PROCESS MONITORING FOR REMOTE LASER MICRO WELDING

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Why should I / you do process monitoring?

- Prevent Welding Failures
  - Laser process monitoring (and control) is quality assurance
- Sensing the machine state
- Track part history for a documented production
- Assessing defects or irregularities for in-situ quality assurance
  - Less waste
- Identify critical trends before failure
  - Less downtime
- Increased quality leads to increased productivity
- Saving / earn more money
- Increased employee and customer satisfaction

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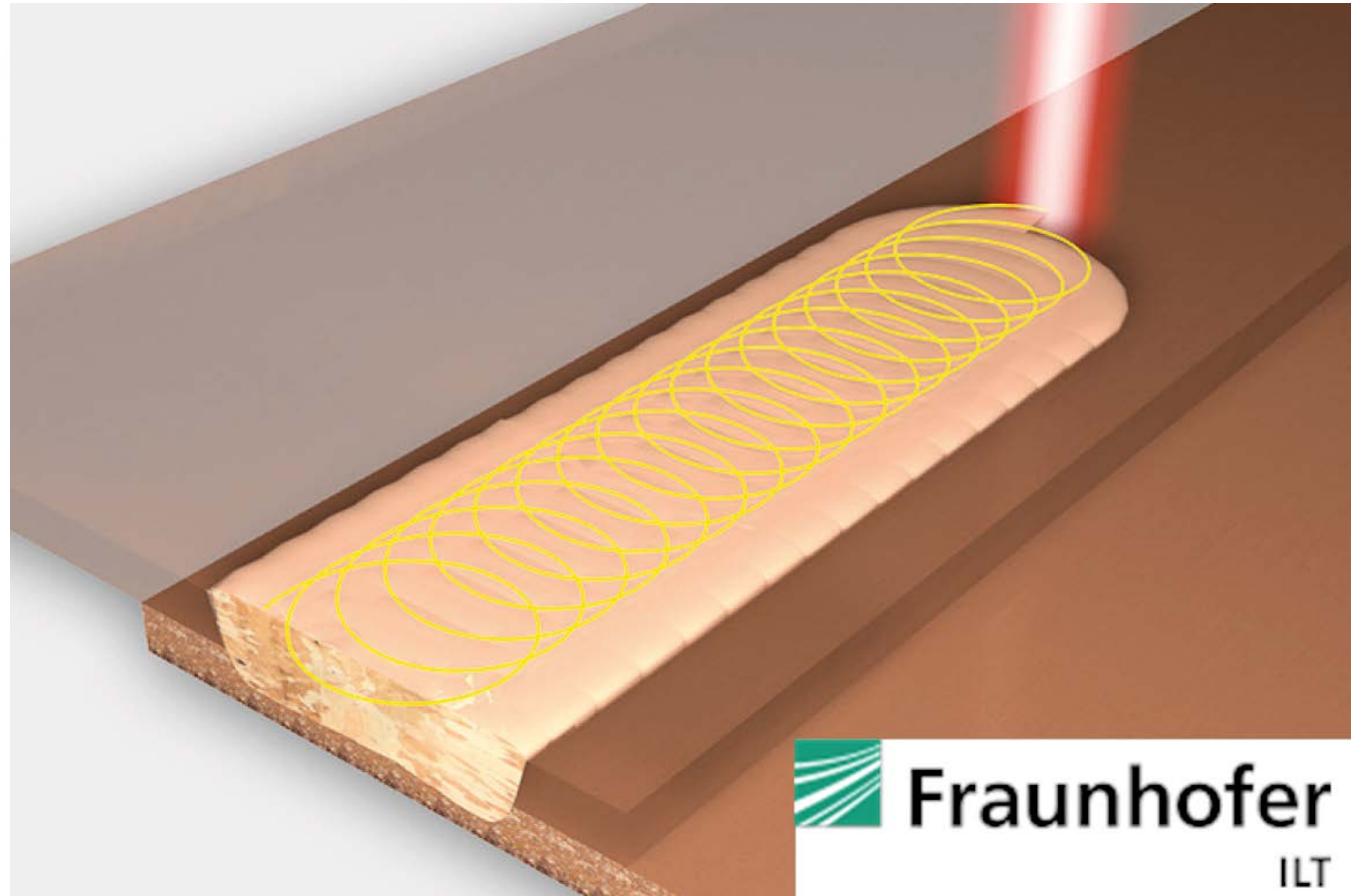# What could be monitored or detected?
Which process parameters can be set?

Machine

- Laser power

- Working distance and spot size

- Scanning velocity

- Scanning strategy / geometry
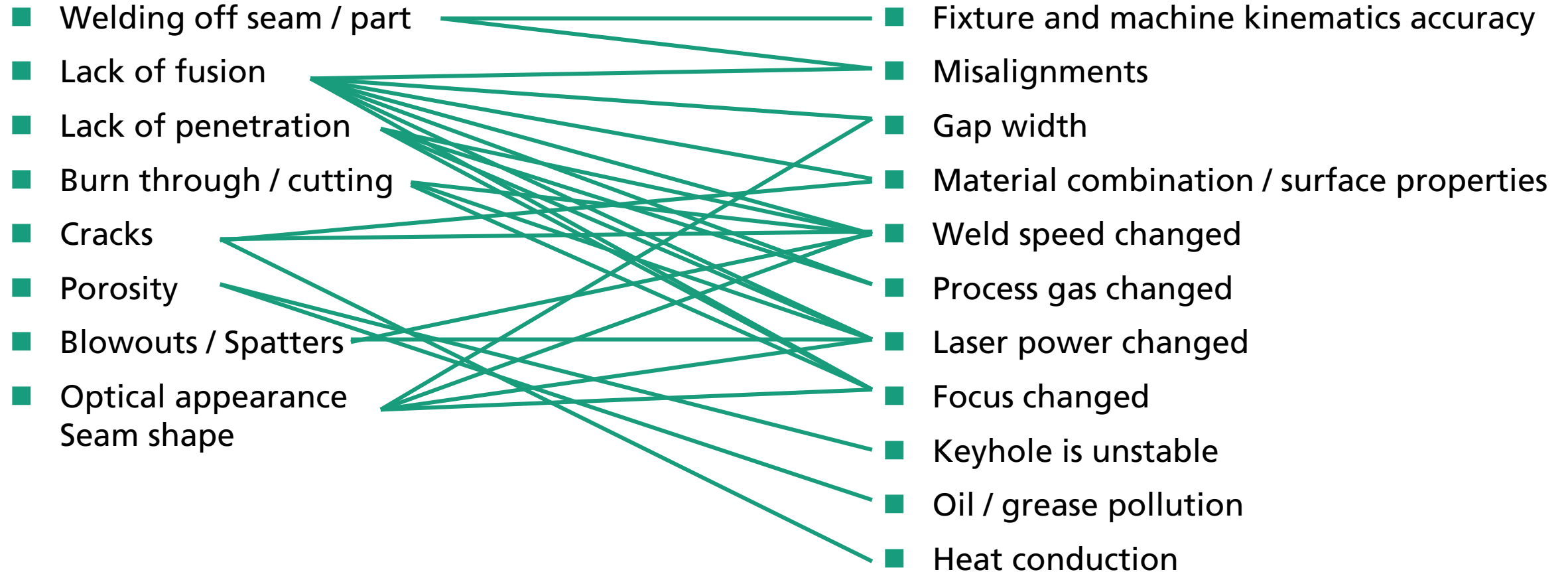
- Protection gas

- Laser wavelength

Material

- Combination Cu/Cu, Al/Cu, Steel/Al

- Thickness and configration

- Heat transfer

What could be monitored or detected?
What kind of failures can occur?

