



4D.TWO 4D.WATCHER

SUPERIOR
PROCESS
MONITORING
AS EASY AS POSSIBLE.

CHALLENGES IN LASER PROCESS MONITORING

QUALITY ASSURANCE UNDER PRESSURE

WHY CONVENTIONAL METHODS ARE REACHING THEIR LIMITS

The requirements for precise and efficient laser processes are constantly increasing. But many companies are facing major challenges in quality assurance. Manual inspections and outdated monitoring systems lead to high error rates, production downtimes and inefficient processes.

TYPICAL CHALLENGES IN PRODUCTION

UNSTABLE PROCESS.

Without intelligent process analysis, it remains unclear which laser processes are reliable and which need to be optimized.

UNNOTICED PROCESS DEVIATIONS.

A lack of real-time monitoring leads to unnoticed deviations. Therefore, especially with complex components, quality problems are detected late in the manufacturing process, making rework, if possible at all, costly and time-consuming.

DOWNTIMES AND CREEPING QUALITY PROBLEMS.

Without automated fault detection, machine problems are often only noticed when it is too late – which costs time and money.

HIGH SCRAP RATE.

Without real-time monitoring, it is not possible to detect a production error in time to send the component for reworking and thus reduce the scrap rate.

OVERLOAD OF EMPLOYEES.

Manual quality controls are time-consuming and error-prone – this ties up skilled workers, preventing them from performing higher-value tasks.

LACK OF TRACEABILITY.

Without automated data collection, it is difficult to identify sources of error and eliminate them in the long term.





APPLICATION EXAMPLE I

CHALLENGES IN LASER WELDING OF BATTERY CELLS

HIGH PROCESS SPEED AND SUSCEPTIBILITY TO ERRORS

Battery welding is a highly dynamic process with numerous variables. Without precise monitoring, process deviations remain undetected, which can affect the quality of the weld seams.

LARGE AMOUNT OF WELD SEAMS

Each module can have thousands of weld seams. The weld quality is in many cases not recognizable from the surface of the weld seam.

FLUCTUATING PROCESS CONDITIONS

Material tolerances, impurities and a low thermal load capacity of the cells make reliable fault analysis difficult. This leads to an increased pseudo error rate and inefficient corrective measures.

LACK OF REAL-TIME CONTROL

Without automated monitoring systems, process stability remains unclear. This can lead to unnecessary rejects, increased reworking costs and inefficient production processes, as well as component failures and recalls.

SAFETY ISSUES

Positioning faults, insufficient clamping or an accidental full penetration can cause a thermal runaway of the cell. In-process monitoring offers the ability for early detection.

APPLICATION EXAMPLE II

CHALLENGES IN LASER WELDING OF HAIRPINS

CRITICAL IMPACT OF WELD FAILURES

State-of-the-art electric drives have 100 to 200 hair-pin pairs. They must reliably maintain the electrical conductivity over the service life. If one connection fails, the motor no longer works, making it essential to monitor each one to ensure consistent quality.

INFLUENCE OF PREVIOUS PROCESSES

The welding process is affected by prior steps such as bending, cutting, and cleaning. Monitoring helps to adjust for these variations and maintain weld quality.

