

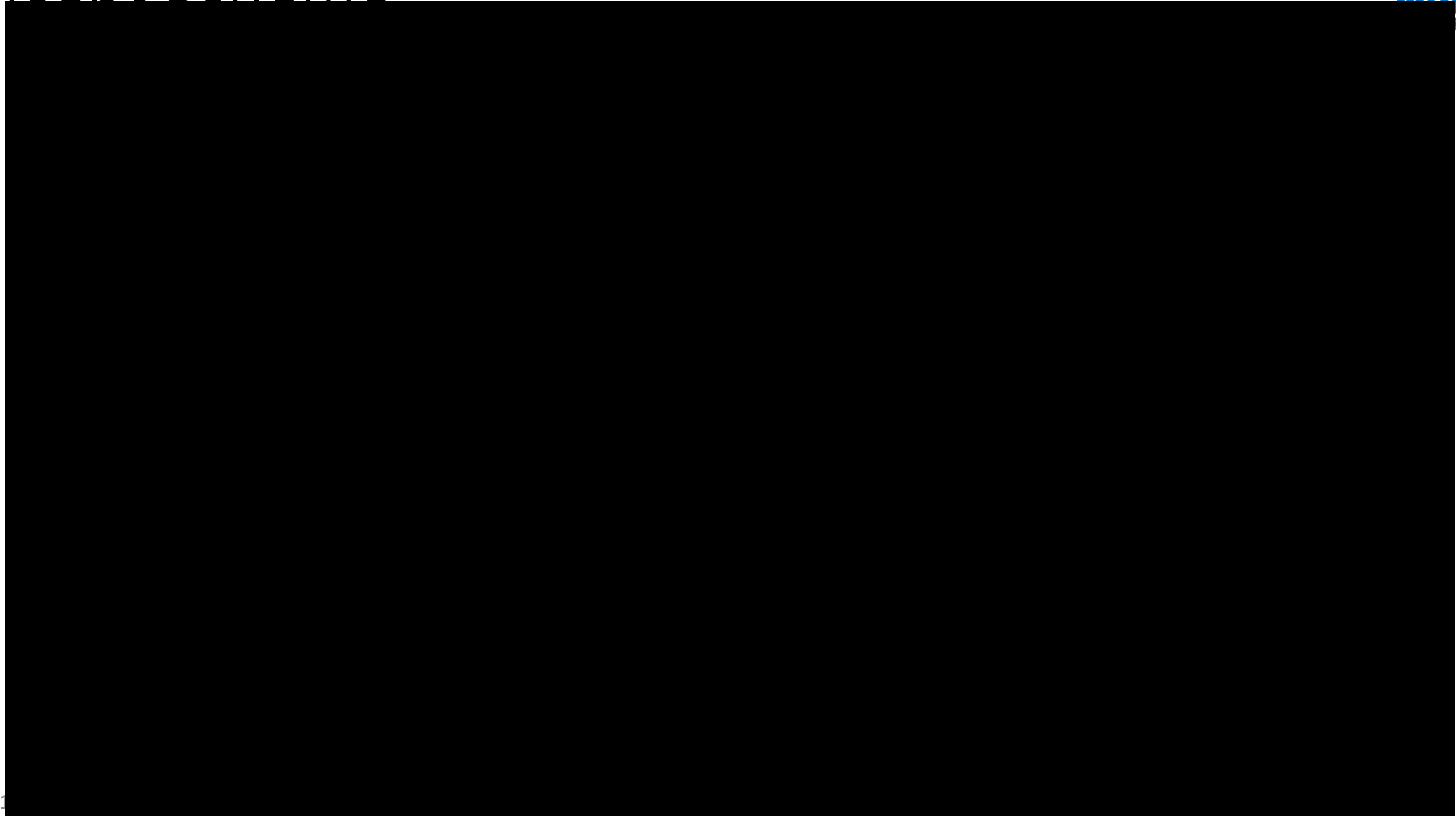
Development and Pilot Line Validation of a Modular Re-Configurable Laser Process Head

Task 1.5 – Training

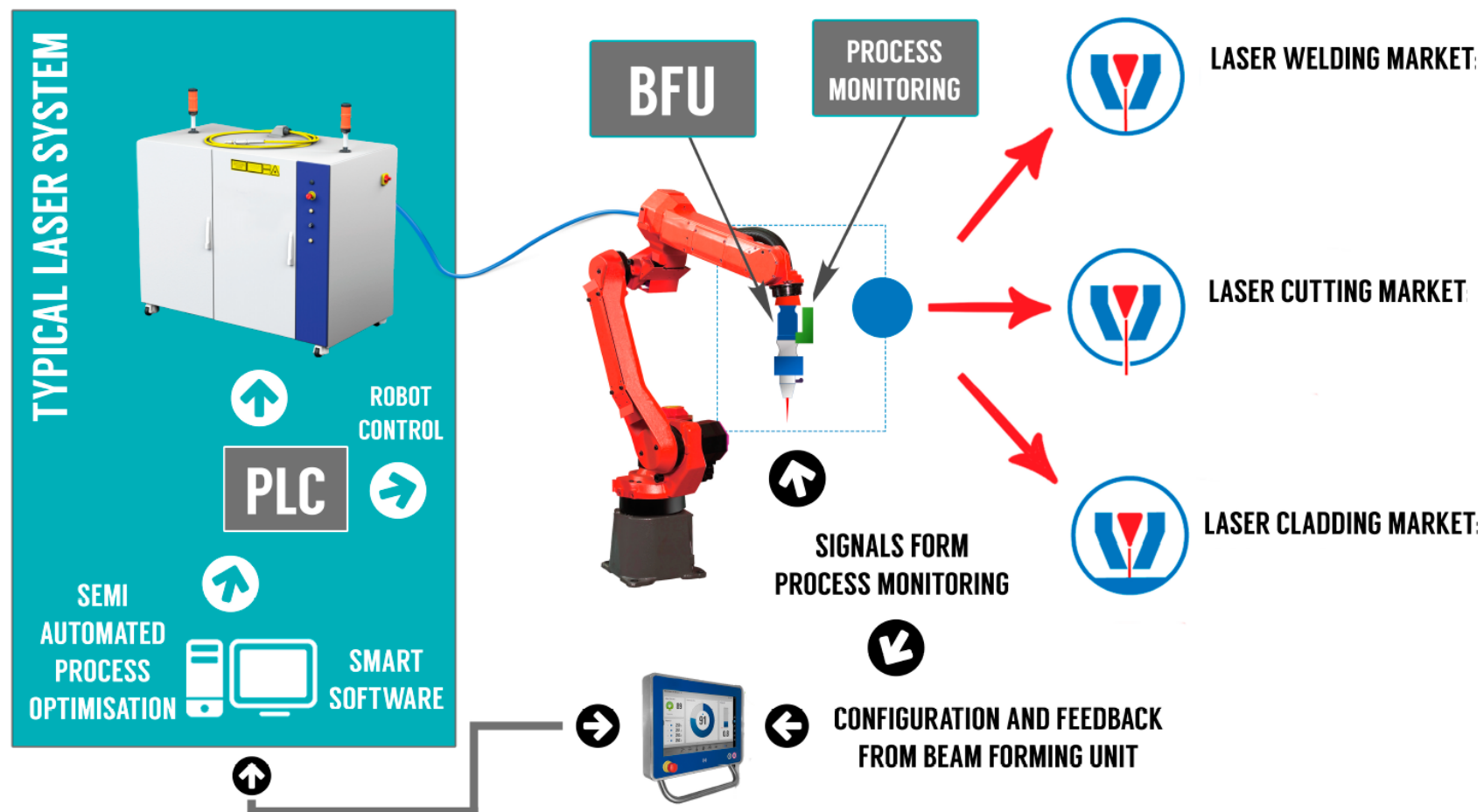
Introduction

- The Modulase project was created to develop a re-configurable laser processing head capable of performing three different processes: **welding**, **cutting** and **cladding**.
- The system is able to perform the three different processes through the use of three modular end-effectors.
- Modulase also includes in-process monitoring through the use of intelligent sensor technologies.
- The monitoring system allows for adaptive process control, quality assurance, and semi-automated process parameter configuration.