- Welding off seam / part
- Lack of fusion
- Lack of penetration
- Burn through / cutting
- Cracks
- Porosity
- Blowouts / Spatters
- Optical appearance
  Seam shape

- Fixture and machine kinematics accuracy
- Misalignments
- Gap width
- Material combination / surface properties
- Weld speed changed
- Process gas changed
- Laser power changed
- Focus changed
- Keyhole is unstable
- Oil / grease pollution
- Heat conduction

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What could be monitored or detected?
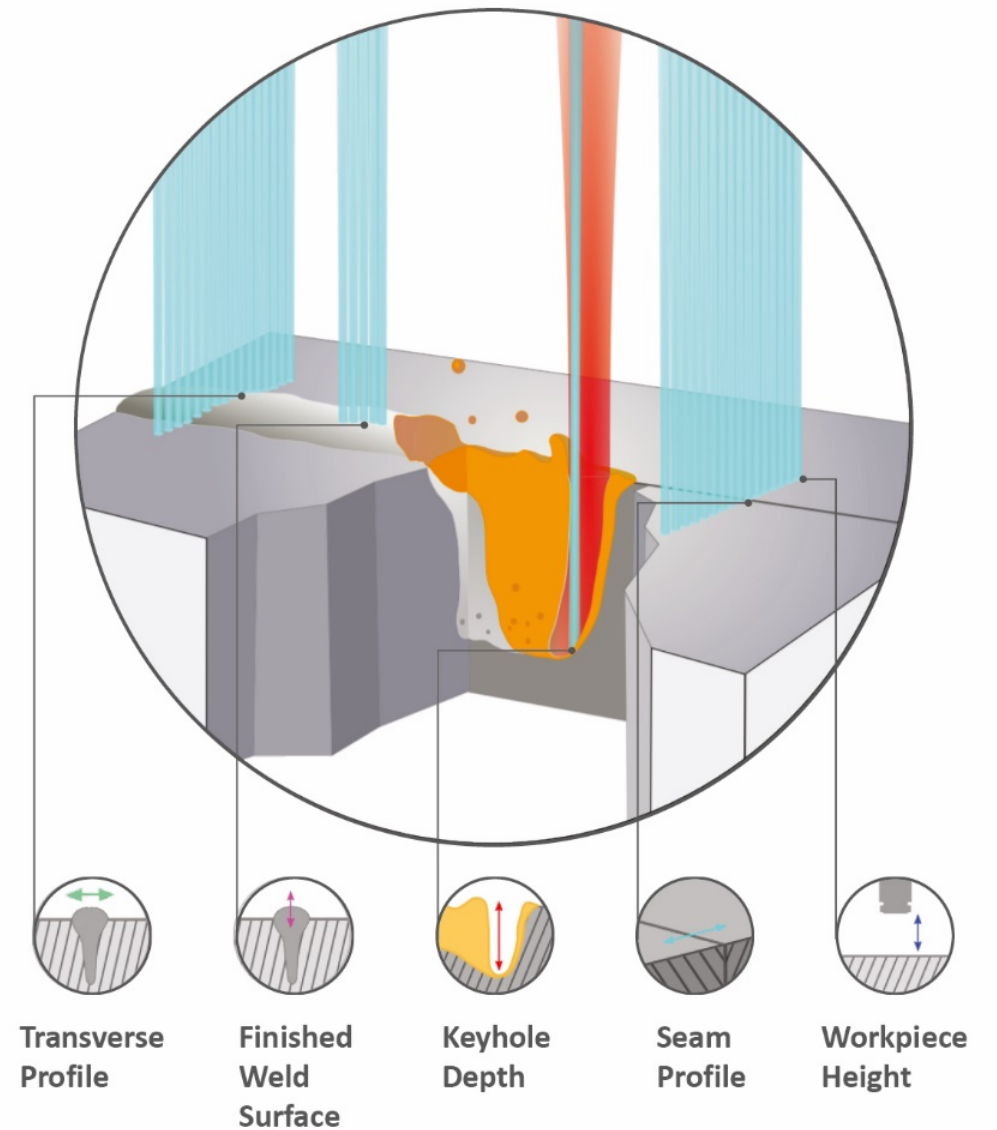What kind of information could be available?

- Machine state
- Part history and number
- Process set parameters
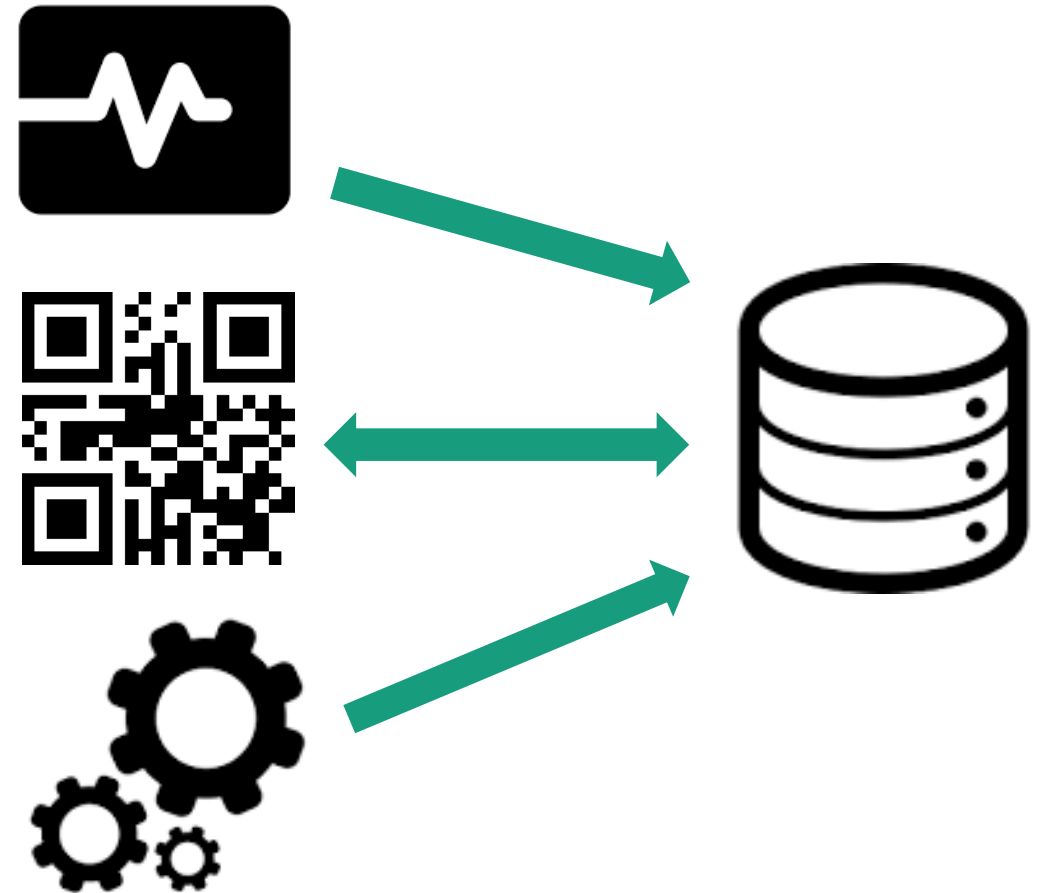
What could be monitored or detected?
What kind of information could be available?