HIGH POSITIONING ACCURACY

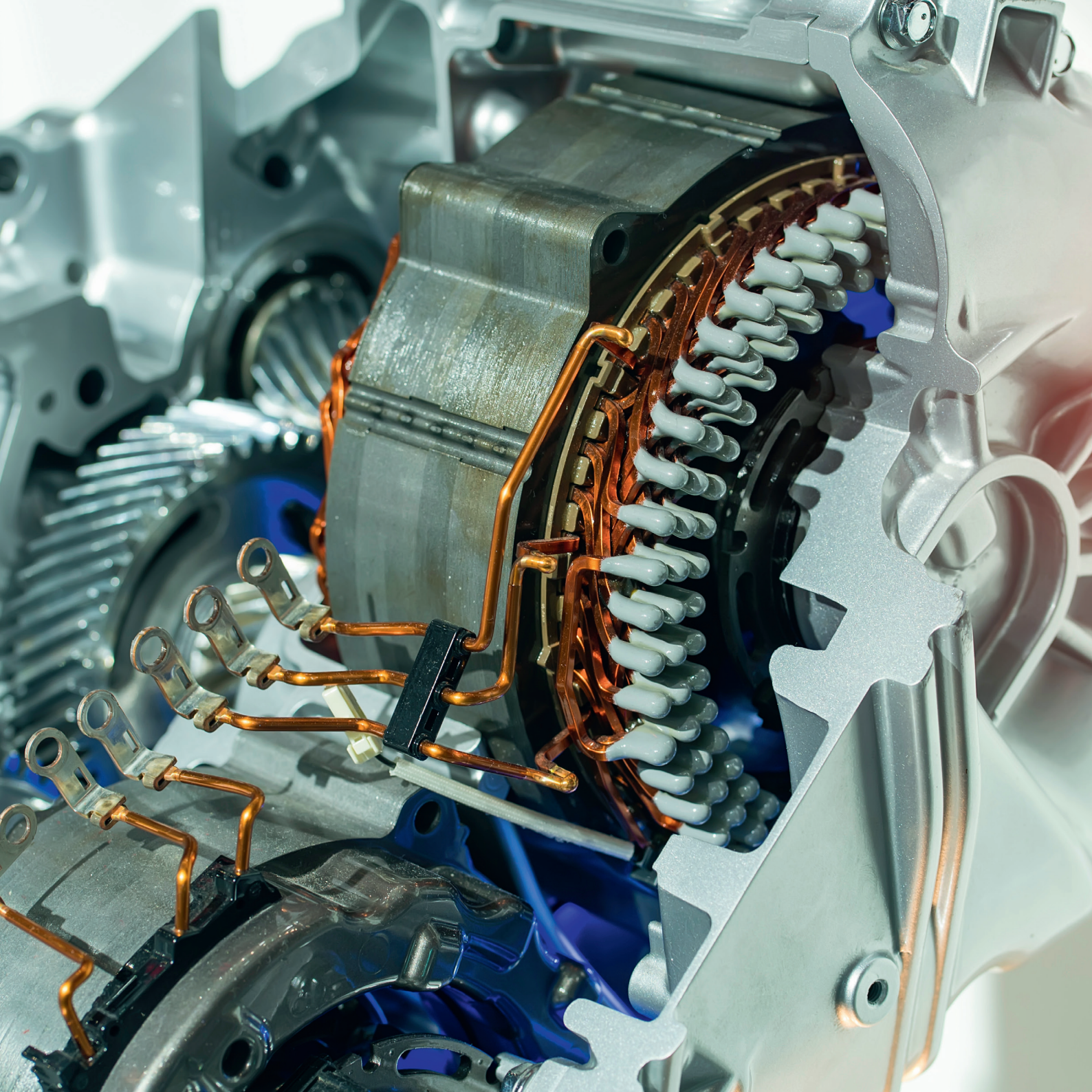
Accurate positioning of the welding contour is essential for high-quality welds, and monitoring ensures this precision.