Concept Scheme



Concept Scheme

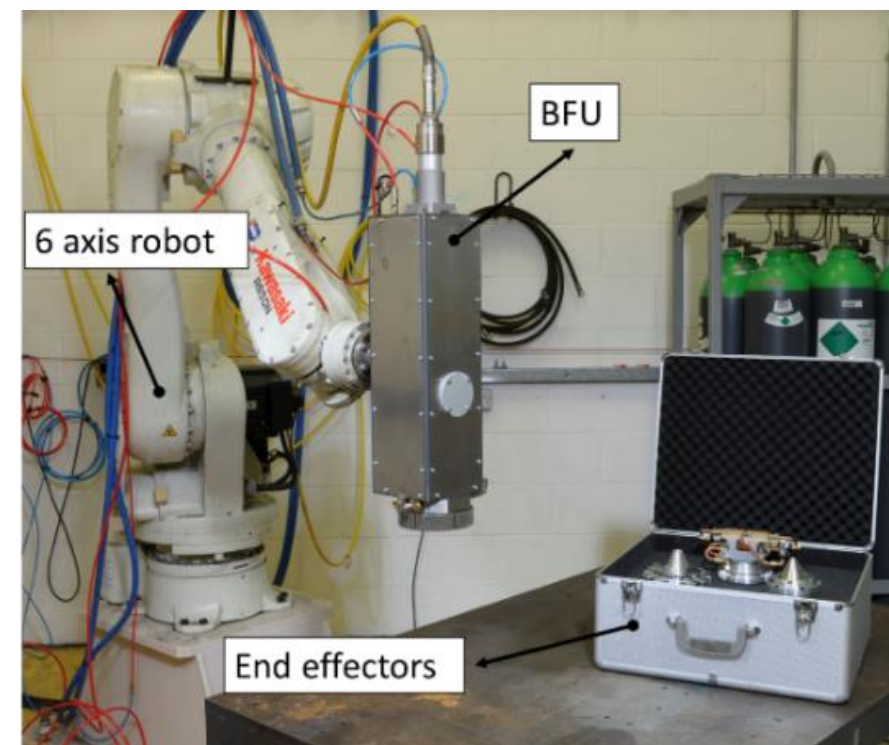
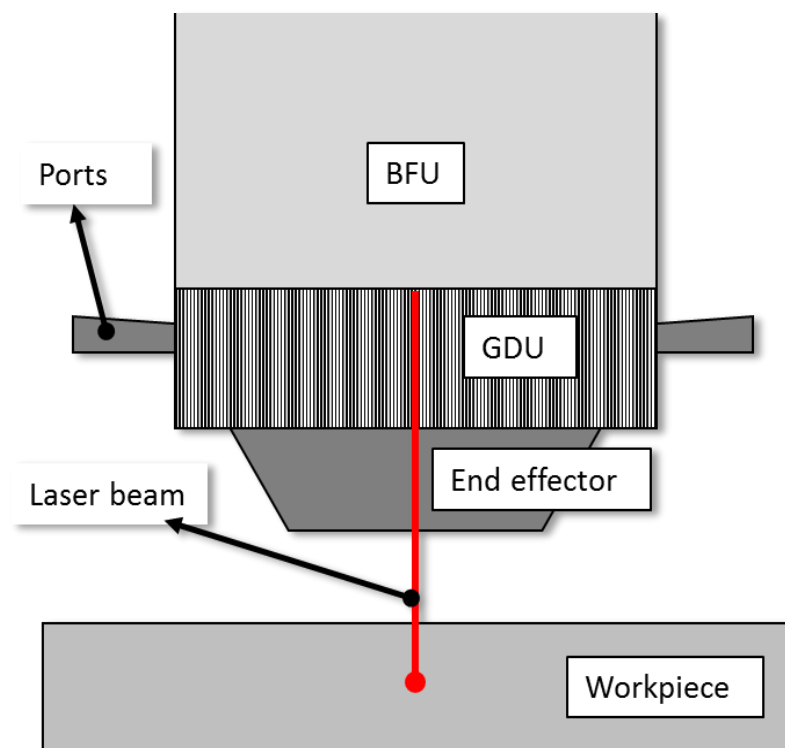


Equipment development – *from concept to prototype*

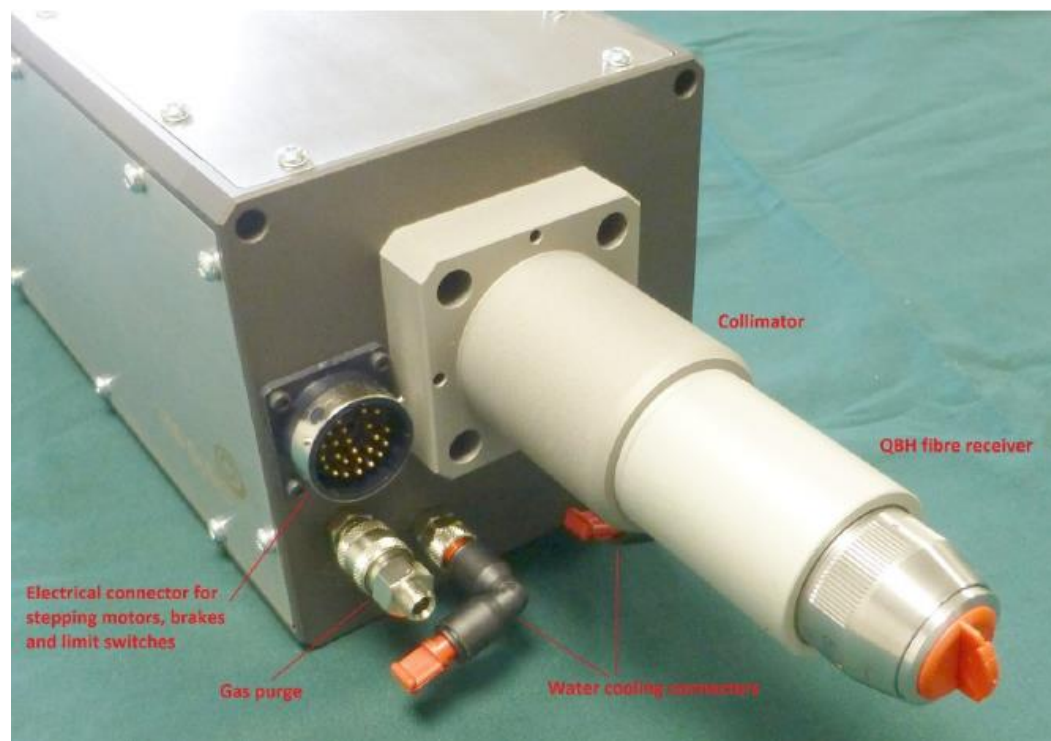
- Beam Formin Unit – BFU
- Gas delivery unit – GDU
- Modular end effectors
- Camera-based quality assurance unit
- Integrated software interface

The system includes dedicated software with a knowledge database and board algorithms which allow for the correct settings and process parameters to be calculated for each application. The camera-based monitoring unit is integrated into the processing head and is compatible with all three of the processes performed by the system.

