Joining Sub-Platform

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Partners

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Objectives

The RADICLE project aims to create a multi-sensor, real-time adaptive control system for laser welding that can deliver zero defects.

The overall impacts of successful implementation of the RADICLE technology through our consortium and the wider welding sectors will enable us to achieve the following impacts:

- 30% reduced energy usage;
- 30% reduced emissions;
- Reduction of the need for part scrappage or rework;
- Saving up to 20% - 30% of labour input;
- Reduction or removal of the need for final NDE testing of the parts;
- Giving a 35% floor space reduction;
- Improved working environment.

Positioning of the Project

The RADICLE project is about the development of laser welding monitoring in three main areas:

- The development of an optical plume analysis sensor;
- the integration of different sensors to allow them to contribute to the adaptive process control system;
- the development of an adaptive process control system that is able to process the data at high speed and optimise the laser welding parameters.

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Where we started from

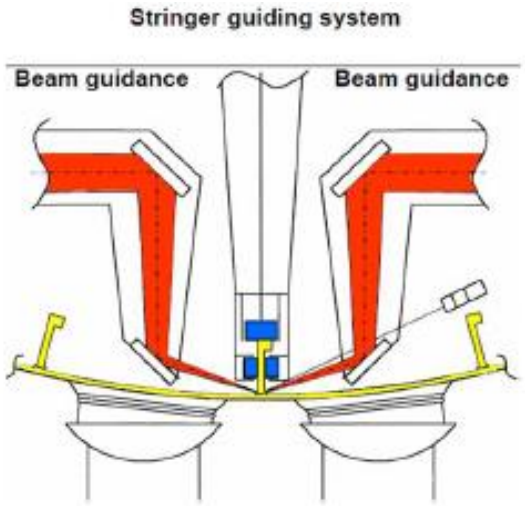
Laser Welding Process Monitoring

Loop 1: ***Seam tracking and pre-process adaptive control***

'Seam tracking' (also known as 'joint tracking') is a technique for providing real-time welding head adjustment when the joint moves from its expected position.

- Several different types of sensors have been considered for use when seam-tracking, including:

- Tactile (probe or stylus, in direct contact with the workpiece) is used to either mechanically, or electro-mechanically, position the welding head12.
- Ultrasonic (sensor in contact with the work piece) is used to perform joint tracking.
- Eddy current (where an inductive coil sets up a magnetic field in the material and a detector monitors the field strength in various positions) is non-contact and produces a continuous monitored signal. However, it can only be used with ferrous materials



Where we started from

Laser Welding Process Monitoring

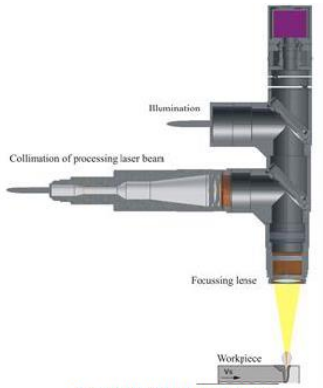
***Loop 2*: In-process Monitoring**

➢ **Process quality signals**

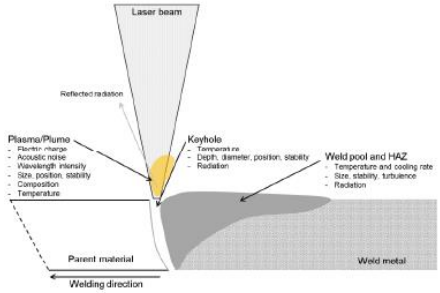
- Are used to correlate signals related to the laser-metal interaction to weld quality features, such as penetration depth and weld spatter;
- Generally, these systems examine laser-to-metal interaction to infer the quality of the weld itself.
- The current state-of-the-art for these sensors is to correlate the output from the sensor to features such as weld penetration, the occurrence of weld pores or pinholes, and the weld shape.

➢ **Operating parameter signals**

- Are related to the equipment being used to perform the laser welding process, and include laser power, welding speed, focus position.
- These are relatively easy to measure and provide absolute data regarding the input parameters being used.



Schematic of a co-axial process monitoring system consisting of an illumination source and a CMOS or CCD camera.



Overview of process quality signals available for analysis in the laser welding process.

