility, October 21, 2024, Dr. Markus Kogel-Hollacher

ELECTRIFICATION CONTINUES TO GROW

- As COVID-19 hammers the auto industry, electric cars remain a bright spot
- According to IEA EV's are set to take a record share of overall market in 2020 and government policy responses to the crisis could accelerate the transition to electric cars

Figure 1: Global annual passenger vehicle sales by drivetrain

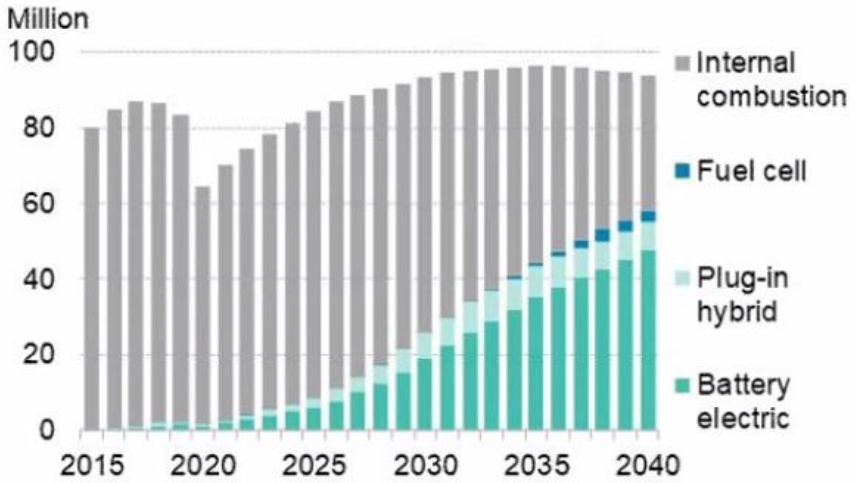
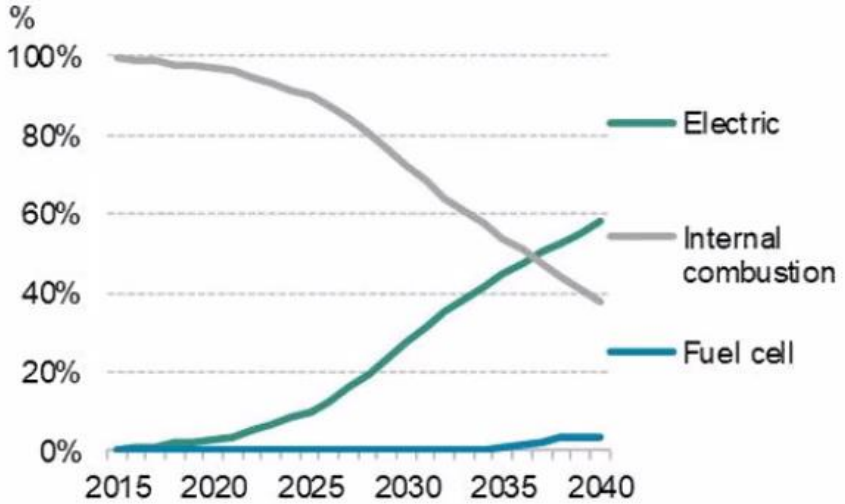


Figure 2: Global share of total annual passenger vehicle sales by drivetrain



Source: BNEF. Note: Electric share of annual sales includes battery electric and plug-in hybrid. June 2020