- Programmed position vs real part position
- Process geometries
  - Key hole
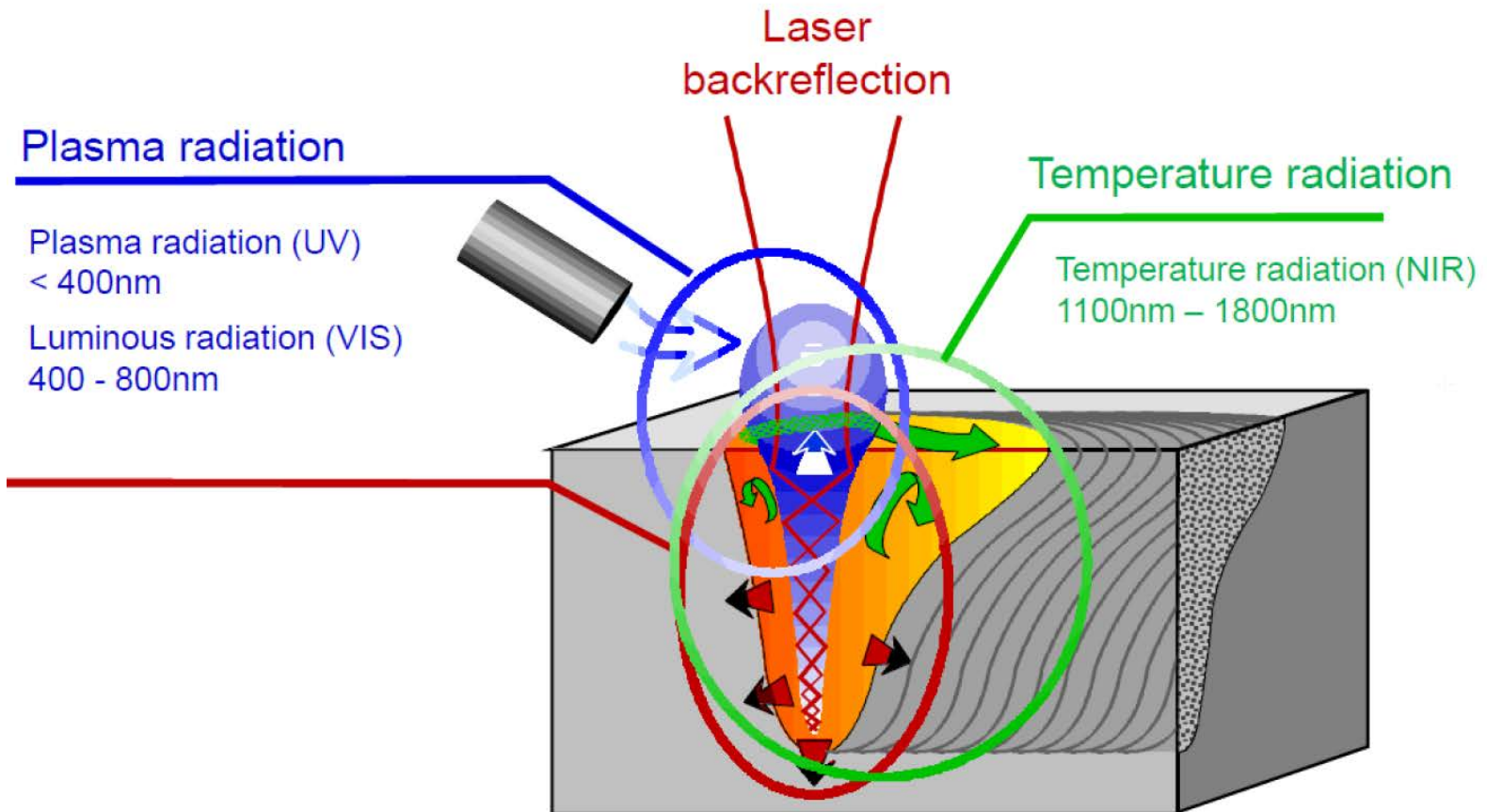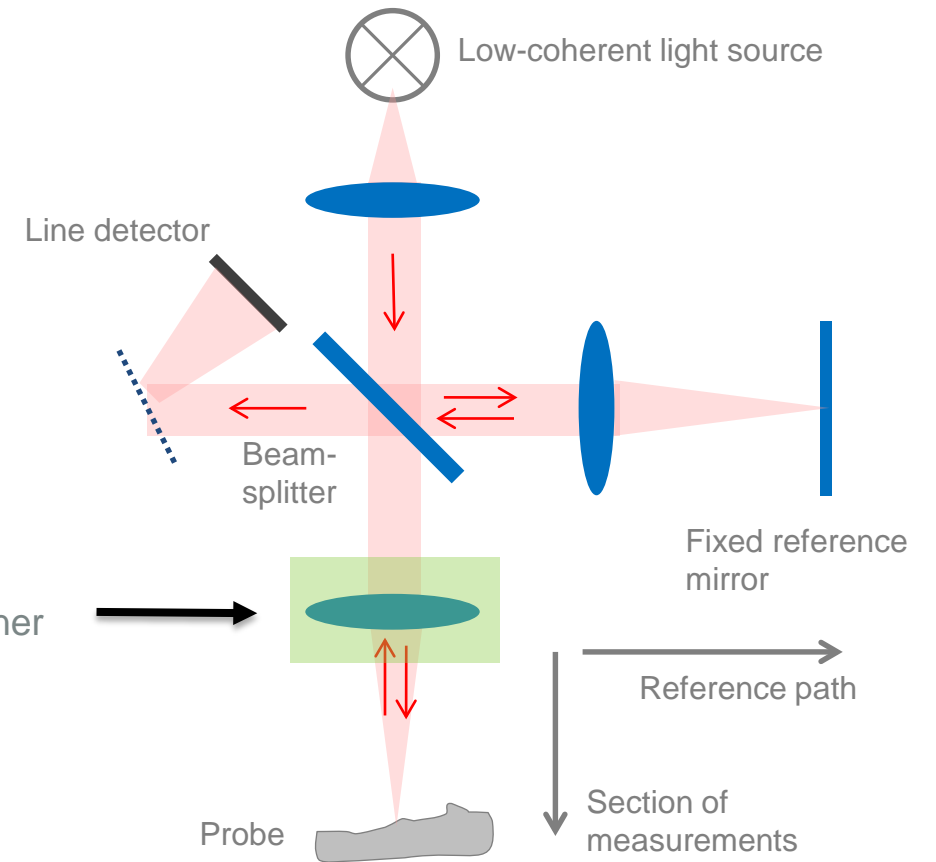 - Weld pool
  - Seam pre- & postweld

Transverse Profile | Finished Weld Surface | Keyhole Depth | Seam Profile | Workpiece Height

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What could be monitored or detected?
What kind of information could be available?