Equipment development – *from concept to prototype*



Equipment development – *BFU*

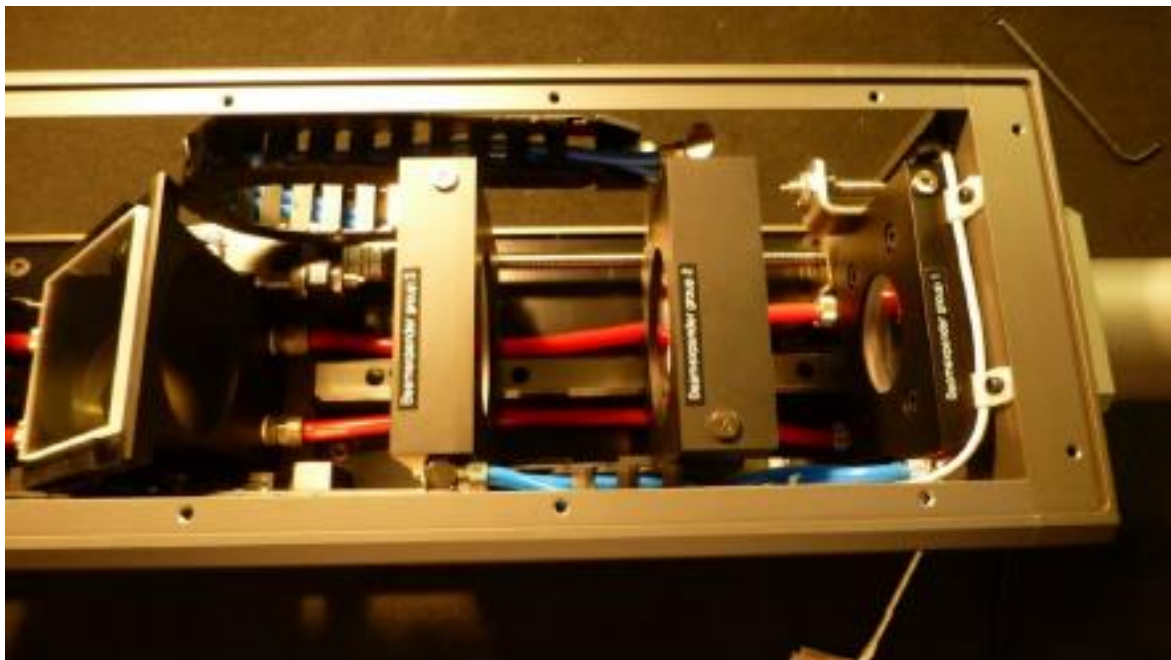


BFU Input End

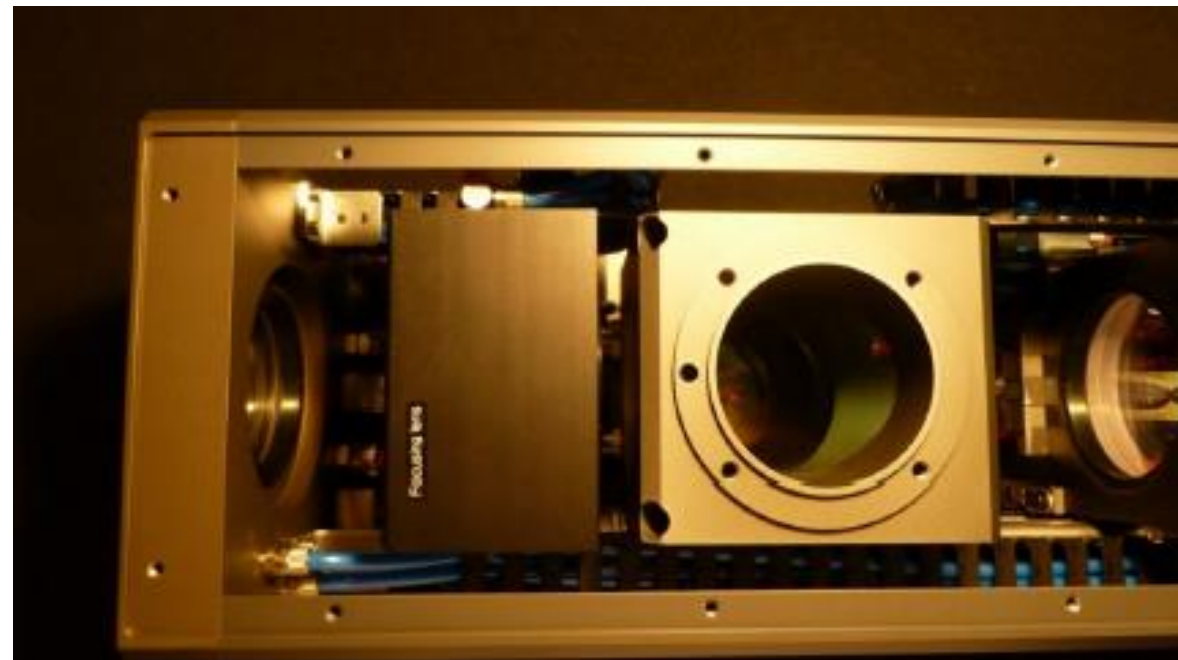


Ball screw and stepping motor

Equipment development – *BFU*

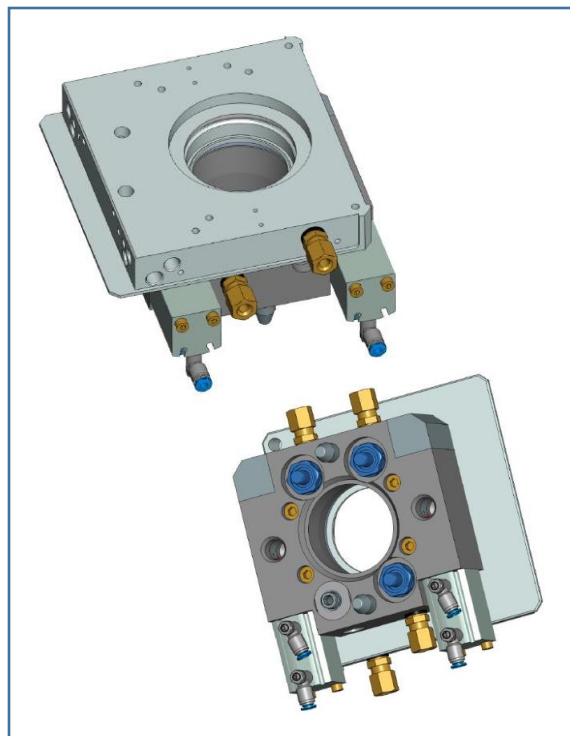


Beam Expander

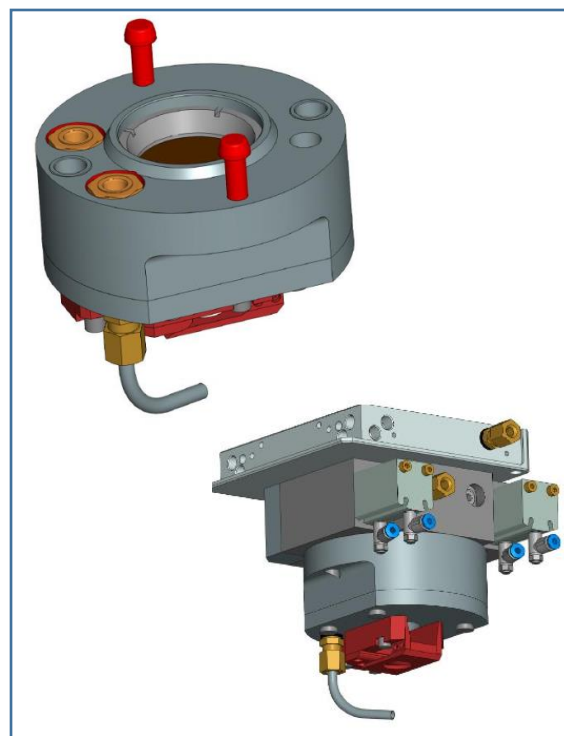


Beamsplitter and focusing lens section with process monitor port

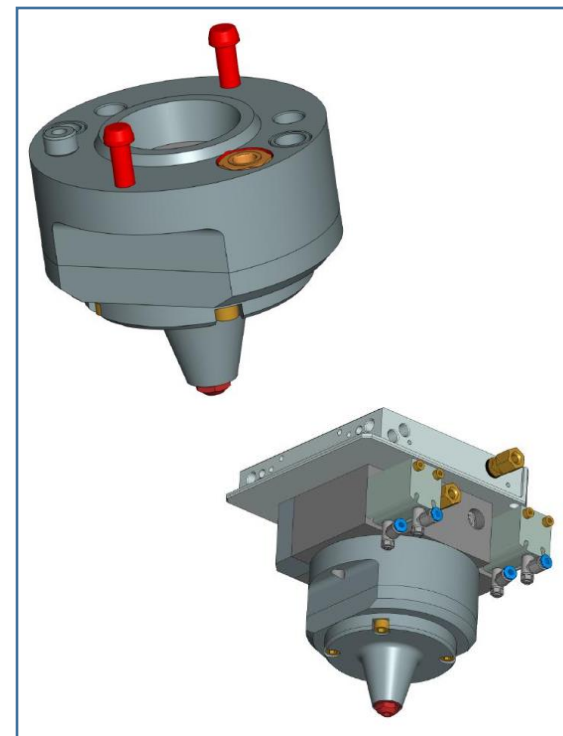
Equipment development – *GDU and End-effectors Design*



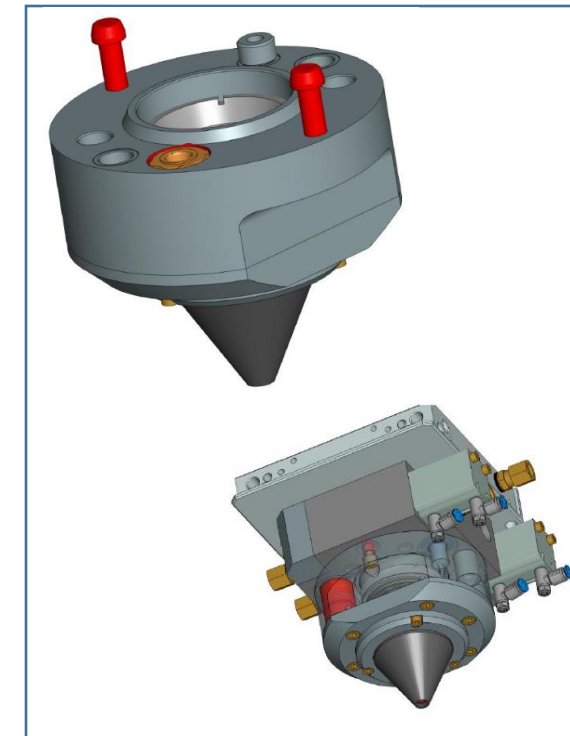
Gas Delivery Unit (GDU)