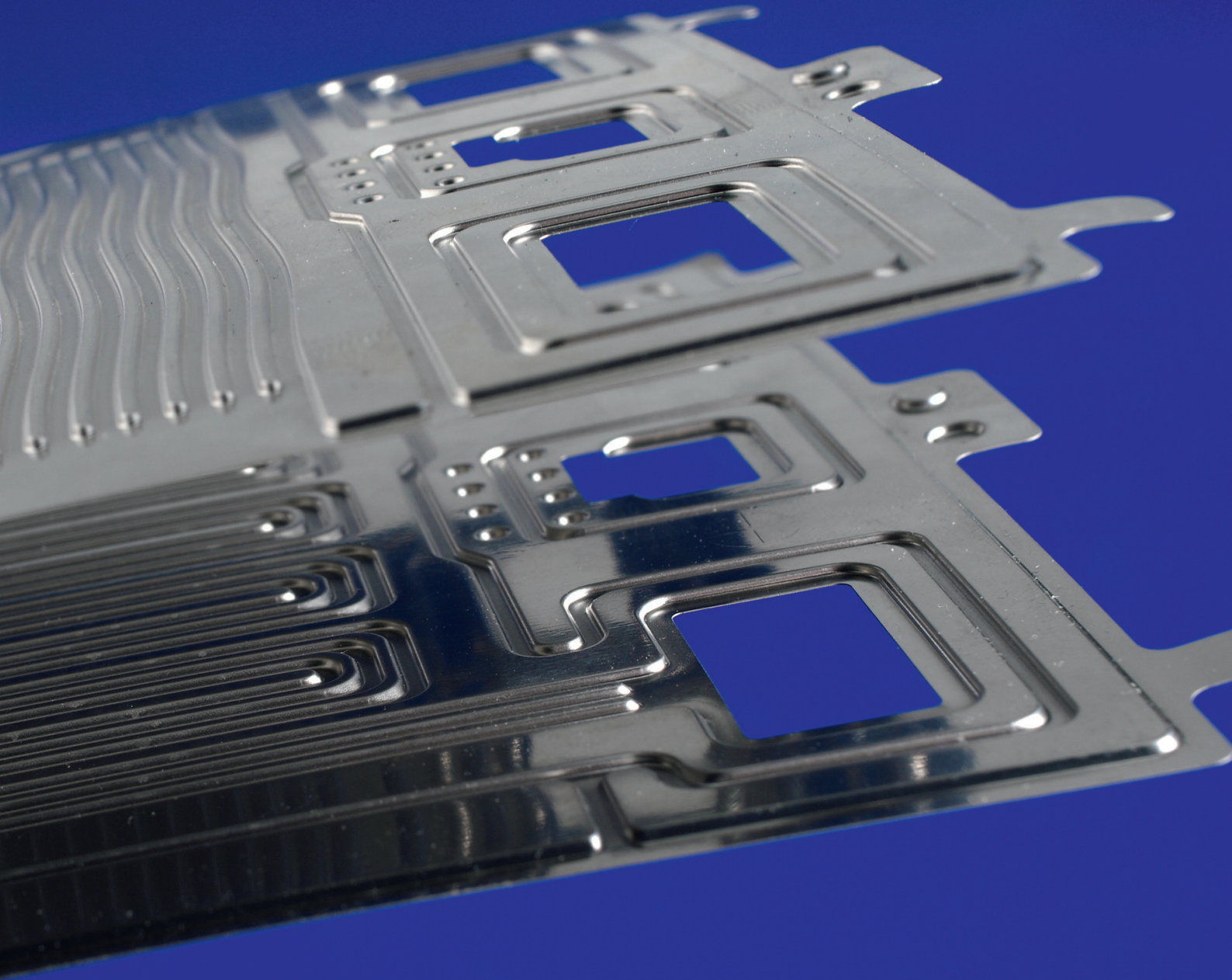
INVISIBLE DEFECTS

Many defects in weld seams are not visible after welding, necessitating real-time monitoring to detect issues immediately.

CLAMPING CHALLENGES

Accessibility issues can make clamping difficult, requiring precise monitoring to ensure proper alignment and positioning.





APPLICATION EXAMPLE III

CHALLENGES IN LASER WELDING OF FUEL CELLS

HIGH WELDING SPEEDS

To produce several meters of weld seams per plate in short cycle times, a high feed rate close to the process limit is required. This significantly increases the probability of welding faults and requires automated, continuous monitoring.

PRECISION AND ACCURACY

Welding must be performed on a very small work area with high speed and precision. The weld width must not exceed specific values to ensure the tightness between the bipolar plates. This requires advanced technologies for process monitoring to avoid non-detected process deviations and decrease the pseudo fault rate.

WELD SEAM QUALITY

The quality of the weld seam is crucial for the functionality of the bipolar plates. Process errors such as insufficient weld seam density or strength can lead to leaks, affecting the separation of reaction gases and the dissipation of process heat. Continuous monitoring of key parameters such as laser power and beam position is therefore necessary.

CLAMPING CHALLENGES

Complex geometries and high clamping forces can lead to distortion and misalignment. Monitoring ensures that the welding process adapts to these challenges, maintaining the integrity of the weld.

PROCESS MONITORING OF THE LATEST GENERATION

MAXIMUM CONTROL OVER YOUR LASER PROCESSES

4D.**watcher** is the central monitoring system for precise and efficient process control in laser production. Thanks to the intelligent extraction of relevant data, a reduced data volume and simplified operation, 4D.**watcher** enables effective error analysis and process optimization – in real time and with reduced manual effort.

4D.WATCHER KEY FEATURES

TEACH-IN PROCESS FOR AUTOMATED ADAPTATION.

Once set up, 4D.**watcher** starts a self-learning process with one click that uses the next signals to create a reference for signal evaluation.

INTELLIGENT FAULT DETECTION.

Thanks to advanced technologies such as *Lossless Technology*, 4D.**watcher** detects even the smallest errors seamlessly.

COMPLETE TRACEABILITY AND DATA STORAGE.