Where we started from

Laser Welding Process Monitoring

***Loop 3*: Post-processs Welding NDT/NDE**

ULTRA SOUNDS

EDDY CURRENTS

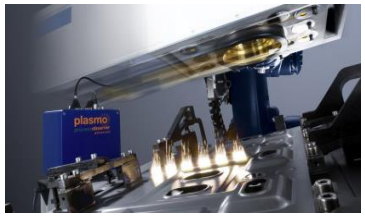
CAMERA

NON-CONTACT SURFACE MEASUREMENT

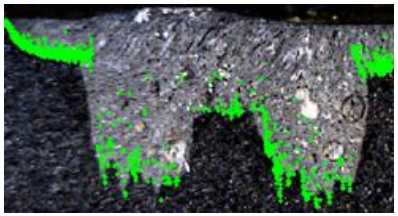
Analyses of the different equipments

Plasma detection	Reflected Laser Power
Camera (Illuminated)	Photodiode
Inline-coherent imaging	Laser Power

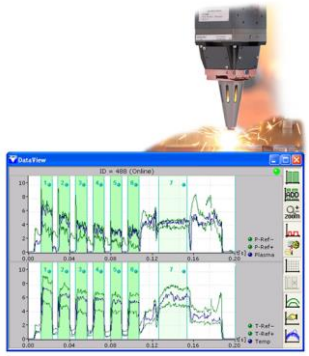
Plasmo	LLD	LWM (Precitec)	Promotec



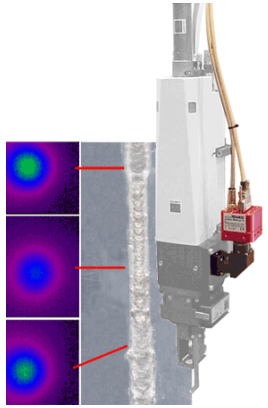
(www.plasmo.eu/site/en/)



(www.laserdepth.com/)



(www.precitec.de/)



(www.prometec.com/)