Welding end-effector

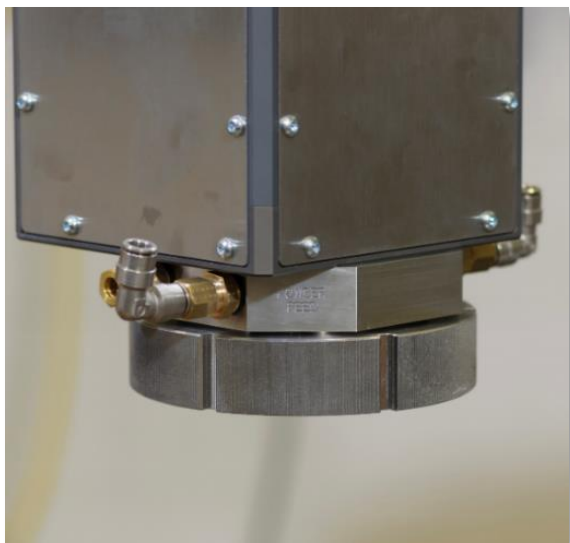


Cladding end-effector

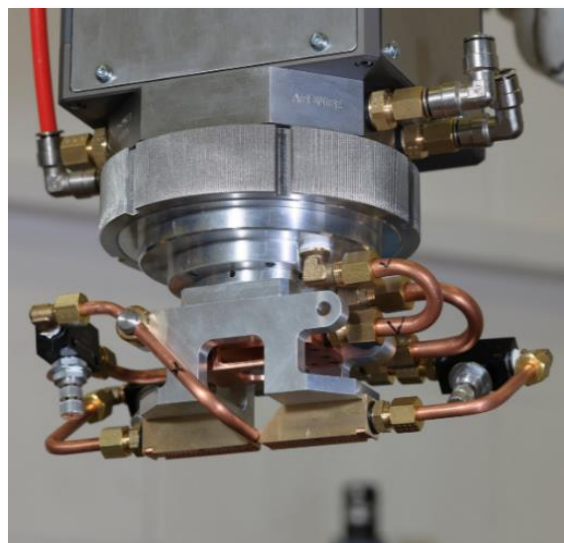


Cutting end-effector

Equipment development – *End-effectors*



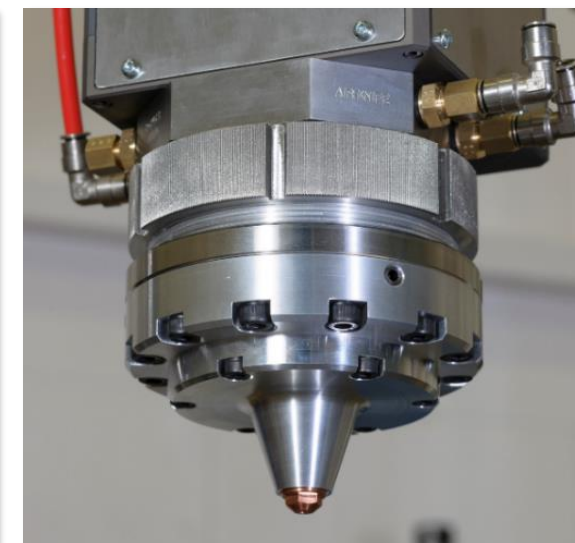
Gas Delivery Unit (GDU)



GDU and Welding
end-effector



GDU and cladding
End-effector



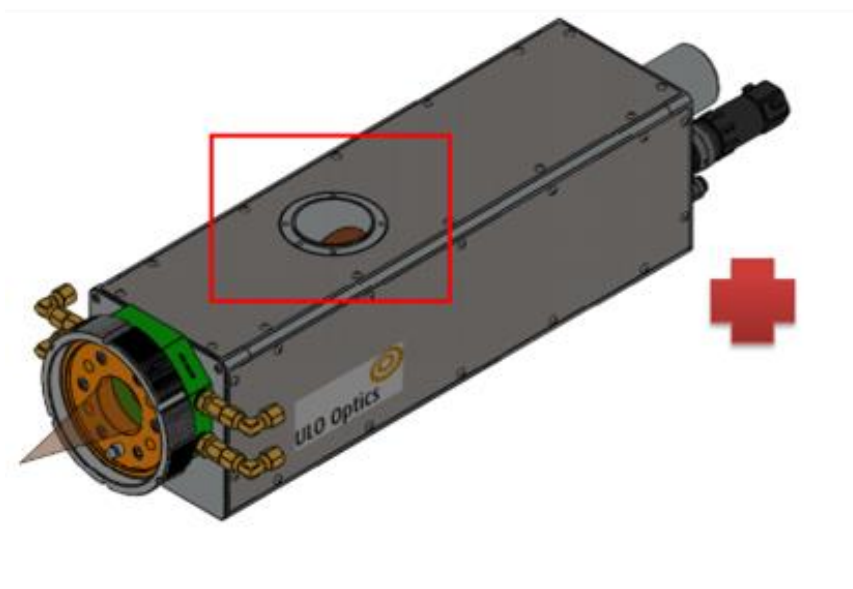
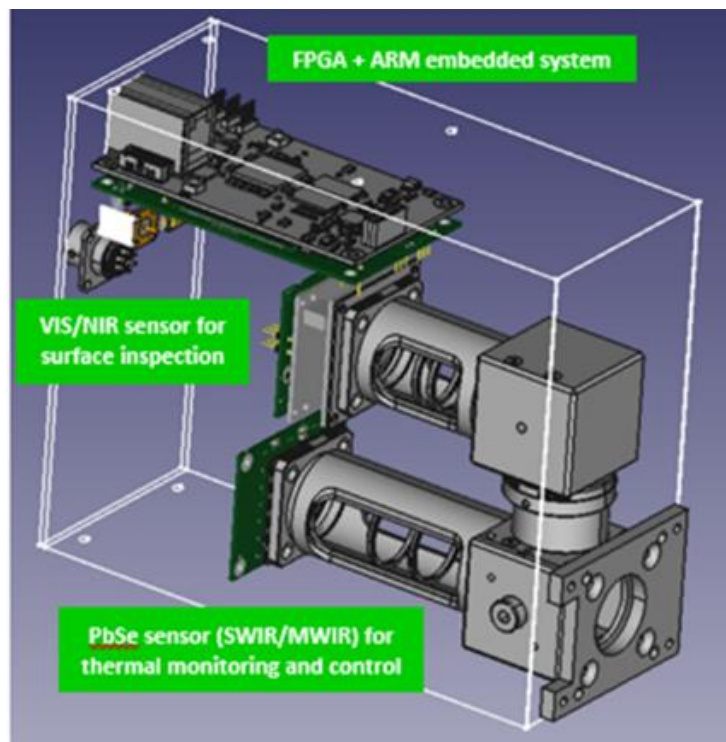
GDU and cutting
End-effector

Quality assurance

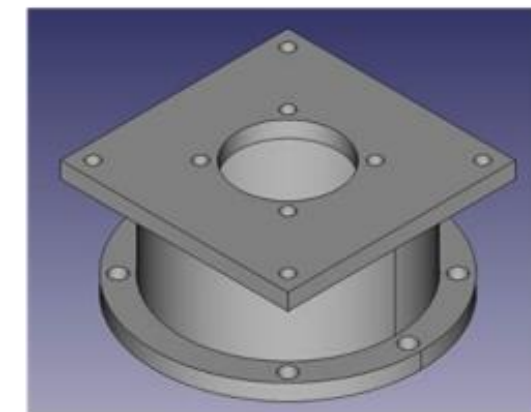
- ✓ Effective and compatible with the three different laser processes
- ✓ The arrangement includes camera-based sensors which cover different spectral bands from visible (VS) to infrared (IR) embedded electronics and optical components
- ✓ The molten bath is monitored in real time
- ✓ Deviations from stable reference conditions are captured, localized and identified as anomalies of the process



Quality assurance – *System design and optical design constraints*



Coupling optical system.