MARELLI

*IEA International Energy Agency

PRECITEC

ELECTRIFICATION CONTINUES TO GROW

Bildquelle: STILL GmbH

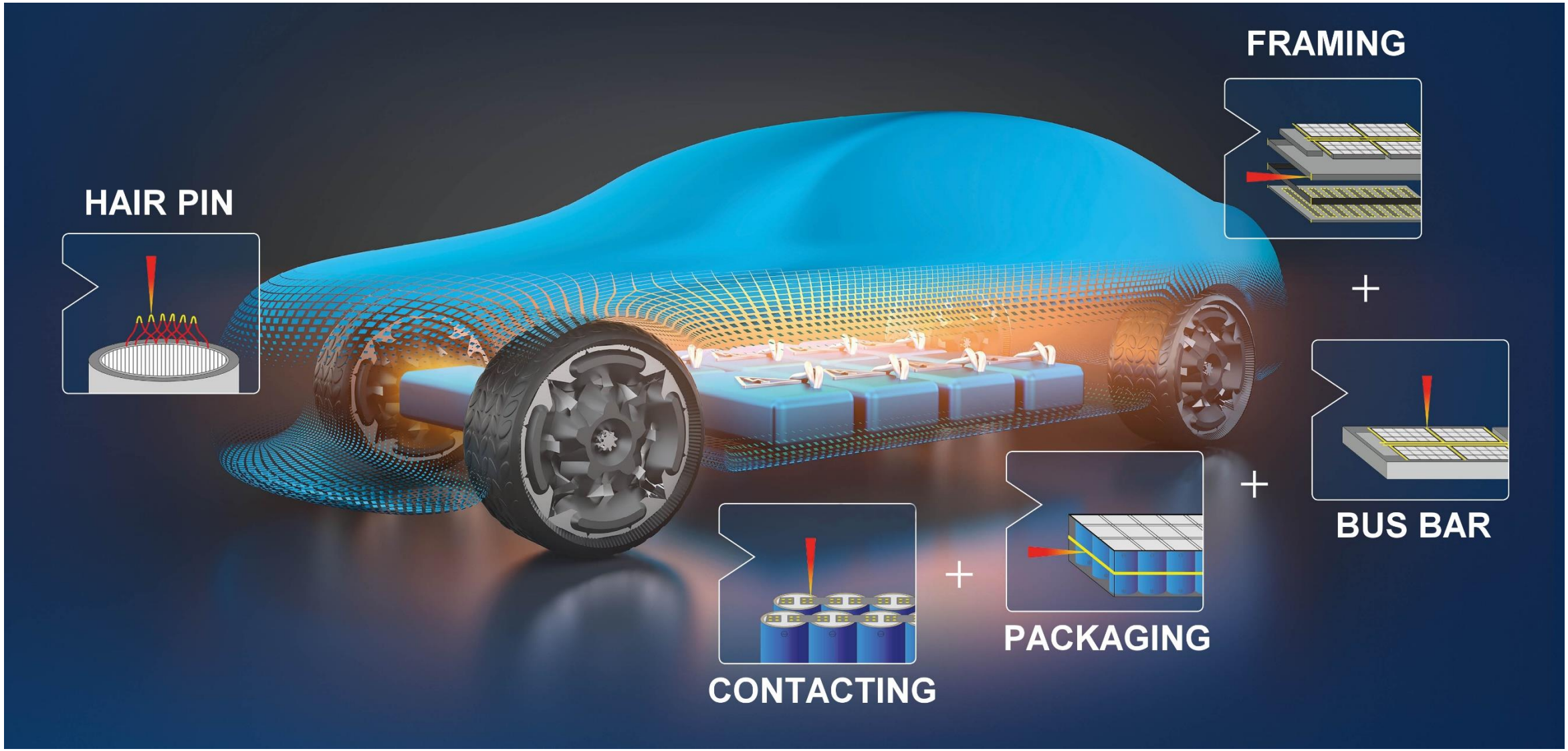
PRECITEC

ELECTRIFICATION CONTINUES TO GROW

KION Battery Systems builds approx. 12,000 batteries per year for mobility in intralogistics