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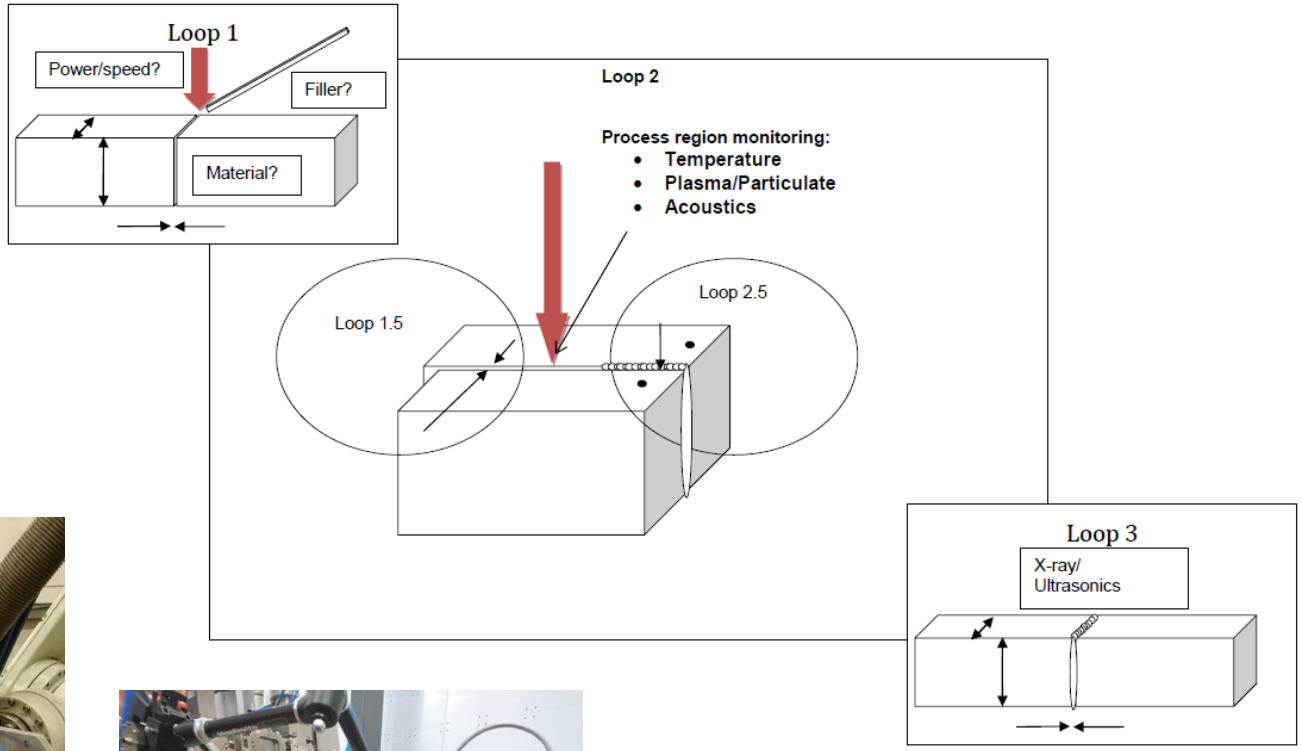
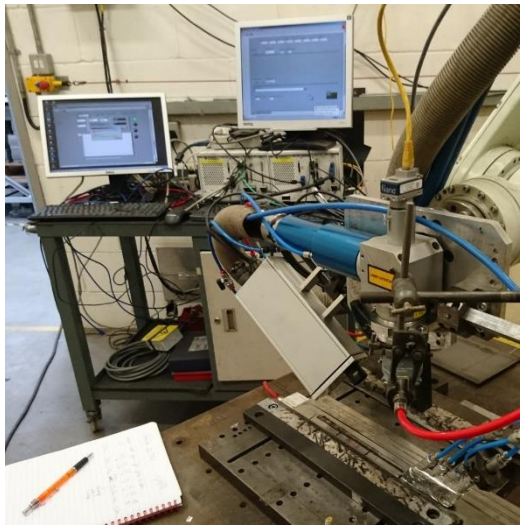
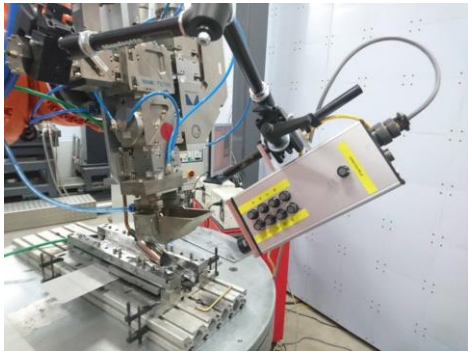
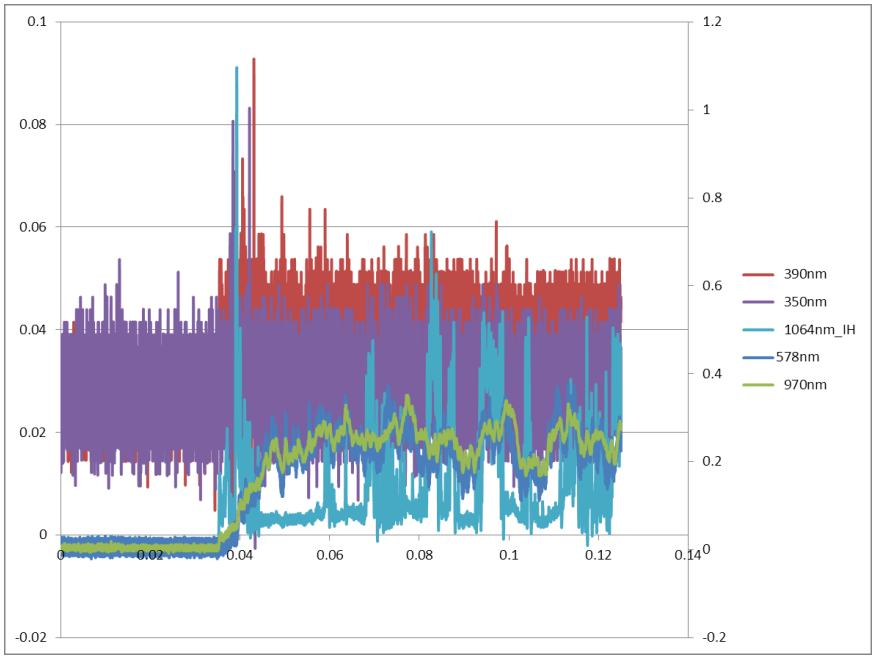
Control Loops