All recorded process data is stored locally and can be transferred to your company's own IT system for long-term analysis.

EVALUATION CHANNELS FOR OPTIMIZED FAULT CLASSIFICATION.

By combining several sensor data, up to nine individual Evaluation Channels can be defined to better identify and classify the causes of faults.





BENEFITS WITH 4D.TWO AND 4D.WATCHER

SENSOR | 4D.TWO

1 **MULTISPECTRAL SENSOR SYSTEM.**

The 4D.TWO records the process light generated during the laser process using a light-sensitive sensor, which is divided into 32 spectral channels – with 16 channels in the VIS and 16 channels in the NIR.

2 **PROCESS CONTROL.**

The 4D.TWO enables the customer to implement fast (quasi-real-time) control of the process parameters based on the sensor-internal calculation of up to 2 sensor channels.

3 **REDUCED DATA VOLUME.**

The 4D.TWO requires only moderate measurement rates for detecting smallest deviations (see *Lossless Technology*).

4 **LOSSLESS TECHNOLOGY.**

By using 2 evaluation units that alternately record the process light, there are no dead times. This enables process monitoring without blind spots.

5 **EXTENSIVE DATA ACQUISITION.**

The 4D.TWO can measure temperature, humidity and air pressure and has a 9-axis motion tracker to provide additional data.

6 **MINIMIZED ADJUSTMENT TIME.**

Almost all settings can be adjusted remotely via software, which minimizes on-site adjustment time.

SOFTWARE | 4D.WATCHER

7 **REAL-TIME MONITORING.**

The 4D.watcher enables real-time monitoring of the laser processes by detecting and reporting anomalies such as cracks, pores, spatter or defects.

8 **FAULT TYPE CLASSIFICATION.**

With 4D.watcher multiple Evaluation Channels can be created and assigned to different root causes. This approach helps to reduce down times after unforeseen production issues.

9 **PROCESS MONITORING.**

The 4D.watcher monitors the entire laser process and ensures that all relevant data is recorded and analyzed.

10 **INTEGRATION AND ADJUSTMENT.**

The 4D.watcher can be adapted to different machines and production lines and offers flexible integration.

11 **DATA EXPORT AND ANALYSIS.**

The 4D.watcher enables the export of data for further analysis and documentation.

12 **CUSTOMIZED ADJUSTMENTS.**

The 4D.watcher can be adapted to the specific monitoring requirements of the customer in order to achieve optimum results.

13 **ADDITIONAL SENSOR DATA.**

The 4D.watcher is able to include third-party data streams for a time synchronized data analysis.