Bildquelle: KION Group

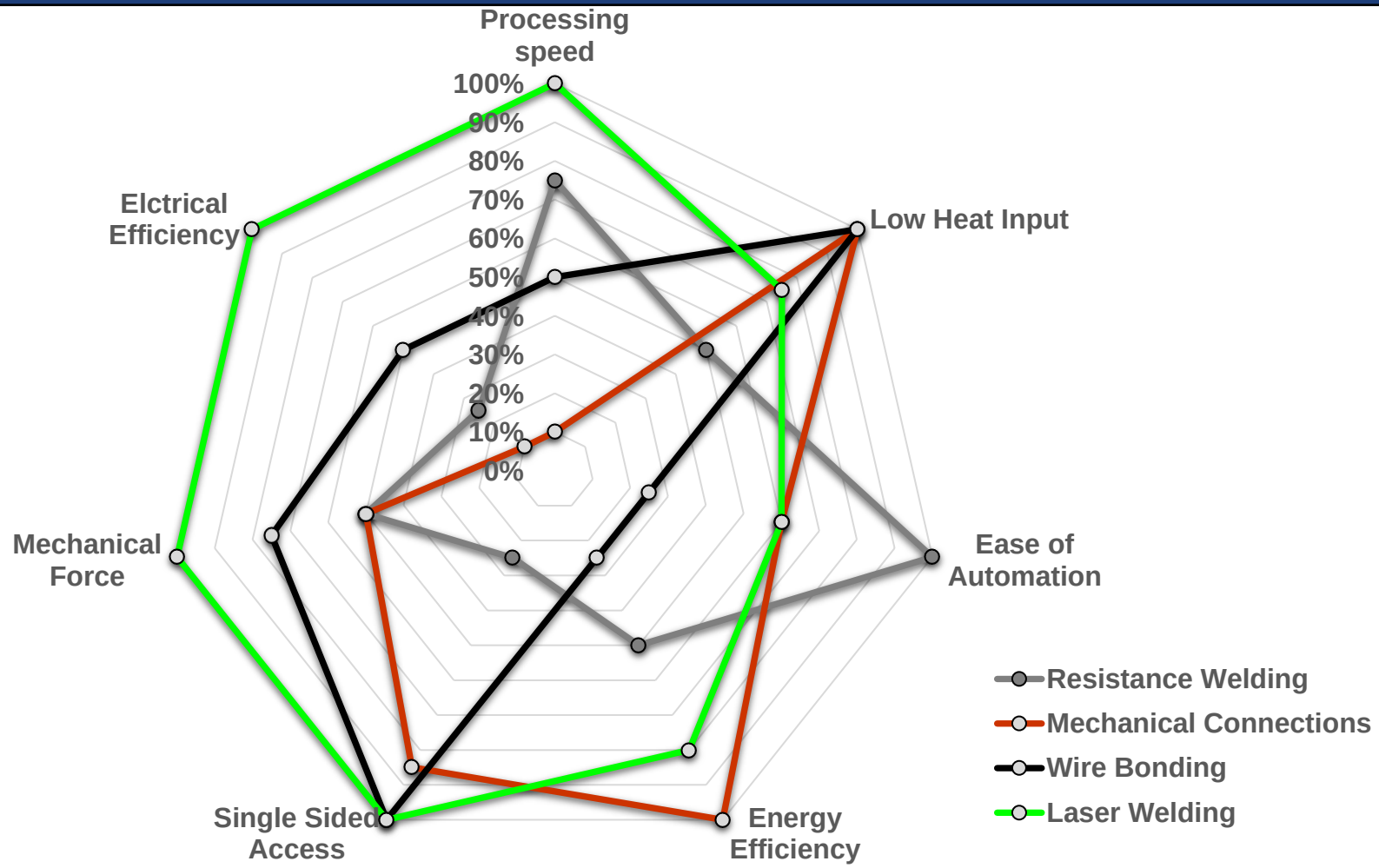
LASER WELDING SOLUTIONS FOR E-MOBILITY



THE LASER AS THE TOOL OF CHOICE

Key advantages for laser welding electrical contacts

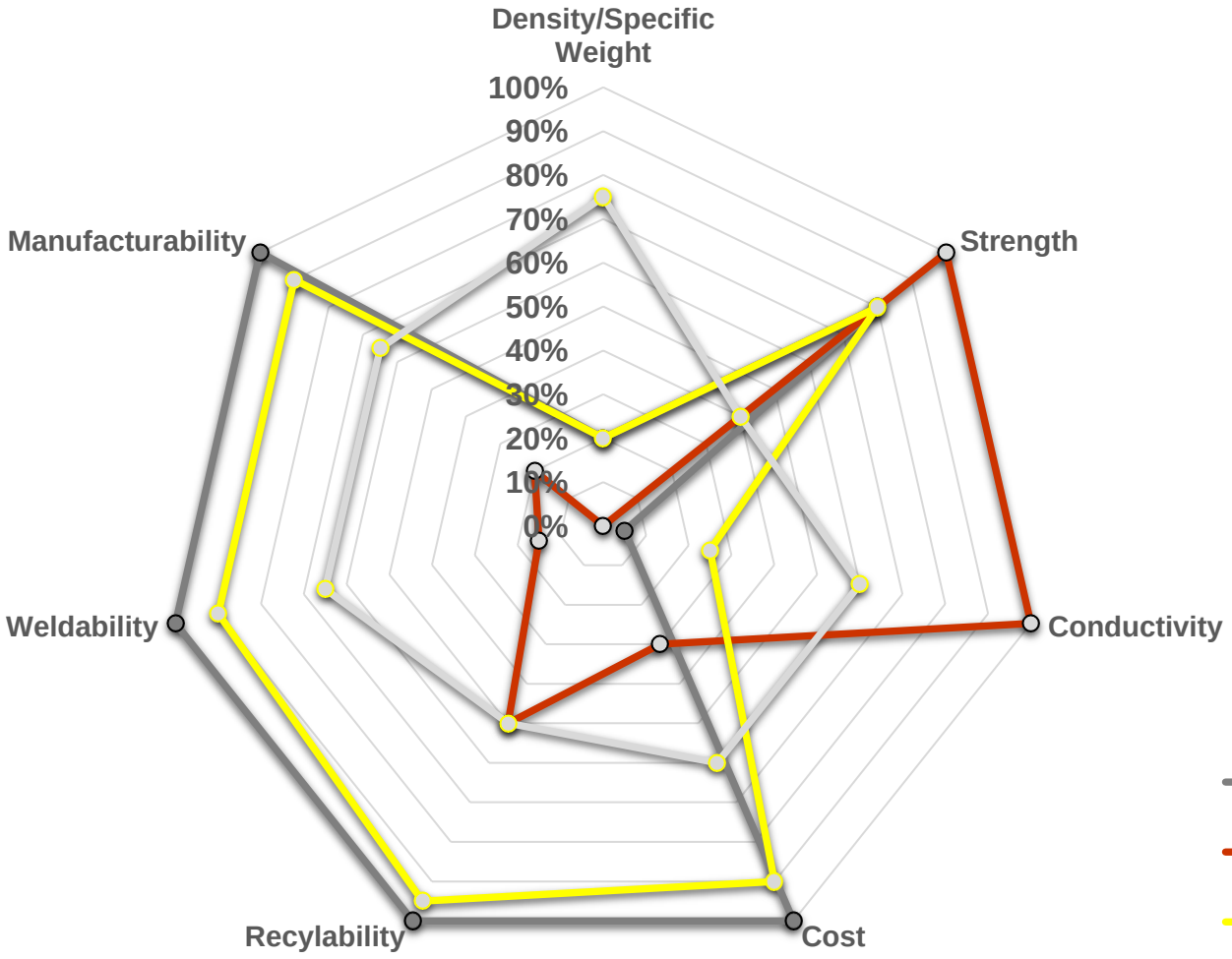
- High processing speed
- Low heat input
- Easy to automate
- Energy efficiency
- Contactless
- Electrical Efficiency



THE MATERIAL CHALLENGES

Materials used for electrical contacts

- Density/specific weight
- Strength
- Conductivity
- Cost
- Recyclability
- Weldability
- Manufacturability