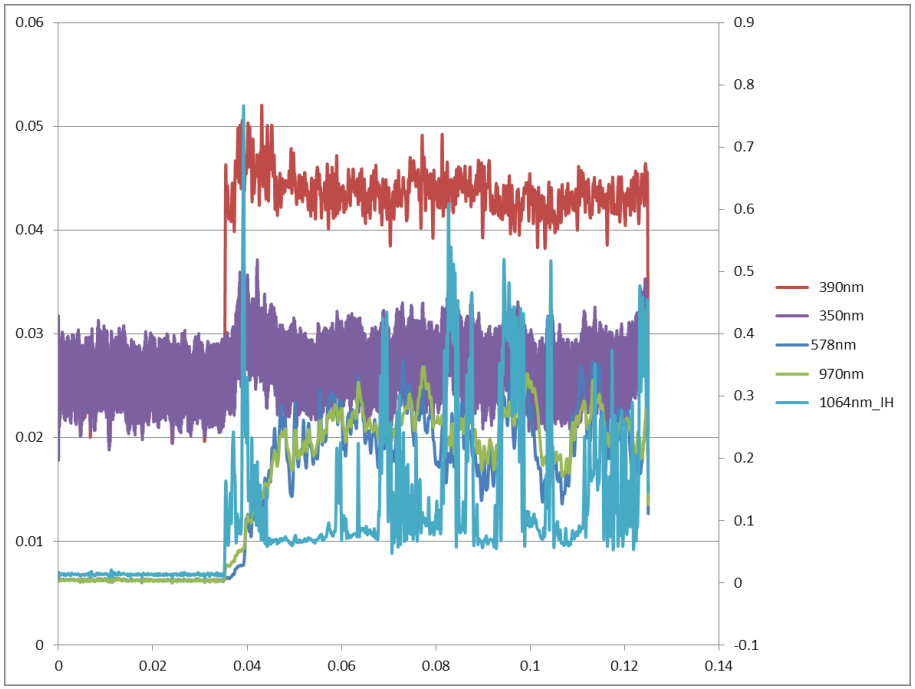


Data filtering and Sensor selection



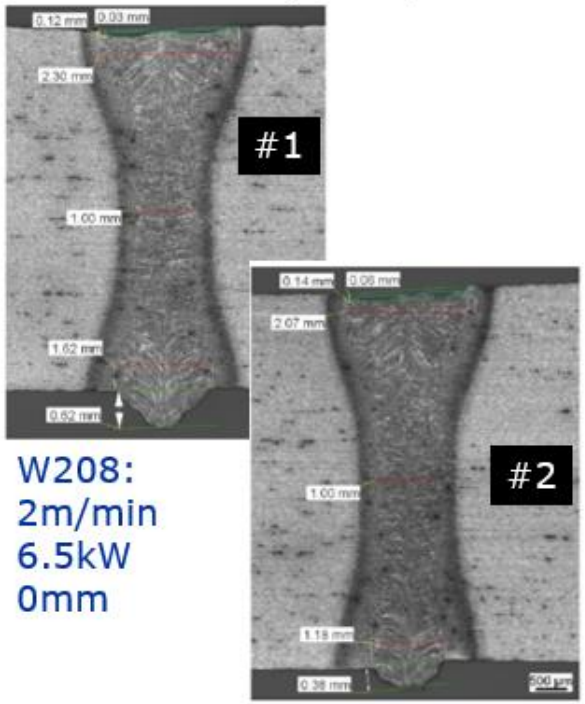
Raw

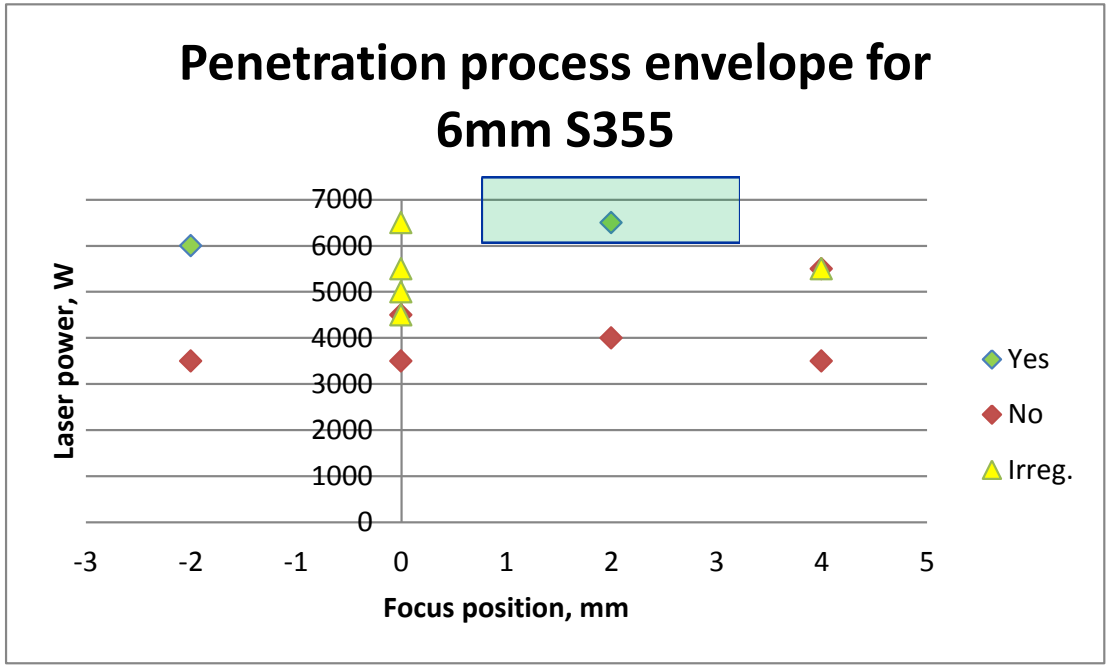