- Process emissions
  - Laser backreflection
  - Temperature radiation (NIR)
  - Luminous radiation (VIS)
  - Plasma radiation (UV)
  - Acoustic (air and bulk)

Laser backreflection

Plasma radiation

Plasma radiation (UV) < 400nm

Luminous radiation (VIS) 400 - 800nm

Temperature radiation

Temperature radiation (NIR) 1100nm – 1800nm

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How to monitor these parameters and failures?

- **Machine state**

- **Part history and number**

  - Access to database

- **Process set parameters**

  - Monitor them directly as close as possible to the workpiece

Ophir Beam Watch

Fest Gas flow sensor

Primes PowerMeasuringModule

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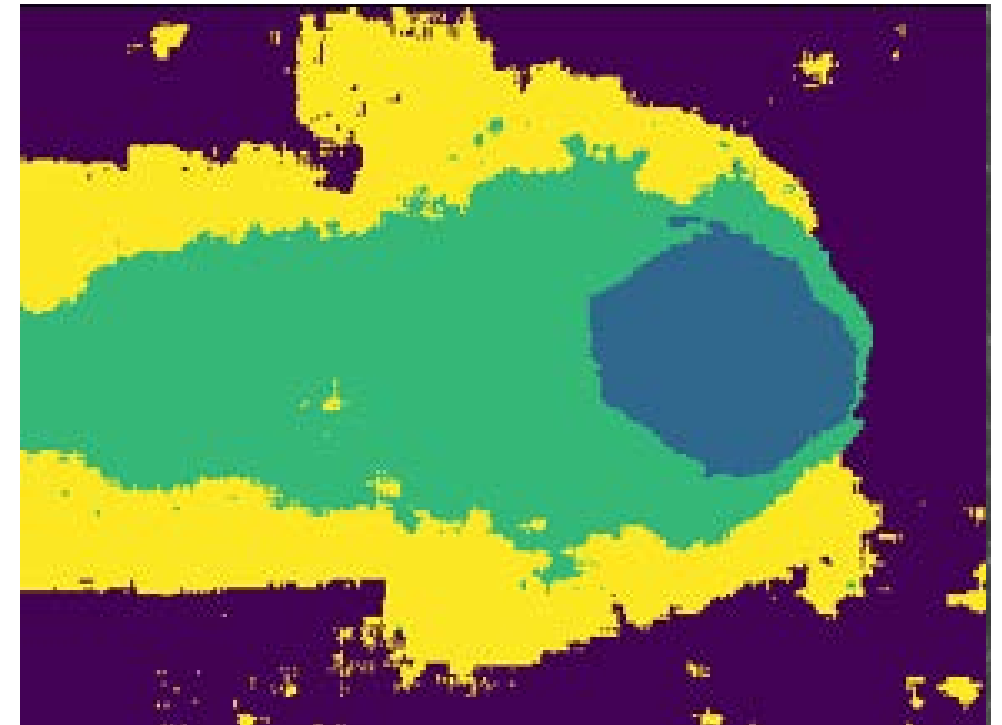ILT

How to monitor these parameters and failures?

- Programmed position vs real part position
- Process geometries
  - Key hole
  - Weld pool
  - Seam pre- & postweld

Low-coherent light source

Line detector

Beam-splitter

Fixed reference mirror
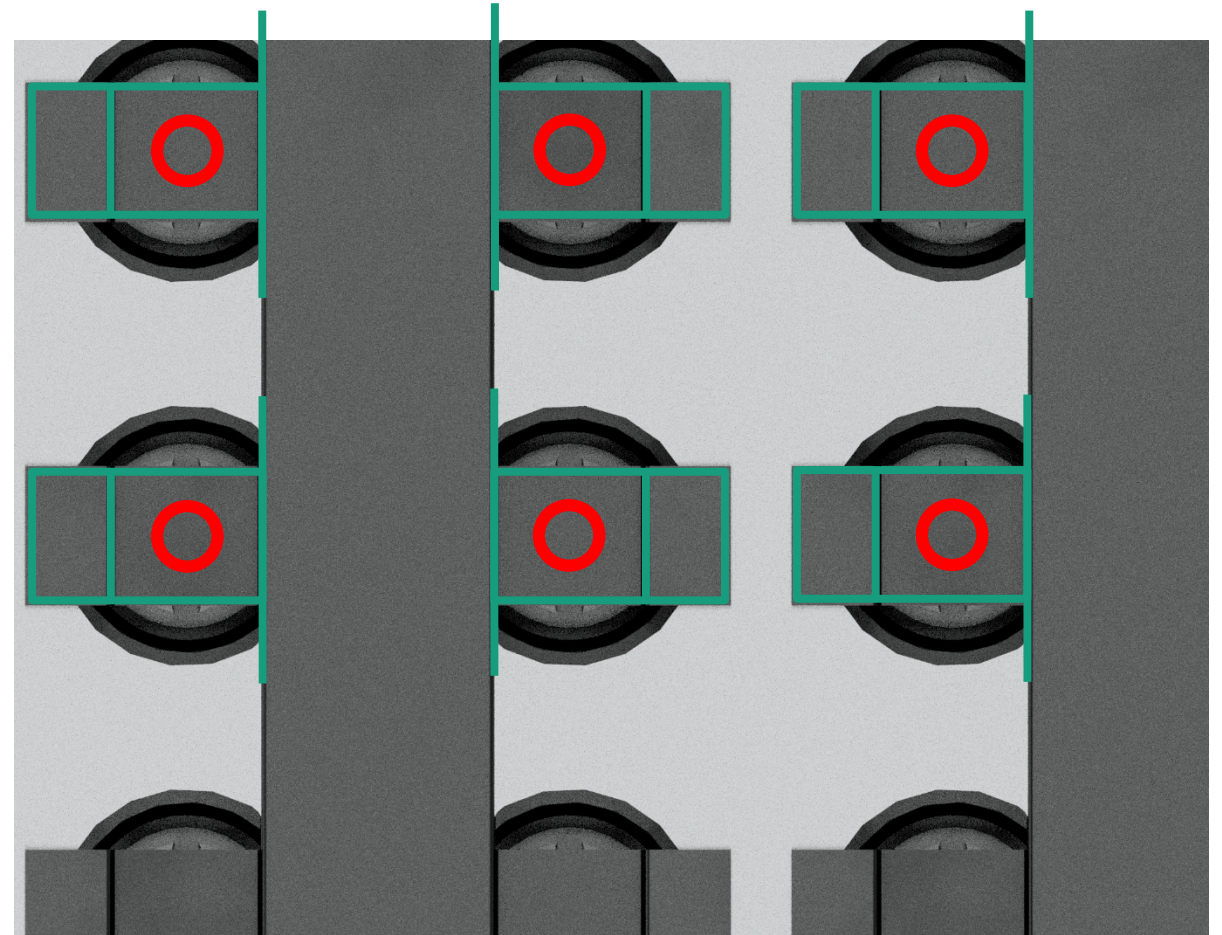
Processing head -