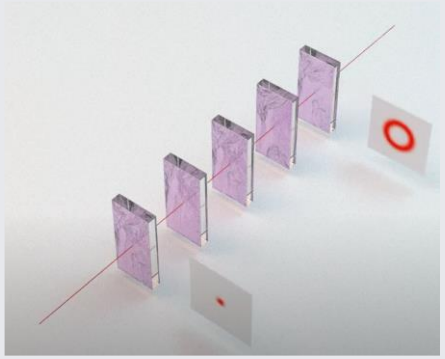
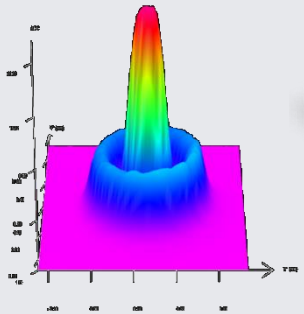
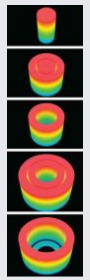
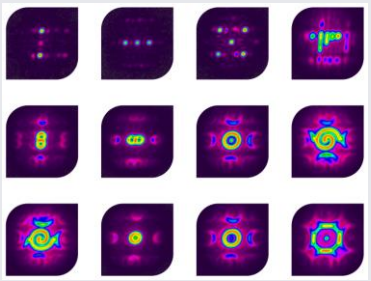


THE PATH TO THE WORKPIECE – HOW TO SHAPE AND GUIDE LASER LIGHT EFFICIENTLY AND APPLICATION-SPECIFICALLY

OR

GOOGLE MAPS FOR COHERENT LIGHT

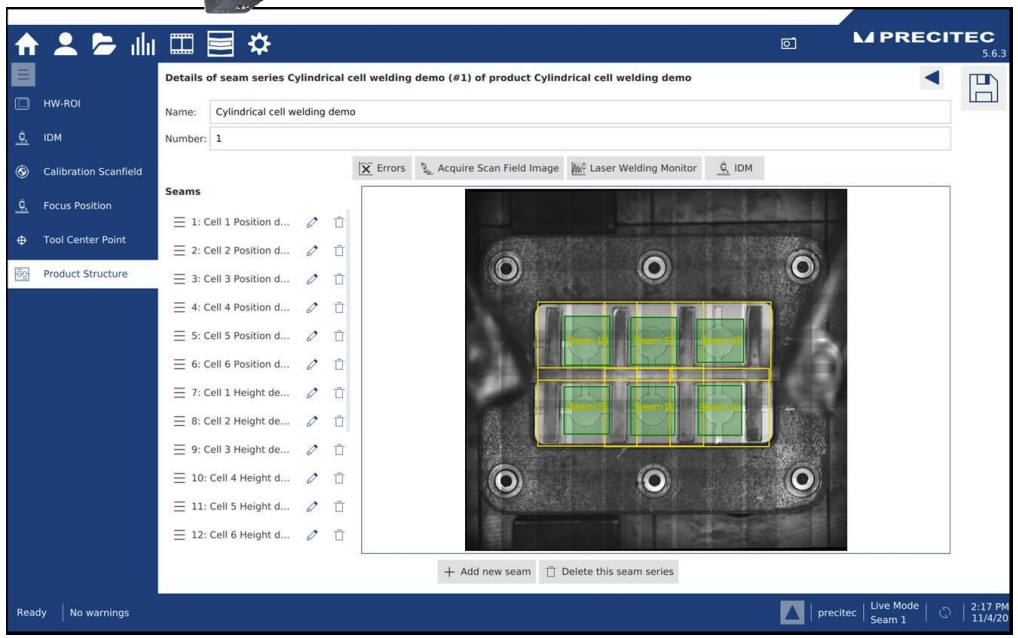
THE CHOICE OF LIGHT

Optical	Combiner Technology	Fiber Manipulation	Coherent Beam Combining
Trumpf BrightLine Precitec EdgeTec Cailabs MPLC Laserline Spot-In-Spot	Coherent ARM IPG YLS-AMB	nLight Corona / AFX	Civan Lasers DBL
Multi-Plane Light Conversion: Beam shaping is implemented through phase plates and free space propagation  Figure: Cailabs	2 independent fiber laser combined Complete independent control; higher price but highly adaptable  Figure: Coherent	Beam Shaping is created in the fiber itself; fast change possible (25 ms) but lower beam quality in outer ring  Figure: nLight	Achieve dynamic intensity distribution by combining multiple singlemode fiber lasers in an optical phased array (OPA)  Figure: Civan

PRECITEC SCANMASTER

One-Stop-Solution

- All-In-One 2.5D scanner
  - Precitec Pre-, In-, Post-Process systems
  - One GUI for everything
- Pre-Process control
  - Fast and precise part position detection (x, y and z)
    - Camera vision system (x, y)
    - OCT/FocusFinder (z)
    - Fast motorized z-collimation ensures autofocus
- In-Process monitoring
  - Process monitoring and long term traceability
    - Laser Welding Monitor (LWM)
    - Laser Power Monitor (LPM)
- Post-Process inspection
  - Gray scale image processing (camera)