MSSA filter



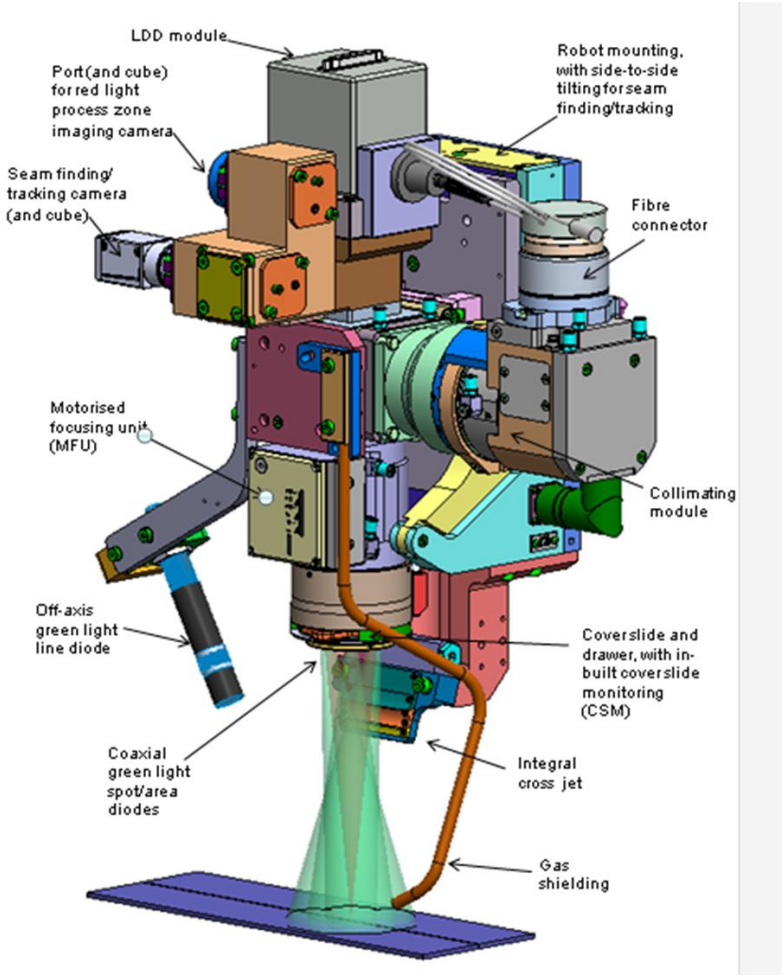
Weld quality windows

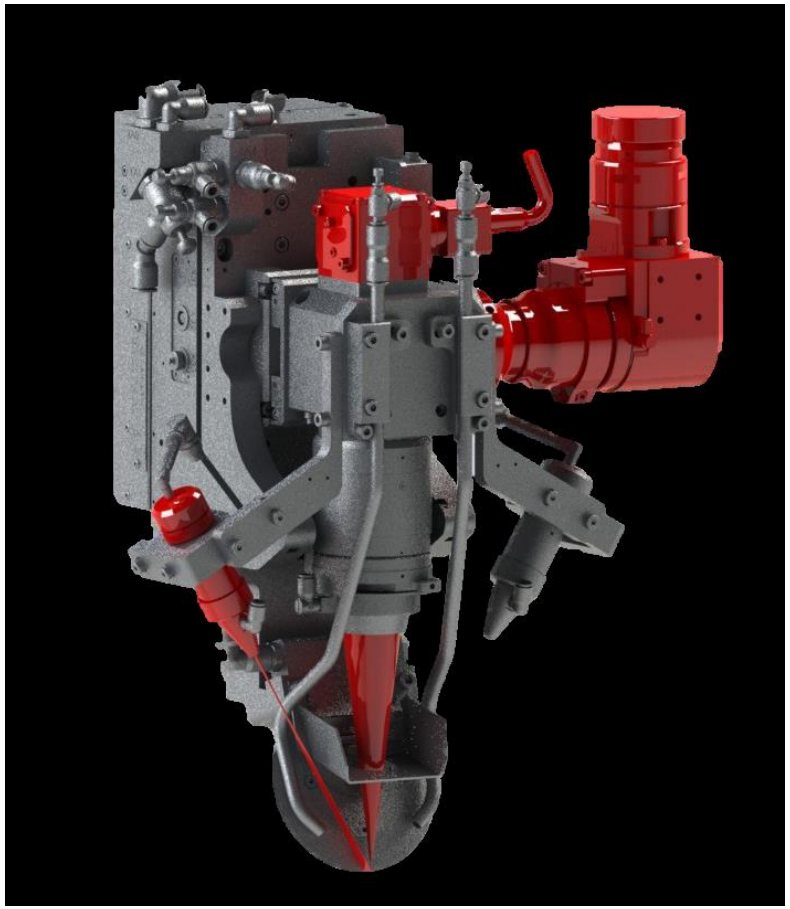