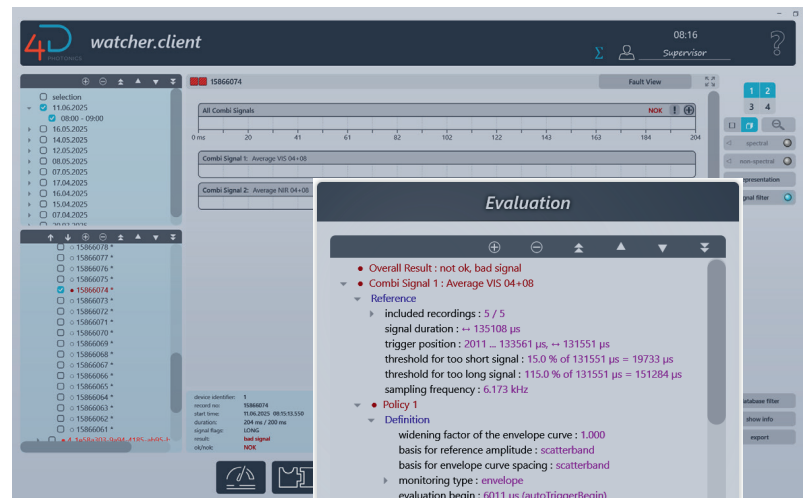
4D.WATCHER | INDUSTRY READY SOFTWARE PACKAGE

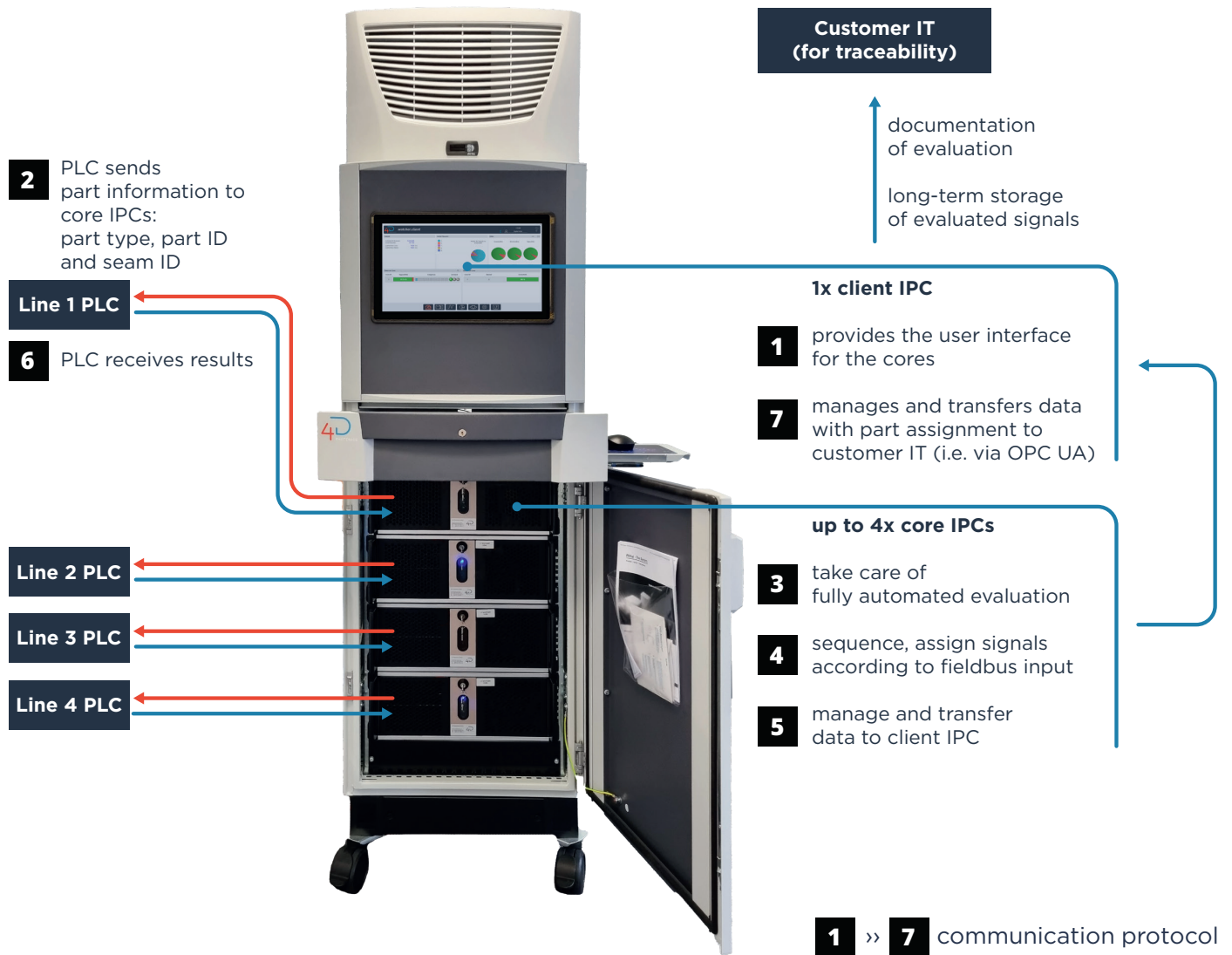
4D.**watcher**.core is receiving all the data – more than 1M samples/s – coming in from 4D.**TWO**. It synchronizes your PLC data and assigns part, group and seam numbers, combines multiple sensor/data channels to your specification and takes care of the whole evaluation process.

4D.**watcher**.client on the other hand is the frontend to you. It enables you to visualize and parametrize multiple 4D.**watcher** cores, thus increasing robustness by using dedicated CPUs. It is also your data hub as it retrieves all evaluated data of all connected cores (up to 4).

The components produced are displayed in the 4D.**watcher**.client component view. One possible representation of the results is to display the individual welds as colored dots. The color of the dots provides information about the evaluation result (green: OK, red: not OK).

But there are many more ways to visualize the welding results. For example, the results can be displayed as signal curves with envelopes or in tabular overviews. Depending on the user's requirements, the software can display the evaluation in different levels of detail.





The 4D.watcher communicates automatically with the customer's system. Based on the evaluation by the 4D.watcher, the customer's system control automatically decides on the OK/NOK status of the weld seam and any necessary rework. For traceability of the evaluations, the 4D.watcher sends the data to the customer's IT.