Precitec ScanMaster

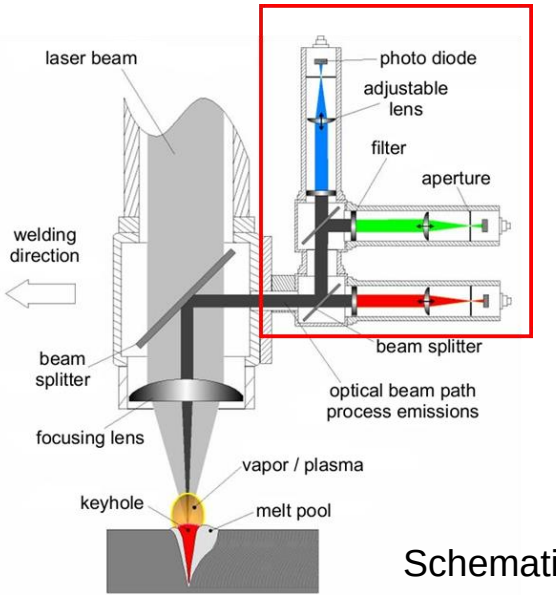
CAILABS CANUNDA-HP + PRECITEC SCANMASTER

Key-performances of CANUNDA-HP

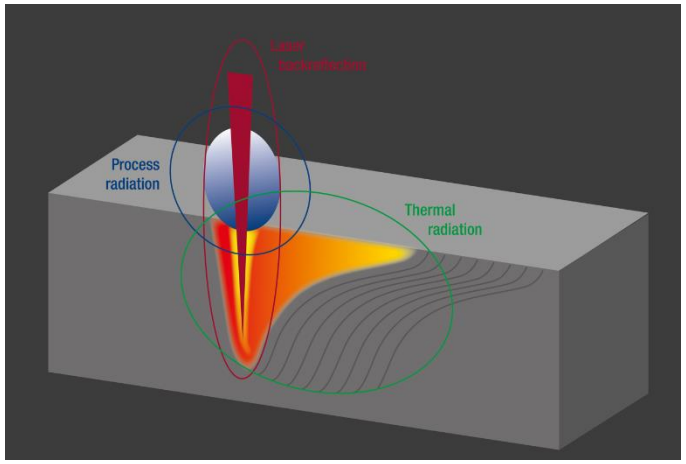
- High quality beam shaping
  - 99% system transmission
  - Maximal focus shift of 1 mm
  - 6% RMS homogeneity around the ring
- An industrial solution
  - Compatible with robot welding arms and very
  - high-power lasers (16 kW)
  - Fast installation: no adjustments or alignment needed
- For an improved process
  - Excellent depth of field (+/-3 mm)
  - Very good joint width and smooth keyhole

TIME SERIES OF PROCESS EMISSIONS

- High power laser material interaction generates process emissions
- These emissions are broadband – from UV to far IR depending on power, material, laser source
- State of the art is capturing, storing and evaluating these emissions with photo diodes



Schematic view



INNOVATIONS IN PROCESS MONITORING

Does real physical information from the welding process and the process result help to improve confidence in sensor technology and process monitoring?

$$\text{strength}$$
$$[N] = [kg\,\frac{m}{s^2}]$$

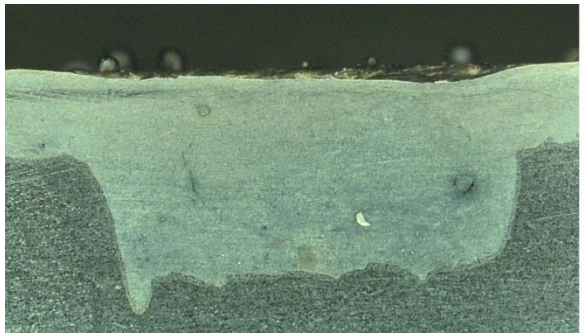
$$\text{electrical resitance}$$
$$[\Omega] = \frac{[V]}{[A]}$$

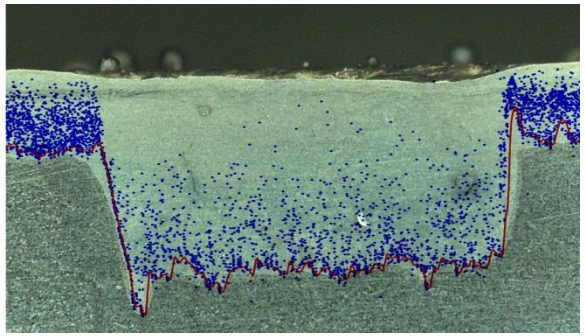
$$\text{depth}$$
$$[\mu m]$$

SOLUTION PATHS

Application of sensors that mirror and output real physical variables from the processing area.

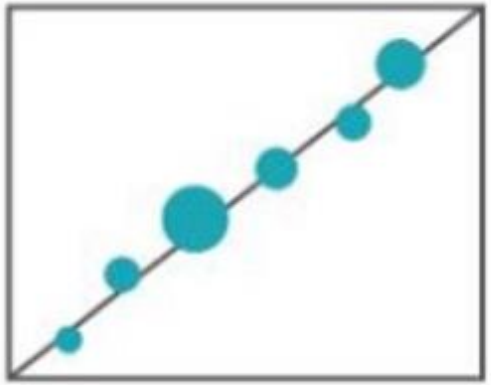
- OCT for penetration depth measurement
- Pyrometer for temperature measurement
- Camera (with external illumination) for geometry measurement





AI-based data processing of process emissions captured with photodiode-based sensors.