in micromachining typically scanner with F-theta lens

Reference path

Probe

Section of measurements

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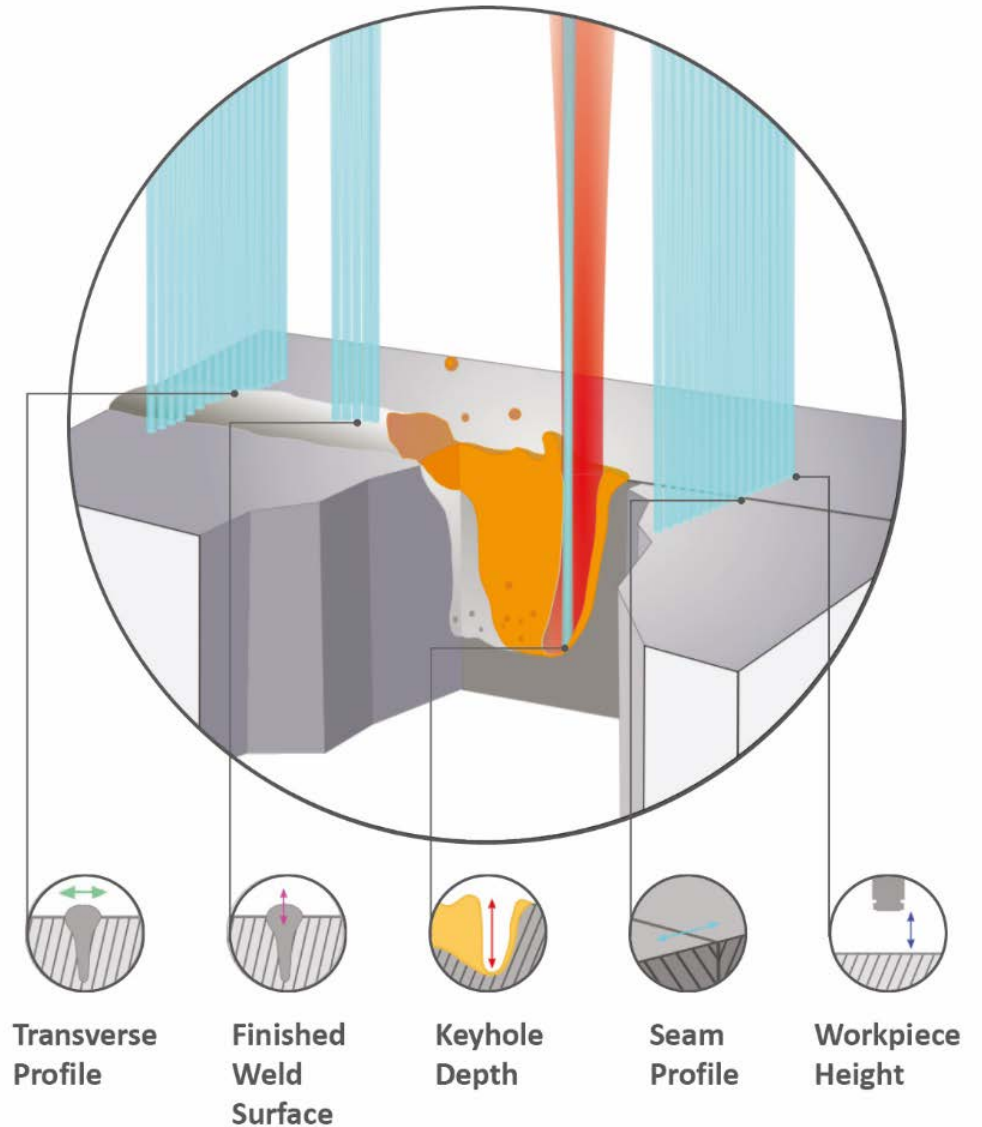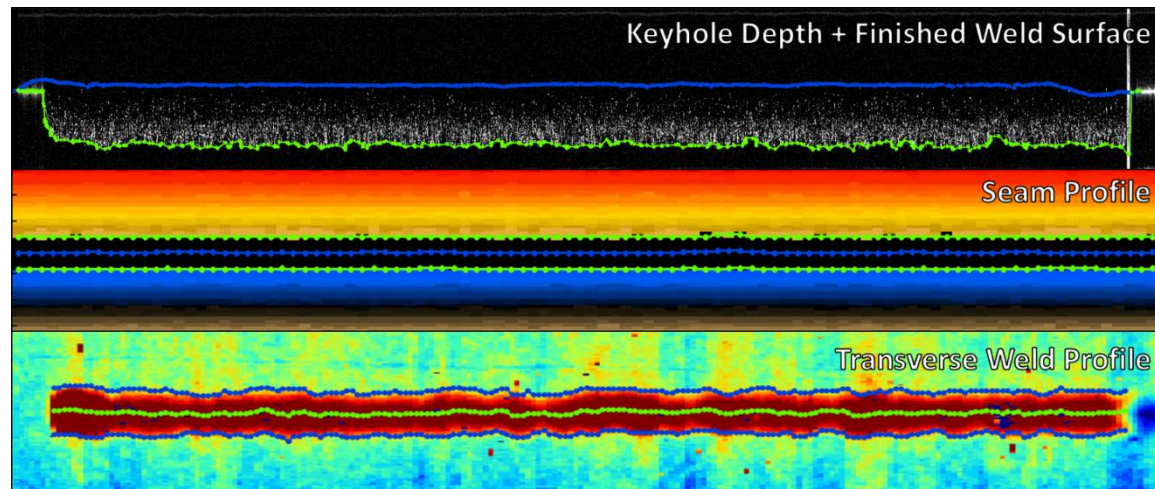
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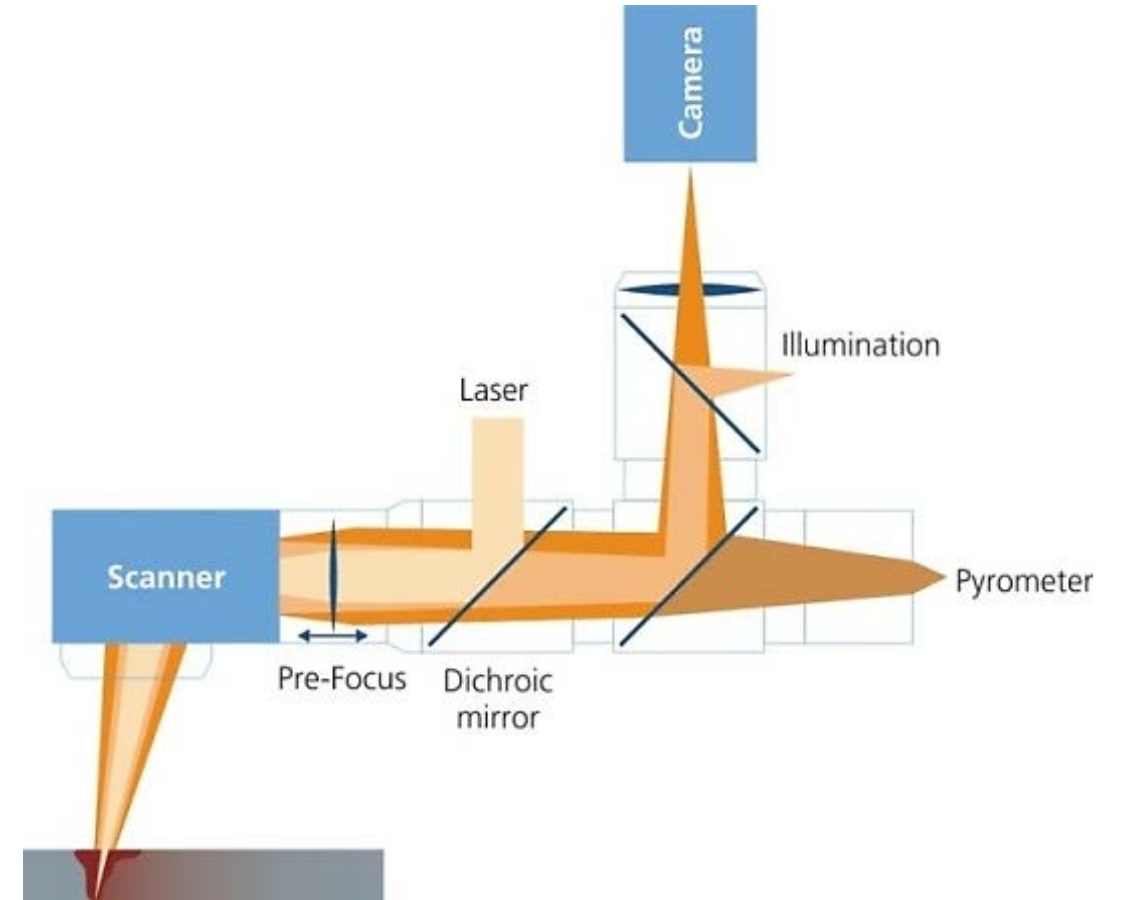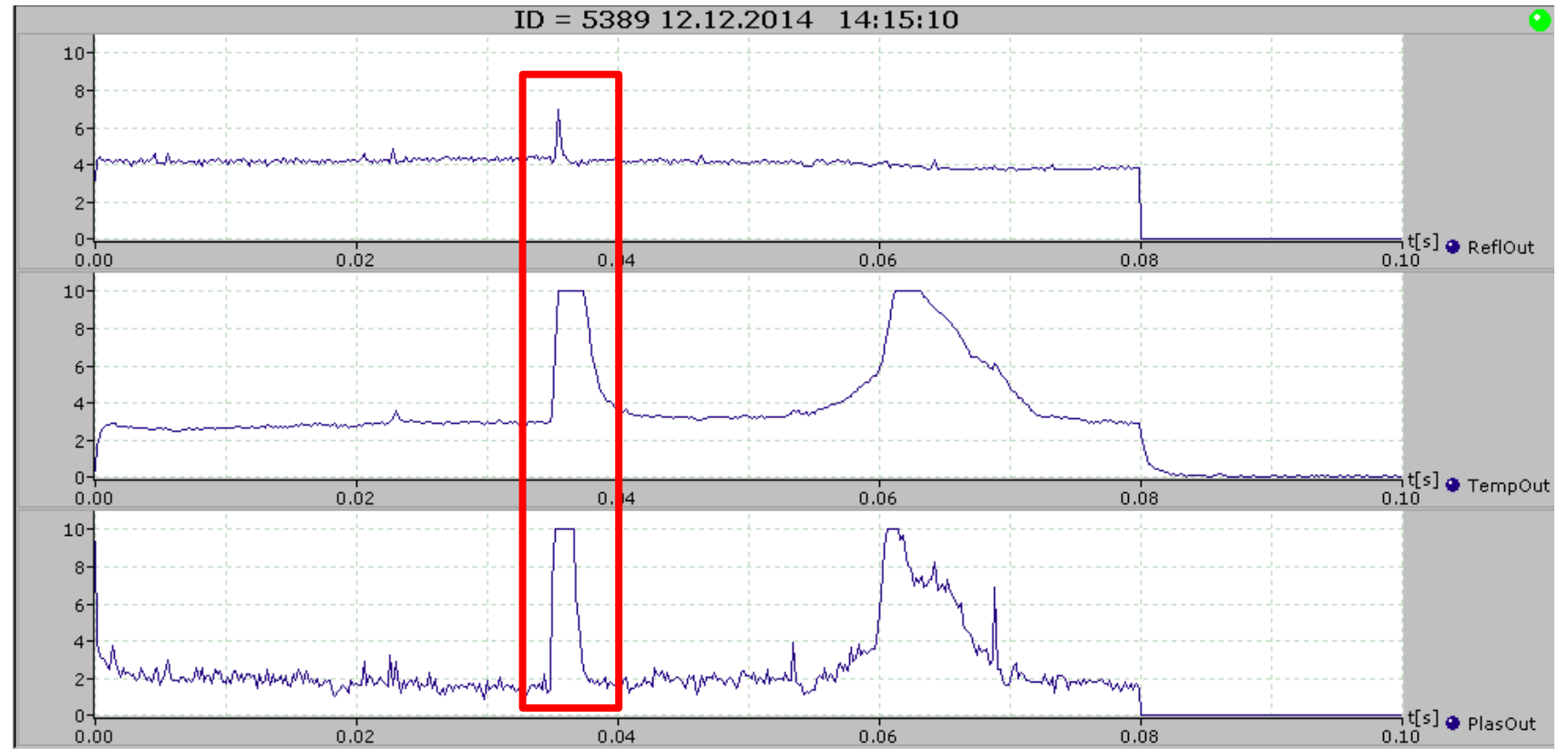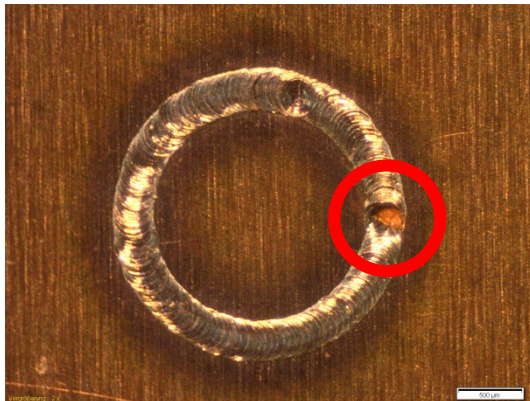
Coaxial integration of