Quality assurance – *Process Validation Trials – Cutting Case*

Process parameters:

Material: Titanium

Thickness: 1,5mm

Power: 650W

Gas flow: 12bar

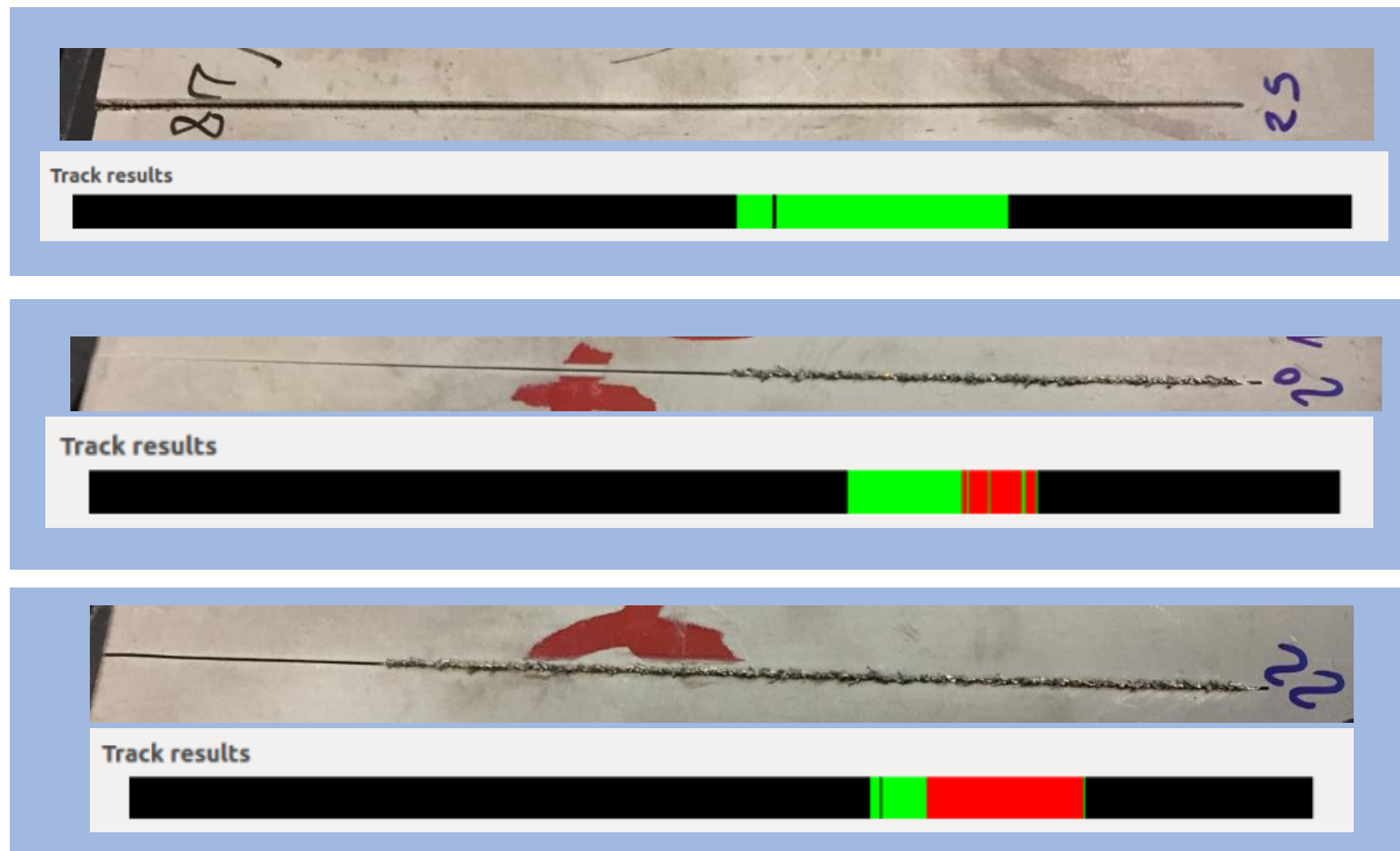
Validation Info

Laser OFF

0 OK 1 NOK

36 Ok 99 Nok

Visualizing: 27360 / 28.3 l
FPA Tmptr: 0.00 Celsius

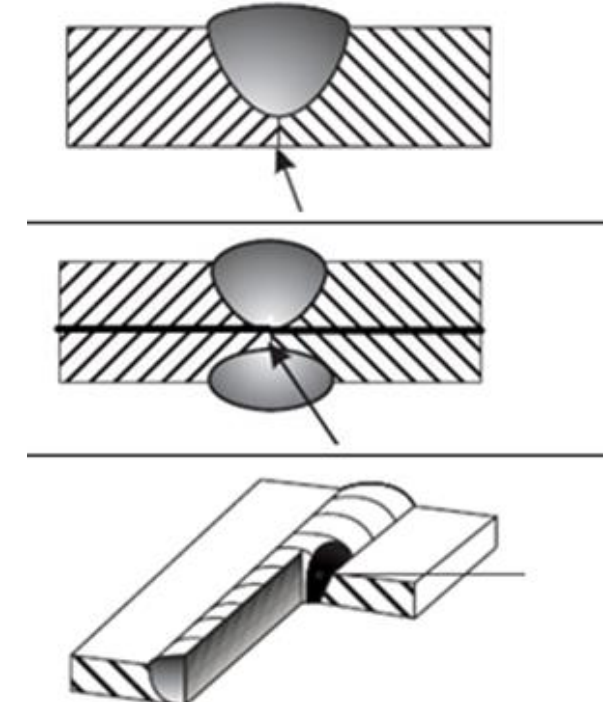
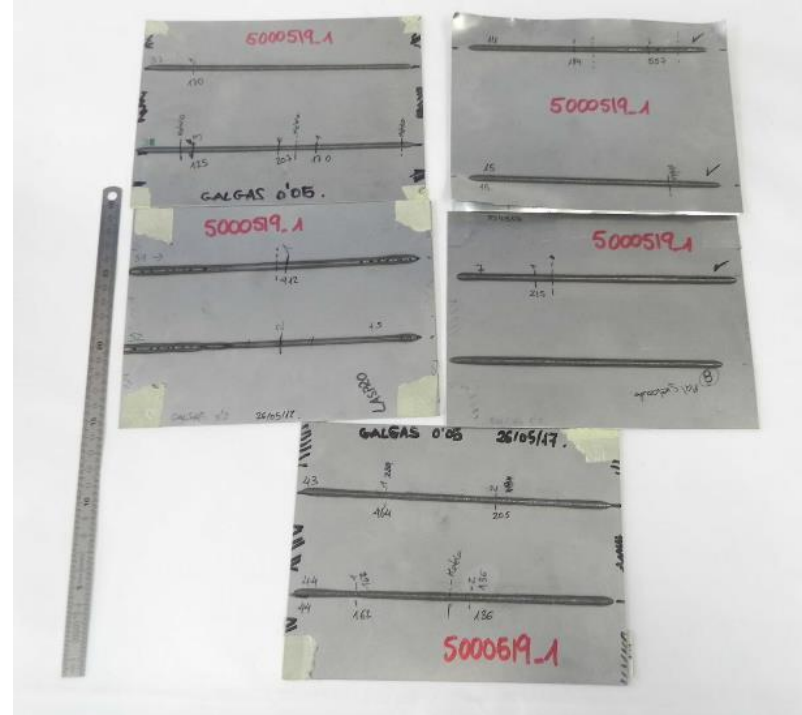


The three images show the results of laser cutting trials on titanium. Each image includes a 'Track results' progress bar below the cut track. The progress bars use color coding: black for 'OK' and red for 'NOK'. The first trial (labeled '28' and '25') shows a mostly successful cut with a small red segment. The second trial (labeled '22') shows a more significant red segment. The third trial (labeled '22') shows a large red segment, indicating a failed cut.

Quality assurance – *Process Validation Trials – Welding Case*

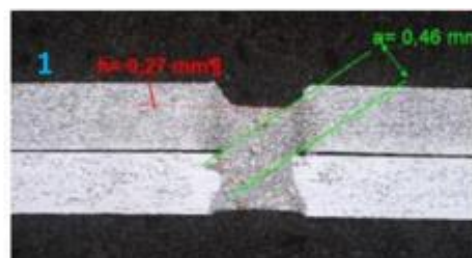
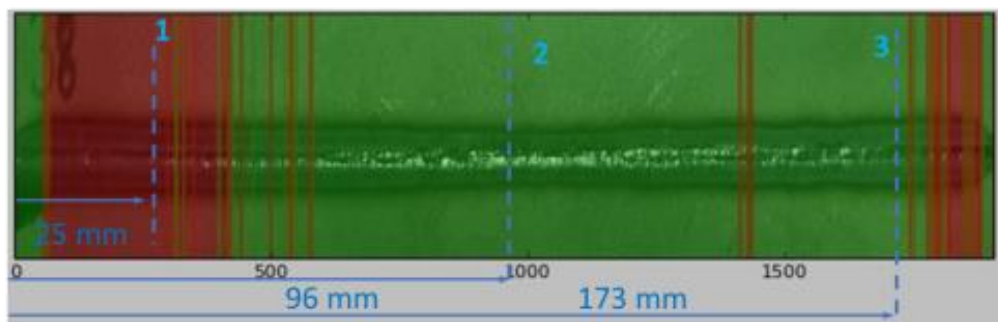
Detected defects:

- Undercuts
- Pores
- Holes
- Lack of penetration
- False Friend



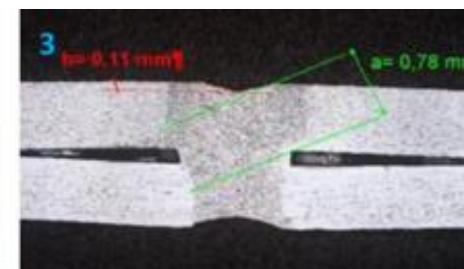
Defects evaluation and defects location in the weld beads are needed as input for system training

Quality assurance – *Process Validation Trials – Welding Case*



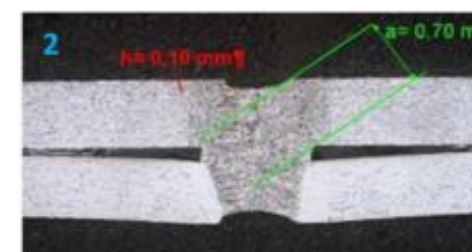
$h1 > 0,170 \text{ mm}$

weld NOK!



$h1 < 0,170 \text{ mm}$

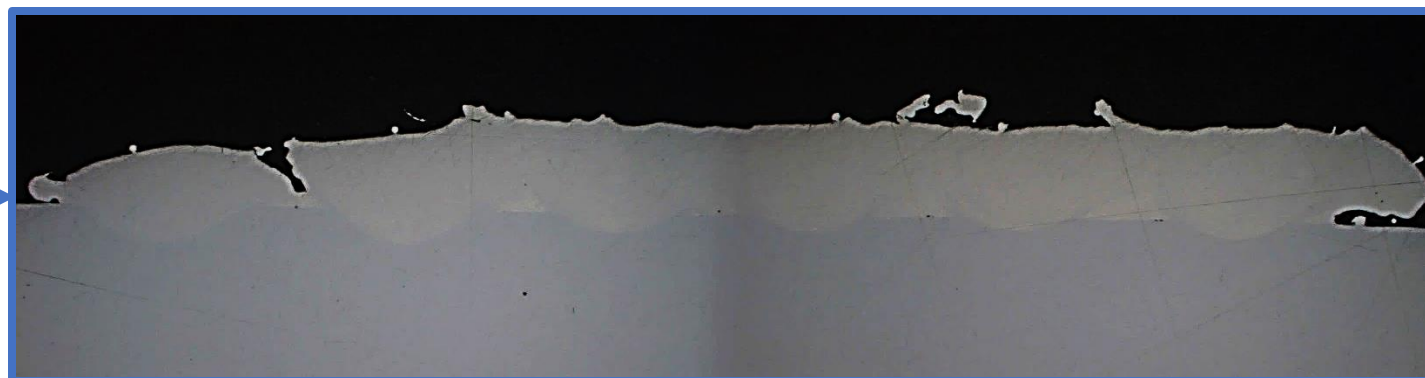
weld OK!



$h1 < 0,170 \text{ mm}$

weld OK!

Quality assurance – *Process Validation Trials – Cladding Case*



Local defects are detected ✓

Metallographic analysis

Quality assurance – *Process Validation Trials – Cladding Case*



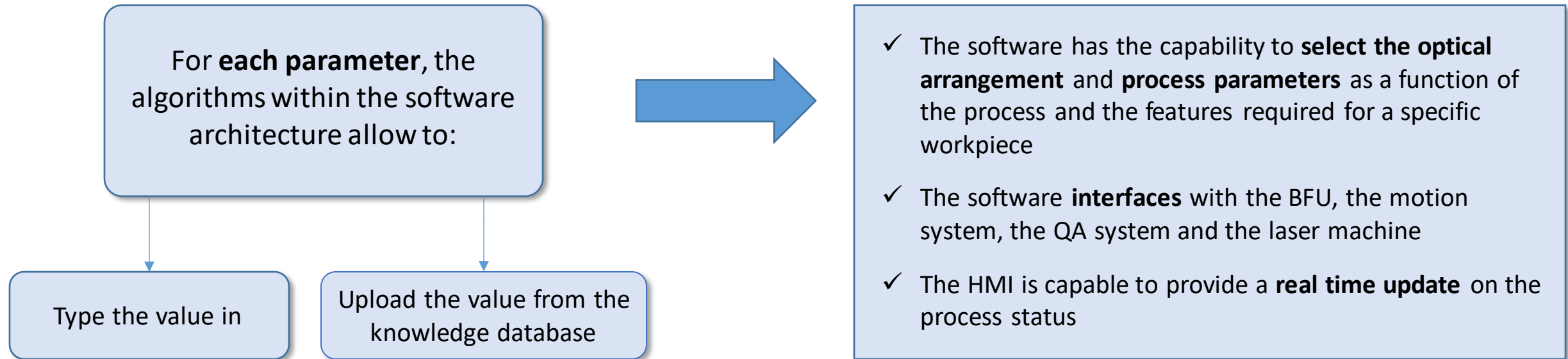
No control

Control

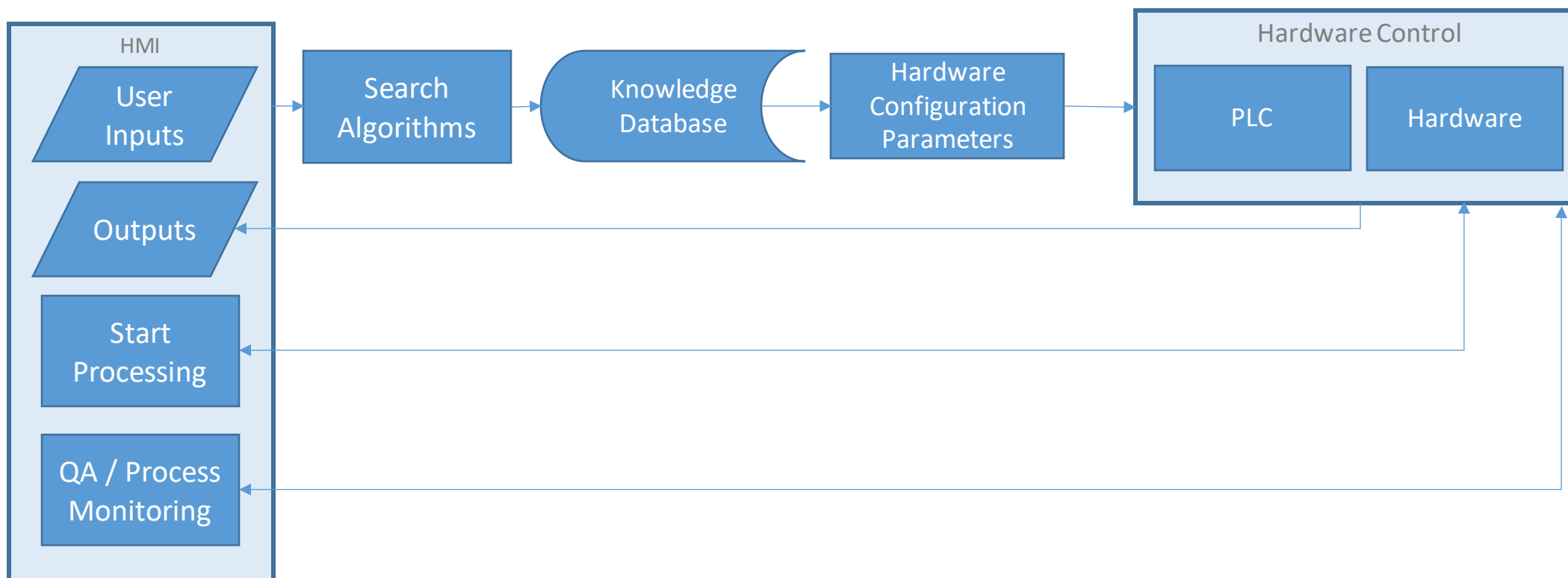
Quality assurance – *Summary*

- ✓ Defects are detected with a success rate higher than 95%. Future improvements will also allow defects to be classified
- ✓ The monitoring system developed is able to detect “non cut” cases in laser cutting process with an accuracy higher than 90%