- Fusion of sensors as a data source
- Labeling of signals which are correlated to the process
- Applying statistical models which lead to a physical value



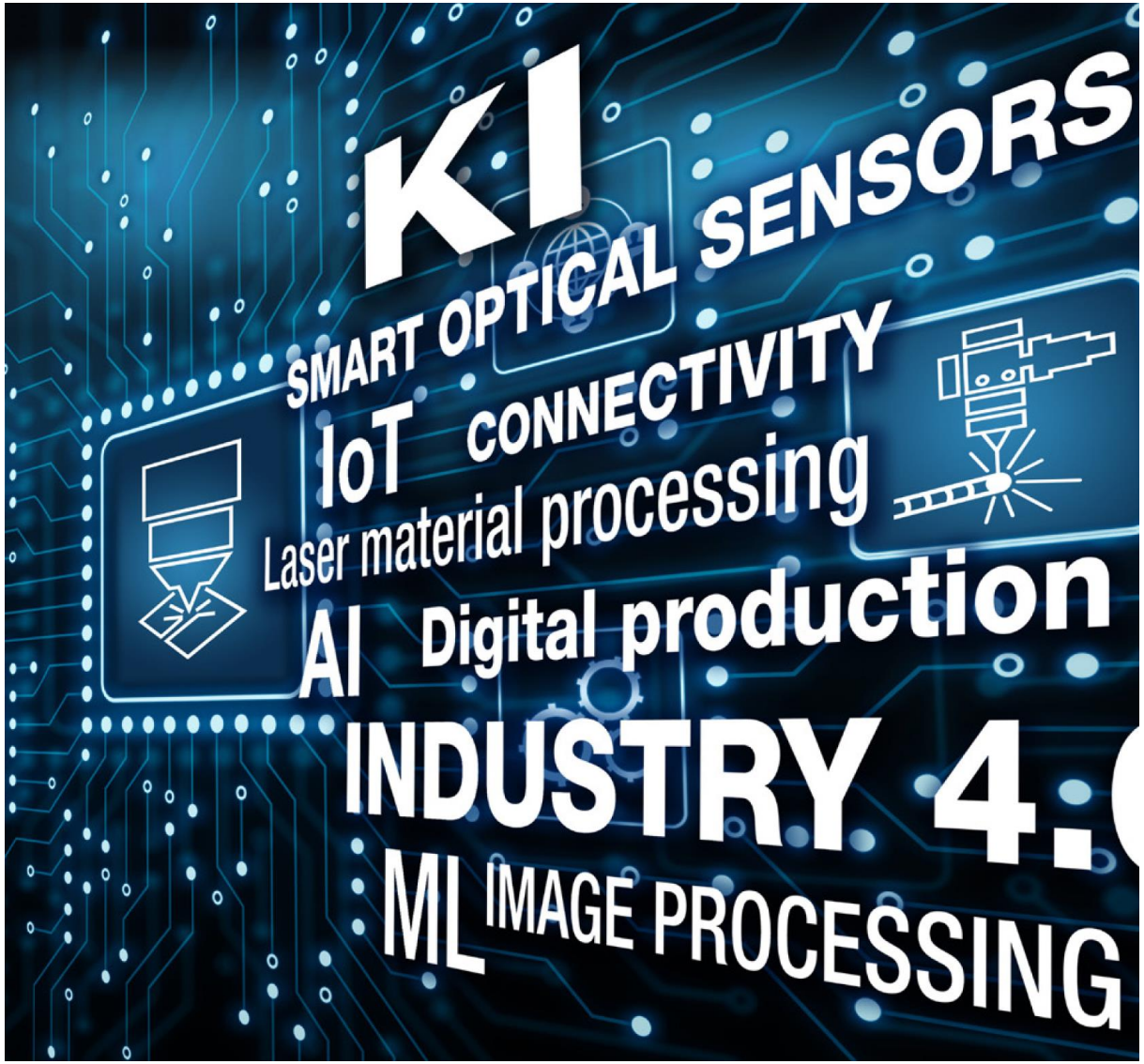
PRECITEC INCUBATOR – GETTING AI ON THE ROAD

Precitec Karlsruhe

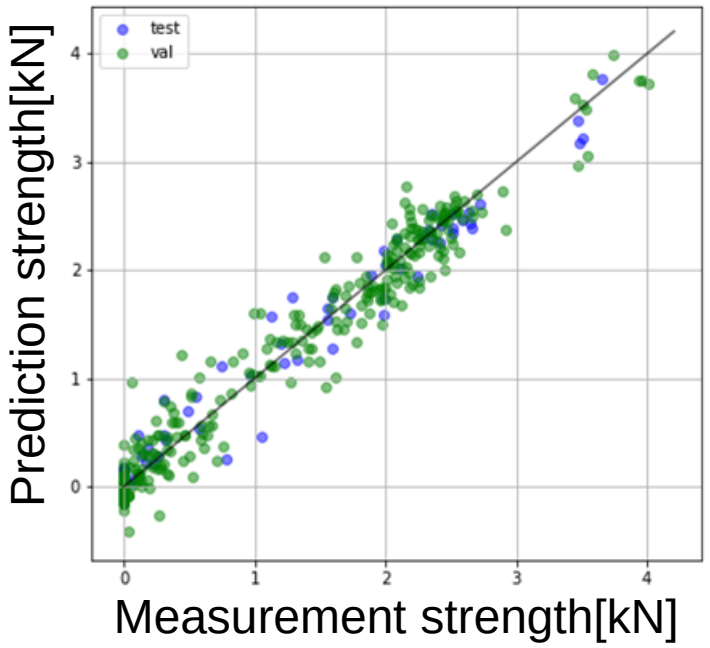
In the so-called "incubator" in a startup-like atmosphere, a team now tackles the concepts
for the laser process of tomorrow:

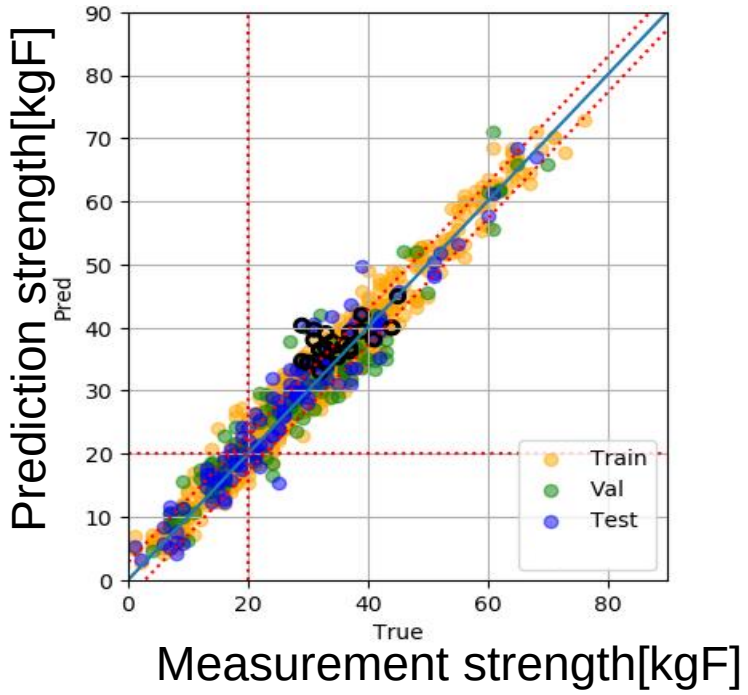
- Machine Learning,
- Internet of things (IoT) or
- Artificial intelligence (AI) and
- Cloud Computing

There is already a close cooperation with the higher education institutions in Karlsruhe.