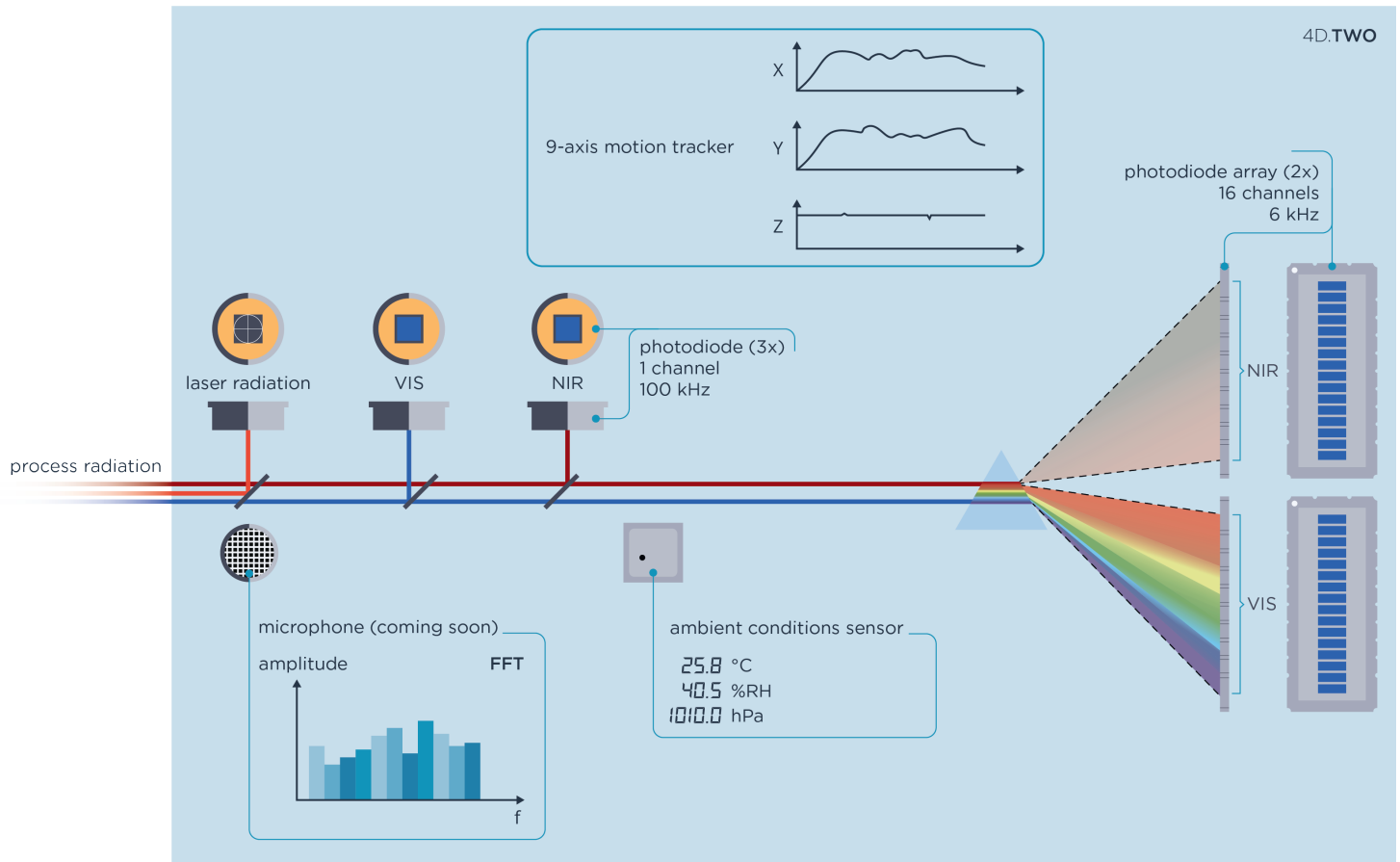
4D.TWO | THE SENSOR FOR ALL YOUR APPLICATIONS