Intelligent software



Intelligent software – *Top Level Software Architecture*

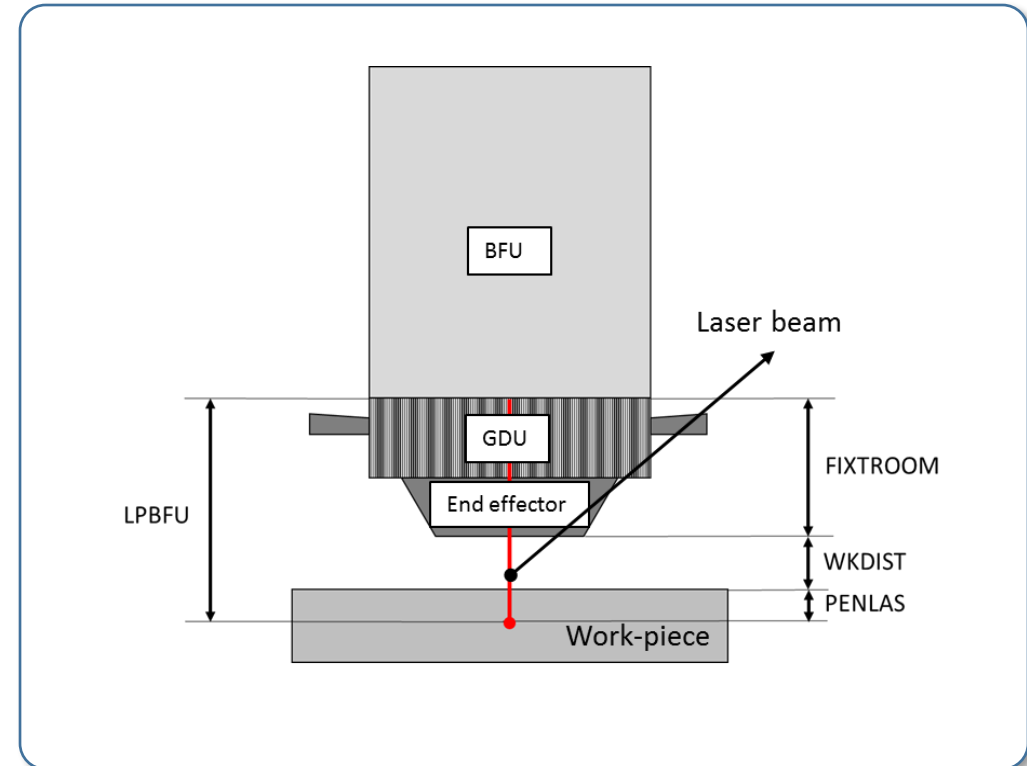


Intelligent software – *Knowledge Database*

✓ Quick process configuration



✓ Reducing the expertise required to optimise the laser processes



Intelligent software – *Knowledge Database*

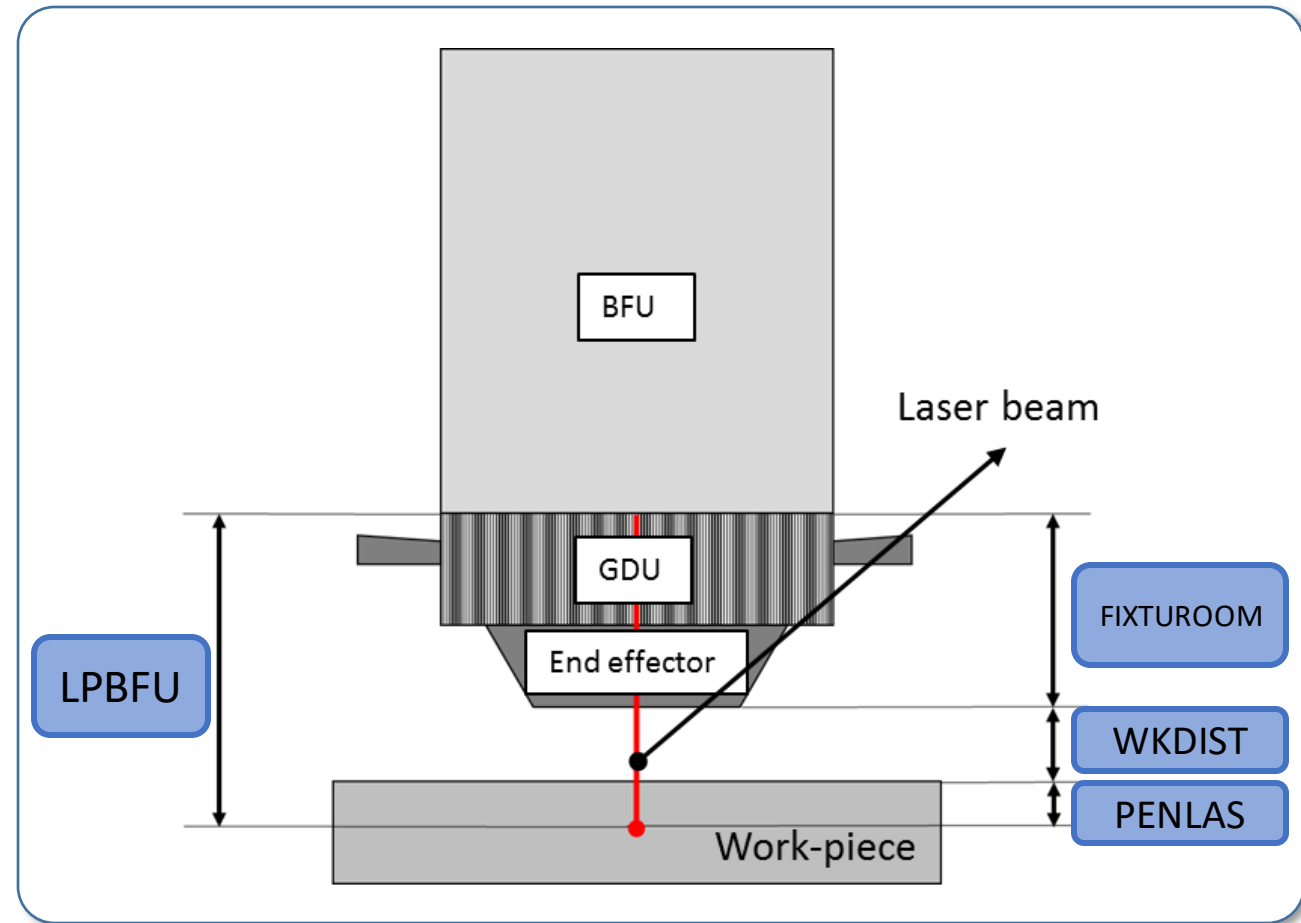
WKDIST and **PENLAS**: Selected by the user and uploaded automatically from the machine's knowledge database

FIXTUROOM: Fixed distance, only dependent on the end effector in use

LPBFU: Indicative of the position of the focus, different beam sizes can be achieved

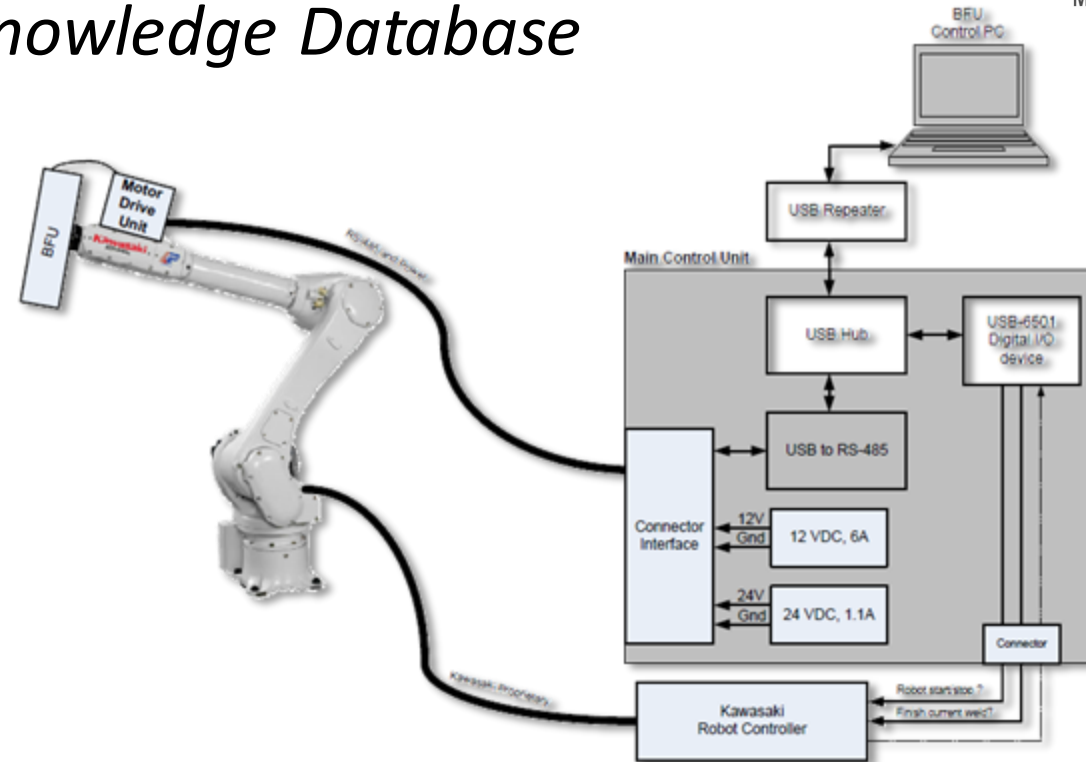
BDSURF: Beam diameter at the top surface.