- All nominally acceptable sections





RADICLE system development





PERMANOVA Lasersystem ab

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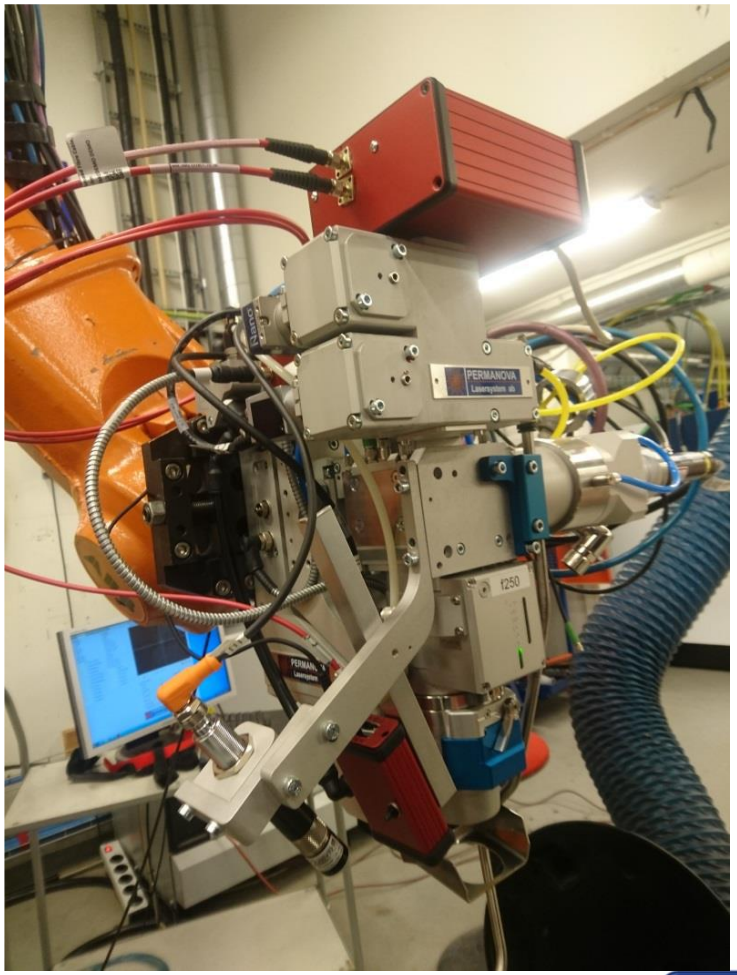
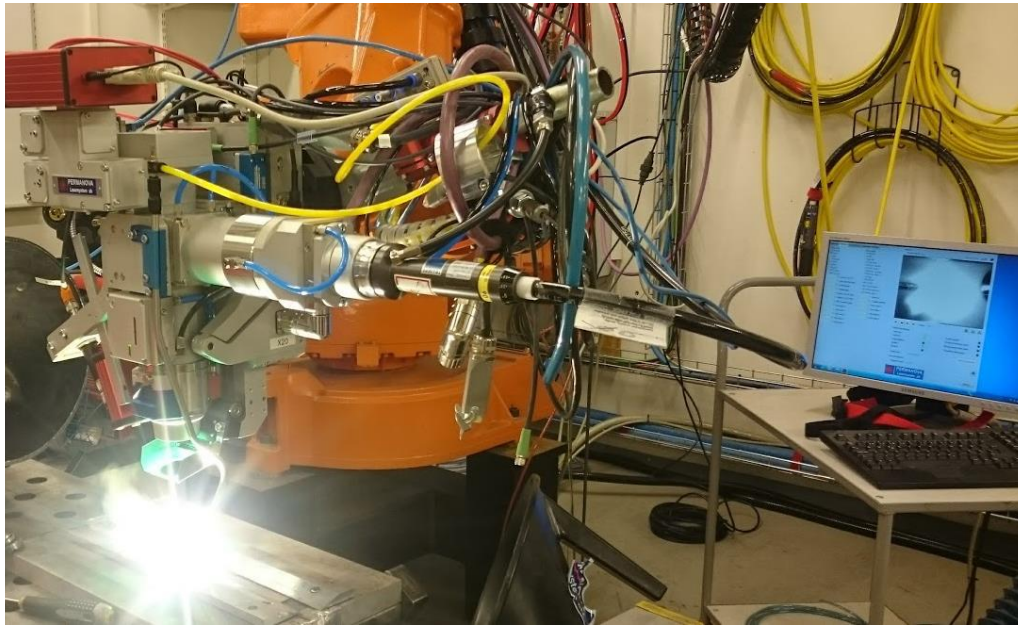
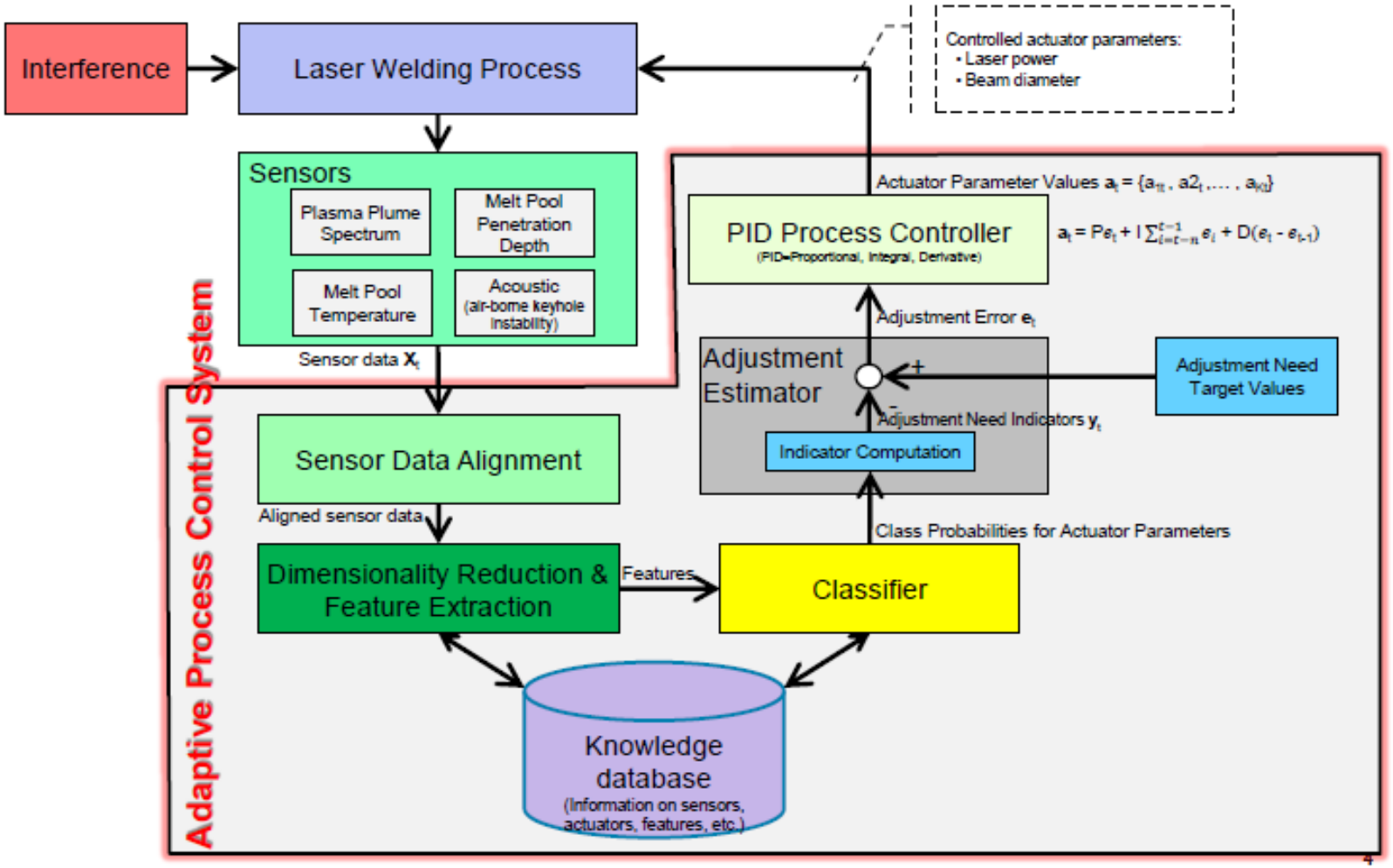
RADICLE system development