- **Photodiodes / pyrometer**
  - Incomplete penetration or lack of fusion
  - Burn through
  - Blowouts
- **Microphones**
  - Incomplete penetration
  - Cracks
- **Camera with / without illumination**
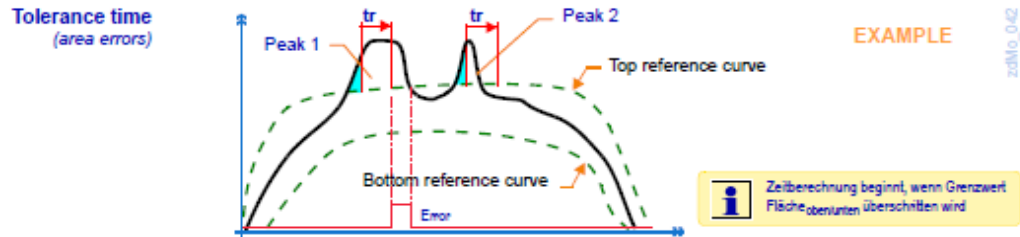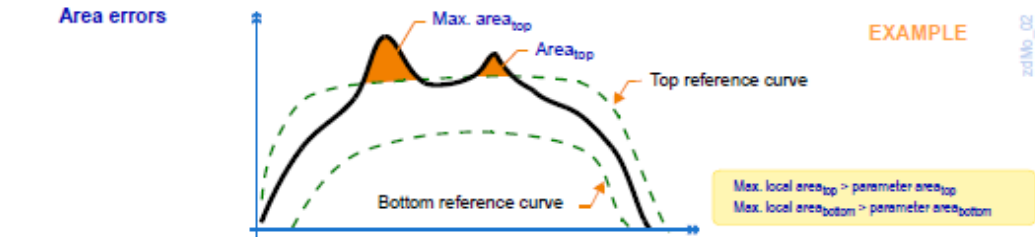 - Weld pool, seam and keyhole monitoring
  - Spatters
  - Welded geometry
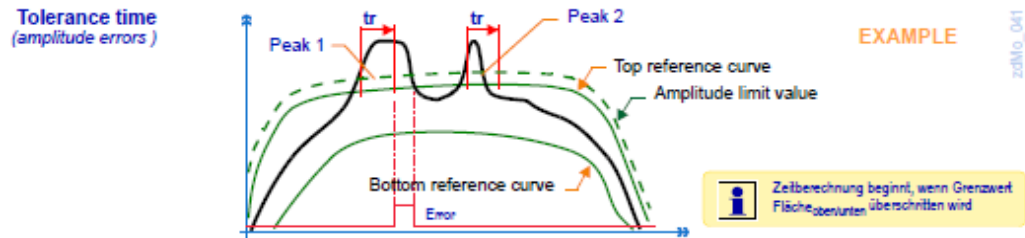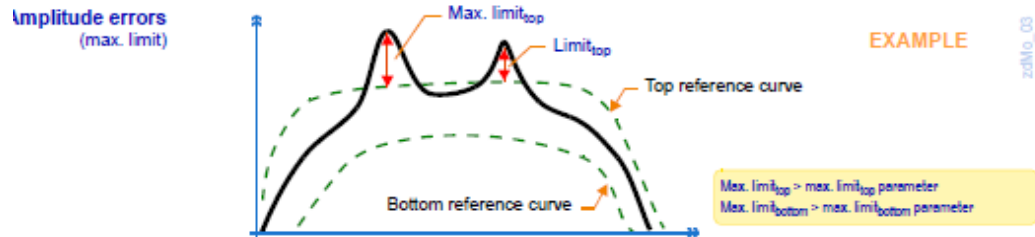
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908 / 1339μm