MINIMIZED ADJUSTMENT TIME

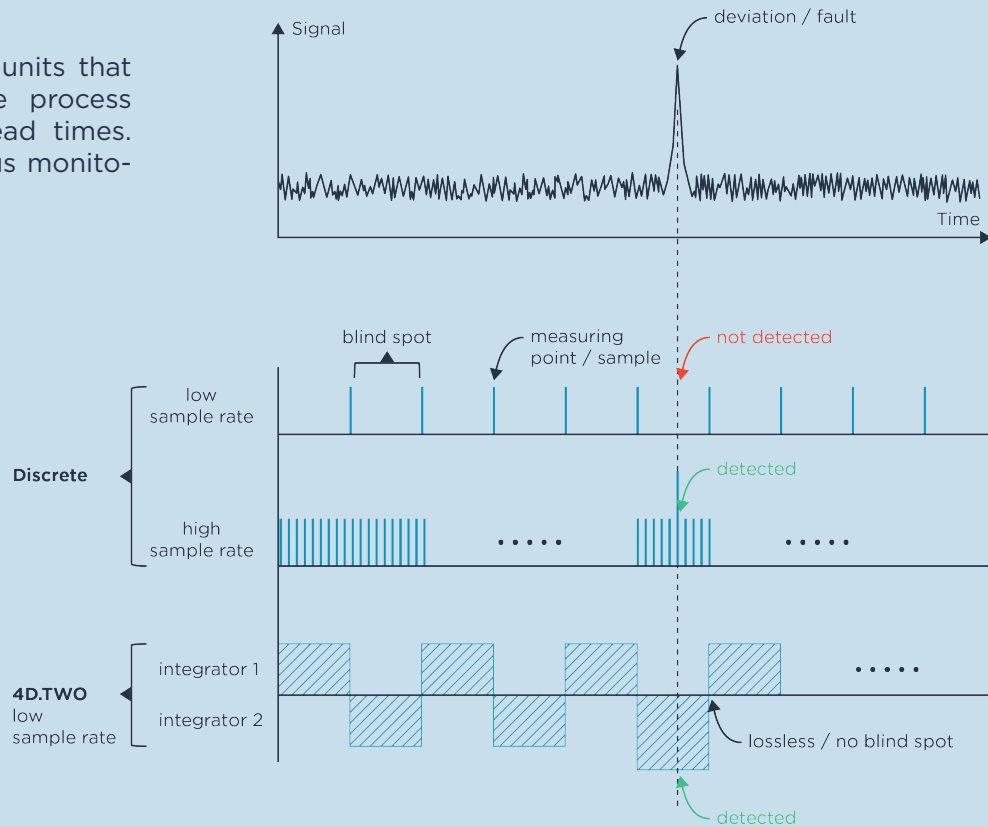
The amount and the duration of on-site adjustment is minimized as almost every setting can be adjusted remotely by software.

FULL SPECTRUM CAPTURING

4D.TWO captures the full spectra both in NIR and in VIS at the same time – with 16 channels in the visible light range (VIS) and 16 channels in the near-infrared area (NIR). In addition to these spectrally resolved channels there are 3 broadband spectrum channels for VIS, NIR and back reflection. With these channels, the spectral ranges are also recorded in full with sampling rates of up to 100 kHz.



By using 2 evaluation units that alternately record the process light, there are no dead times. This enables continuous monitoring of the process.



LOSSLESS TECHNOLOGY

State-of-the-art data acquisition requires high sample rates and extensive data storage to recognize and trace short deviations. With the *Lossless Technology*, you now generate significantly less data volume thanks to the lower sampling rate. Due to the integrated measuring concept, the system is able to detect even small deviations that would otherwise only be detectable with a significantly higher sampling rate. This makes the 4D.**TWO** suitable for applications with high welding speeds such as bipolar plates (≥ 1 m/s).

EXTENSIVE DATA ACQUISITION

The sensor is also able to track orientation and acceleration with a 9-axis motion tracker, e.g. in order to detect deviations in the robot path during the process. Recording temperature, relative humidity and air pressure is possible as well. In the future, acoustic emissions will be captured, too.

CLASSIFY FAULT TYPES

FIND PRODUCTION PROBLEMS QUICKLY

With 4D.**watcher** you can create multiple Evaluation Channels and assign them to different root causes to your fault types. This approach helps to reduce down times after unforeseen production issues.





EXCELLENT DETECTION LESS PSEUDO FAULTS

By extracting and combining only relevant data which correlates to your fault types best, it is now possible to eliminate disturbance values which decreases the amount of pseudo faults.