DEEP LEARNING

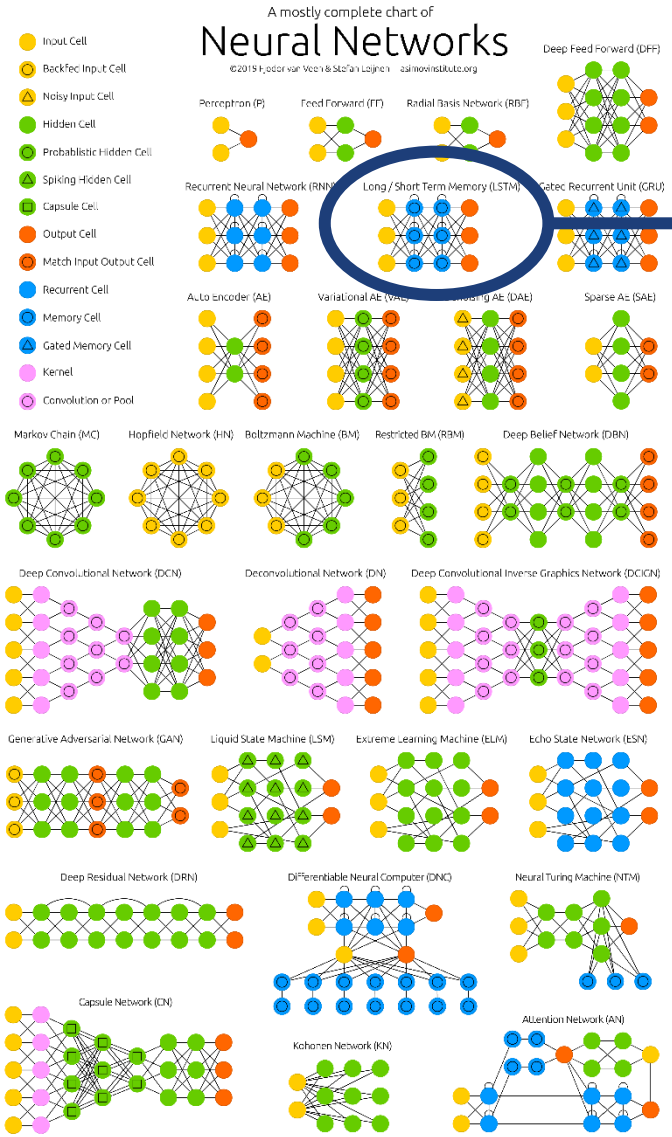




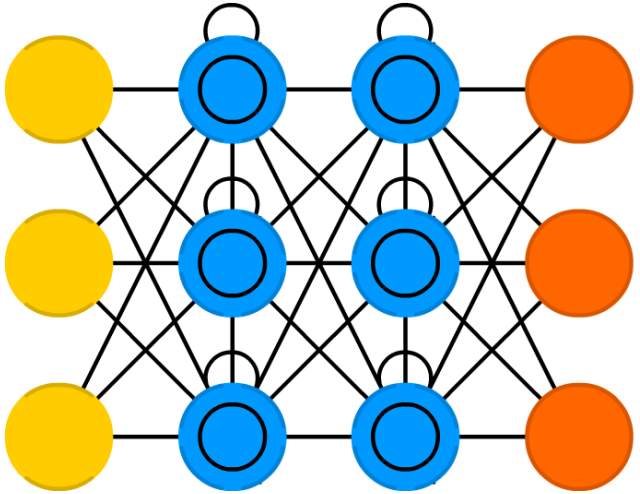
- 1050 Al,1 .2mm auf 3003 AL 4mm
- Overlap, 3.8KW
- 400 Samples, 40 Test Samples
- RMSE = 0.2264 kN
- R2 95.19%

- Dissimilar material welding (Al – Cu)
- Thickness: 50 µm – 200 µm, Overlap, 100W
- 1165 Samples, 116 Test Samples
- RMSE = 3.6kgF = 35.3N
- R2 93.4%

DEEP LEARNING



Long / Short Term Memory (LSTM)



Humans don't start their thinking from scratch every second. As you read this, you understand each word based on your understanding of previous words. You don't throw everything away and start thinking from scratch again. **Your thoughts have persistence.**

Traditional neural networks can't do this, and it seems like a major shortcoming. Recurrent neural networks address this issue. **They are networks with loops in them, allowing information to persist.**

Essential to these successes is the use of **"LSTM's",** a very special kind of recurrent neural network which works, for many tasks, much much better than the standard version.

2019 Fjodor van Veen & Stefan Leijnen asimovinstitute.org

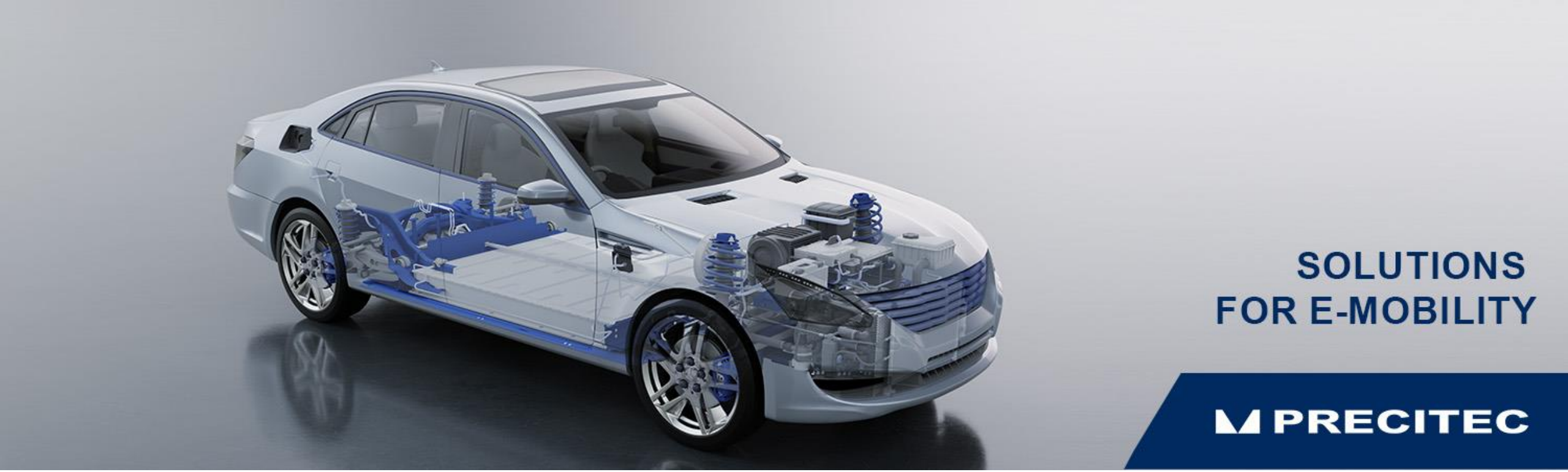
TAKE AWAY MESSAGES

- Beam-shaping is a successful path to cost reduction, robust processes & quality improvement – that is why Precitec is partnering with CAILABS
- Process monitoring equipment needs to provide more than just RED-GREEN information - Customers expect an additional "feature," even if that last mile is extremely costly
- What is the extra mile in AI:
  - Labeling signals that are correlated to the process is time-consuming and expensive
  - The effort to get an AI system into production is much more expensive than for a classical system.
  - Getting enough labeled data is expensive
    - We all need to do more research on unsupervised learning

WHAT CAN YOU DO FOR THEM AND WHAT CAN THEY DO FOR YOU

We can provide knowledge on the applicability of AI methods in combination with laser welding process monitoring

We need more customers who are willing to provide their data – just being open to new technologies and do not slow down innovation



THANK YOU FOR YOUR KIND ATTENTION

Dr. Markus Kogel-Hollacher
Head of Dept. R&D Projects

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