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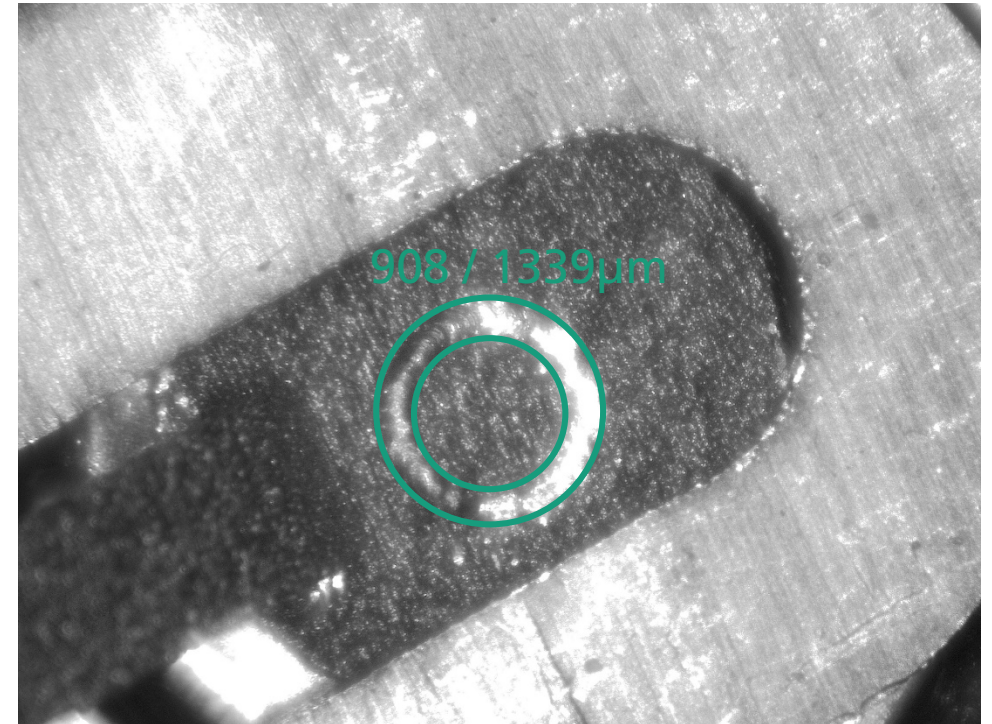
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- Detection of burn throughs

Train the computer to be an expert!

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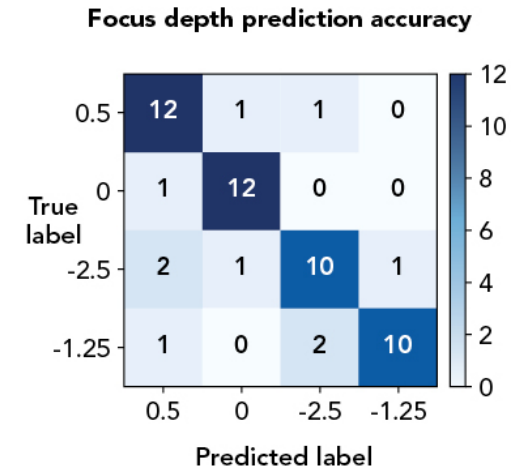
- Machine learning can use full waveform data

- Algorithms can identify "interesting" sections of the waveform data

- Extracted data features from each of these sections

- Identified which features are important for modeling or prediction tasks.