WE ARE 4D

30 YEARS EXPERIENCE IN LASER TECHNOLOGY

4D Photonics is an independent supplier of application-optimized systems for laser process monitoring. We develop and produce high-quality sensors, which record the optical radiation for high-performance laser processes (e.g. welding, powder and wire buildup welding or additive manufacturing, cleaning, surface finish, cutting etc.) and software for evaluating these recordings. Our products enable automated monitoring helping quality assurance for different laser processes in the industry.

4D IN NUMBERS

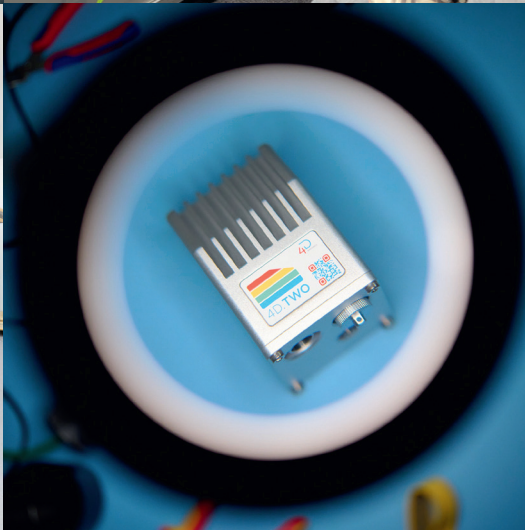
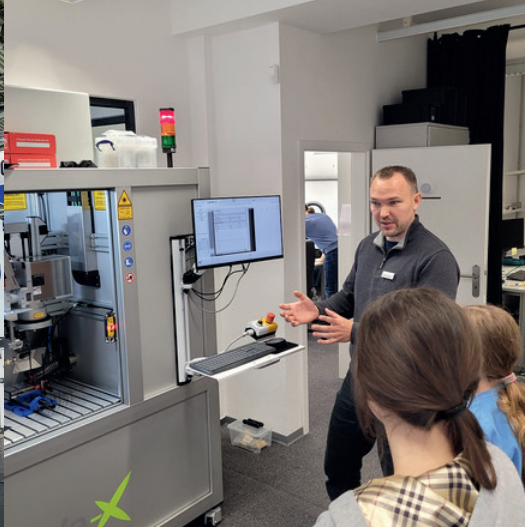
More than 2,000 of our process monitoring systems are in use all over the world. We have a strong global service network with more than 20 trained process monitoring specialists. Depending on your region, language and application, we will recommend a local service partner for immediate support on site for you.

2,000+
SYSTEMS

20+
SERVICE ENGINEERS

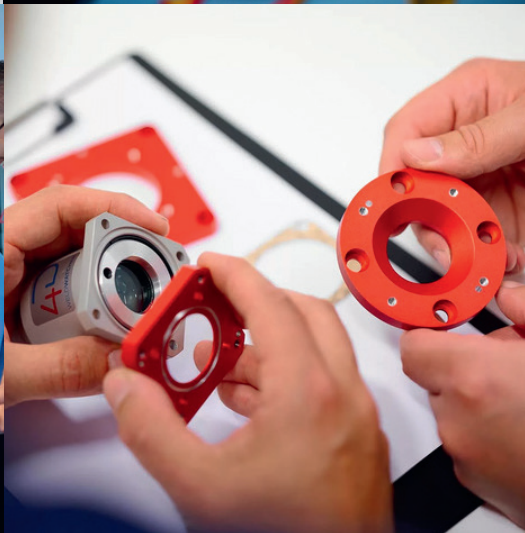
100+
CUSTOMERS

1
PARTNER NETWORK
(MILKY WAY ONLY)




Unsere Vision für
die Prozessüberwachung
in einer zunehmend
komplexeren Produktionswelt

**Mit einfachen Lösungen
gemeinsam Maßstäbe setzen**

INCREASE PRODUCTION QUALITY - WITH 4D

Benefit from the advantages of automated, precise and efficient process monitoring with 4D Photonics. Our solutions reduce waste, support quality assurance and enable seamless traceability – in real time and individually customized to your requirements.

OUR SALES TEAM - YOUR CONTACT

We operate worldwide with different Sales & Service partners. Ask for your options for a local partner via mail to sales@4d-photonics.com or simply call us: +49 511 235947-0.



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**SCHEDULE
AN APPOINTMENT
WITH US.**



**LEARN MORE ABOUT
4D.WATCHER AND
4D.TWO ON OUR WEBSITE.**

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IT ONLY TOOK US 30 YEARS TO REACH 4D.TWO.