Architecture for Control



“Teaching” the System

1 st – Define the stable parameters for the process:

- Based on customer specification for integrity and geometry;
- There may be multiple parameter regimes for stable processing.

2 nd – Map how defects manifest with changes in parameters.

Allowing the system to be:

- Independent of the application;
- Able to work with diferente materials.

“Teaching” the System

Typical defects	Detection duty (1=low….5=high)	Dimension
Pores	4	Diameter of normal pores should not exceed 1.0mm
Micro-pores	2	Pores less than 0.2mm in diameter
Cavity	5	Pores with diameter greater than 1.0mm
Fusion-weld seam	5	No welding is present in the seam, which looks like laser fusion weld seam
Poor connection of welding	4	Welding is not connected to the sides of work pieces and the seam at the point of connection looks like "scattered wisps"
Single-sided connection of welding	5	Welding is connected to one side only
Irregular weld seam	2/3	Weld seam is dented or raised
Scaled piling	2/3	The surface of weld seam is not smooth and looks very rough;
Problem at the front/end of welding seam:	2/3	Insufficient or excessive infill at the weld seam at the edge of the work piece, or un-melted welding residue is found on the orbit

What are the optimal mitigration strategies?

How it correlates with loop 1 and 3 measurements?

What sensor set detects best (per process/material)?

How does it typically occurs?

Development and integration of control algorithms

a) Set of **features** that describe the welding process reliable and with proper resolution;

b) **Machine learning techniques** to teach the system state of the welding process and possible actions;

c) **Action selection mechanism** that uses the information available according to the process parameters that can be changed.

Identifying the Industrial Needs

Application	Material	Thickness	Configuration	Key issues
1 	INCONEL Ti SS S355	3mm, 6mm, 11mm	Butt	Porosity. Surface geometry.
		1mm, 3mm, 8mm	Butt	Cracking. Surface geometry.
		1.2mm – 1.2mm	Overlap	Material ejection. Cap underfill.
3 		0.6mm – 10mm	Overlap (partial penetration)	Cracking.
Generic material: No specific target application		6mm	Butt	Cracking. Porosity.

Future Work

The RADICLE project enters it final year it will develop the following:

- Validation of RADICLE system against process windows already defined.
- Algorithm training to allow for fault correction
- Validate with End-user case studies

Questions

RADICLE
Real-Time Dynamic Control System for Laser Welding

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