https://www.industrial-lasers.com/articles/print/volume-33/issue-3/features/data-usage-improves-process-monitoring-in-laser-welding.html
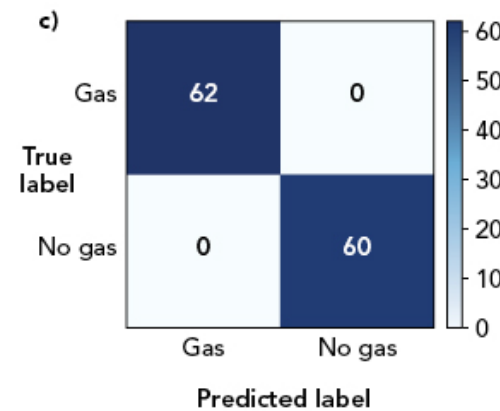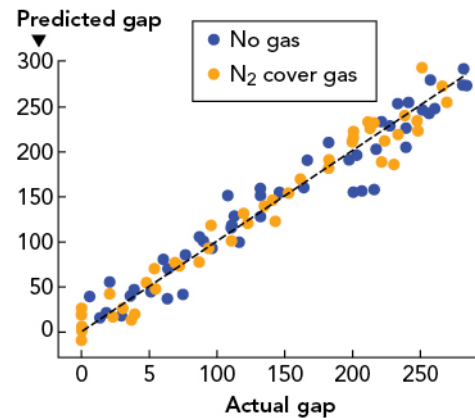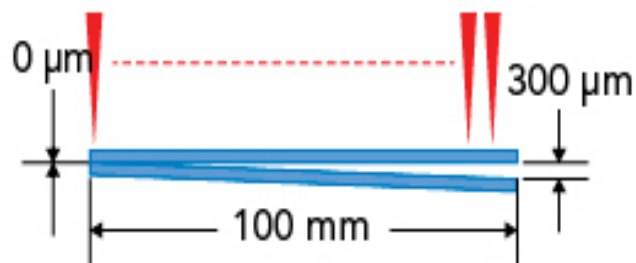
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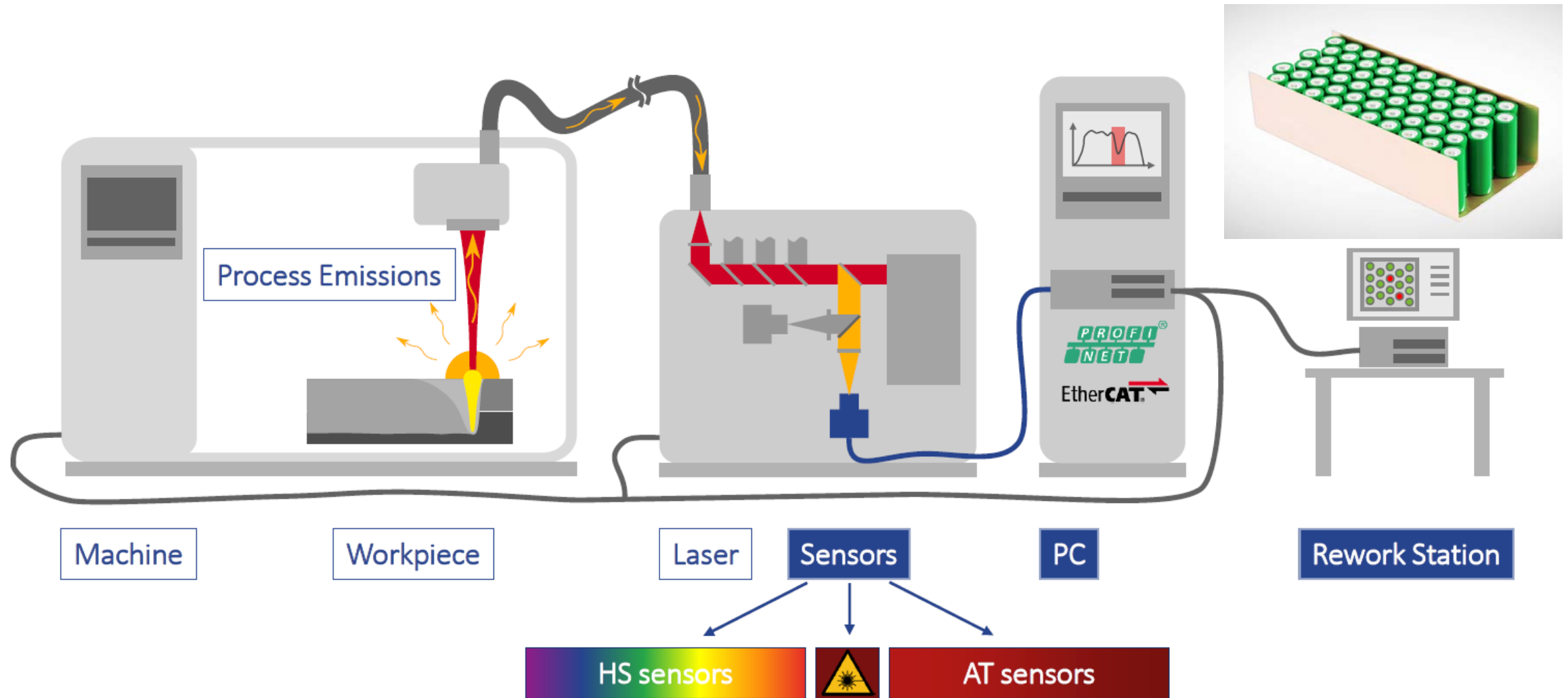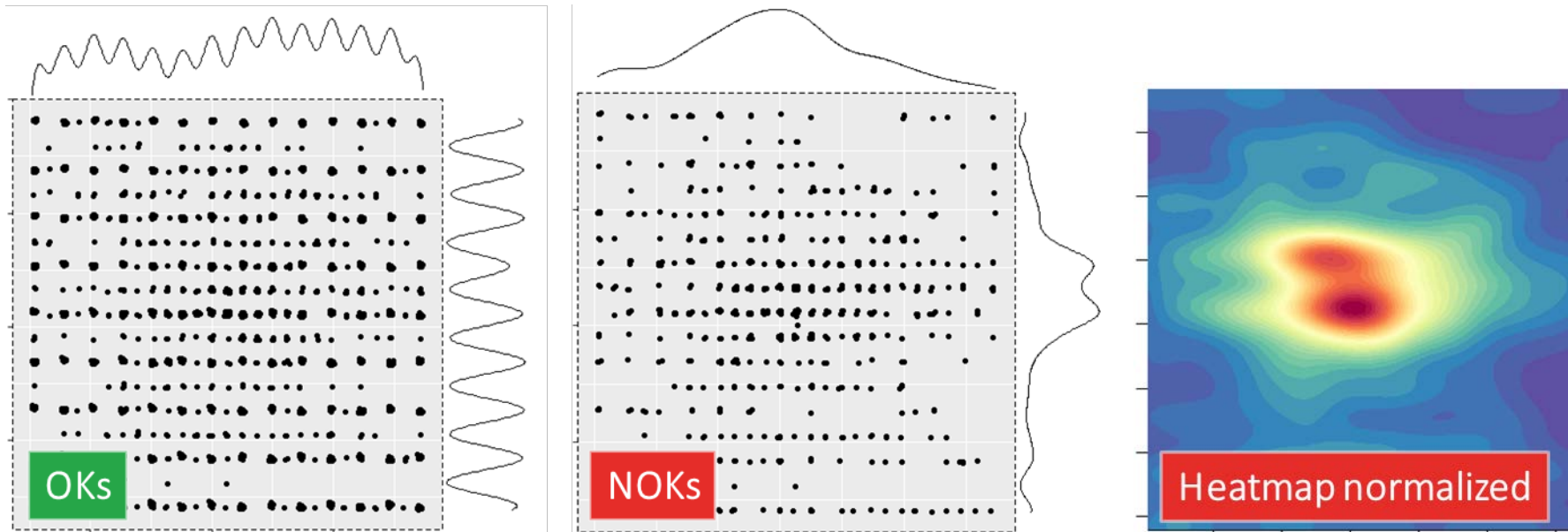
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Example: Fully automated monitoring battery pack welding

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Example: Fully automated monitoring battery pack welding

- No increase of cycle time for in-situ quality assurance

- Traceability of pack-ID, cell-ID, etc. through integrated database

- Results transferred to machine and rework station fully automatically

- Automatic rewelding strategy possible

- Machine learning to optimize detection rates and classification possible

OKs

NOKs

Heatmap normalized

Example: Scan field of 30.000+ welds shows: machine calibration may be improved in center

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