The optical arrangement within the BFU will be accordingly adjusted to achieve specific values of beam size and focal position



Intelligent software – *Knowledge Database*

- Laser Material Interaction Conditions
 - **TIMEINT**: Time of interaction
 - **AVPD**: Average Power Density
 - **ENESPOT**: Specific Point Energy



$$TIMEINT = \frac{BDSURF}{TS}$$

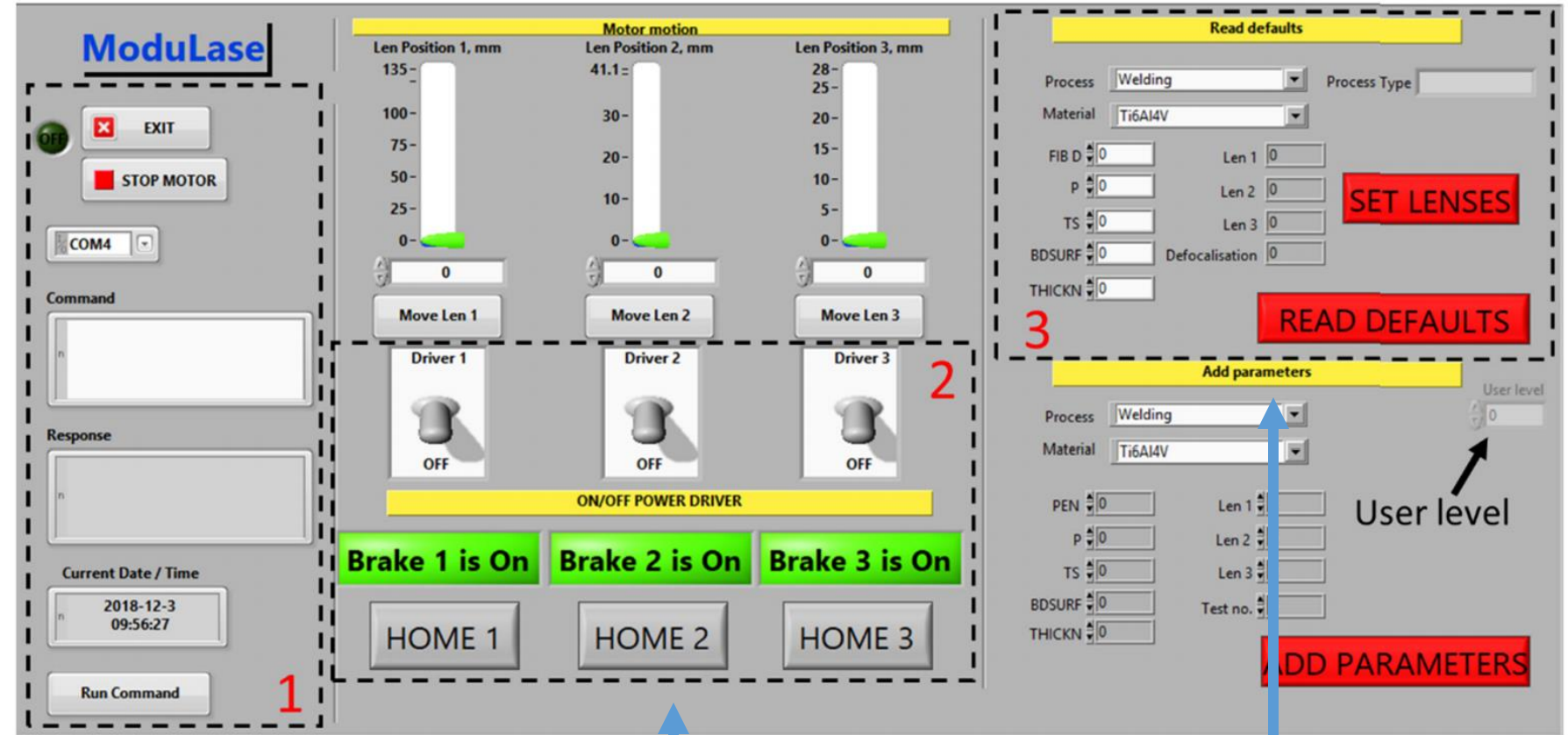
$$AVPD = \frac{4 * P}{\pi \times BDSURF^2}$$

$$ENESPOT = P \times TIMEINT$$

P – Laser power
TS – travel speed

Intelligent software – *Control User-Interface*

- User-friendly
- User-levels:
 - basic
 - intermediate
 - administrator



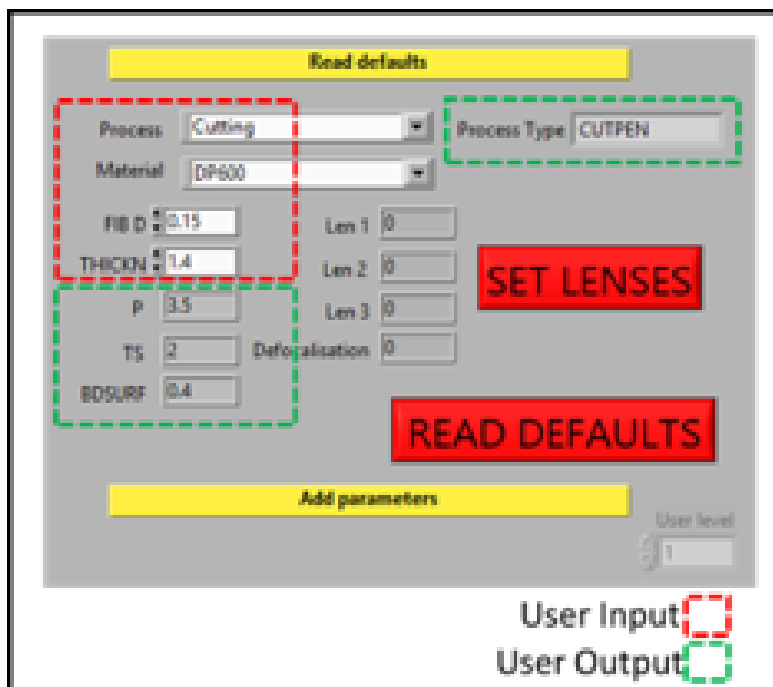
Communication Panel

Home Buttons

Process Parameters

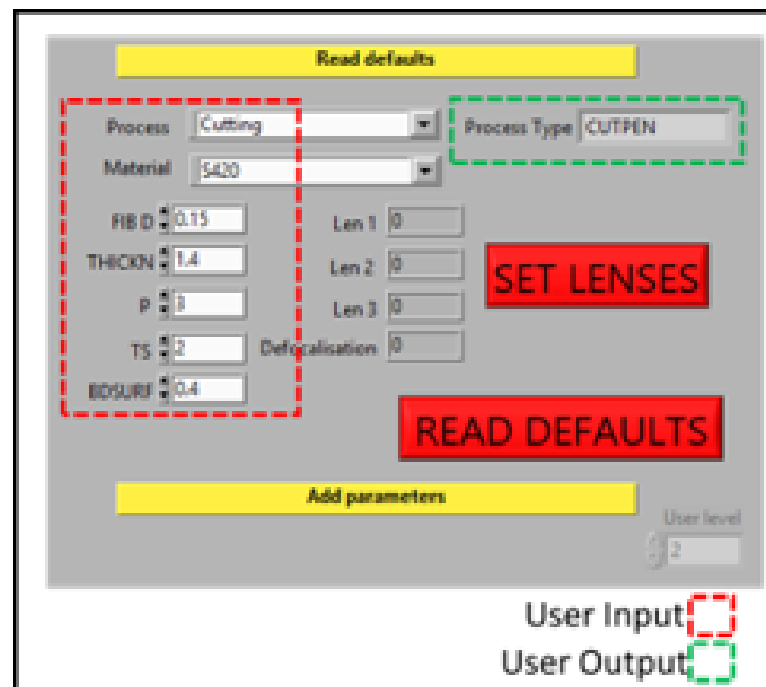
Intelligent software – *Control User-Interface*

Basic User level



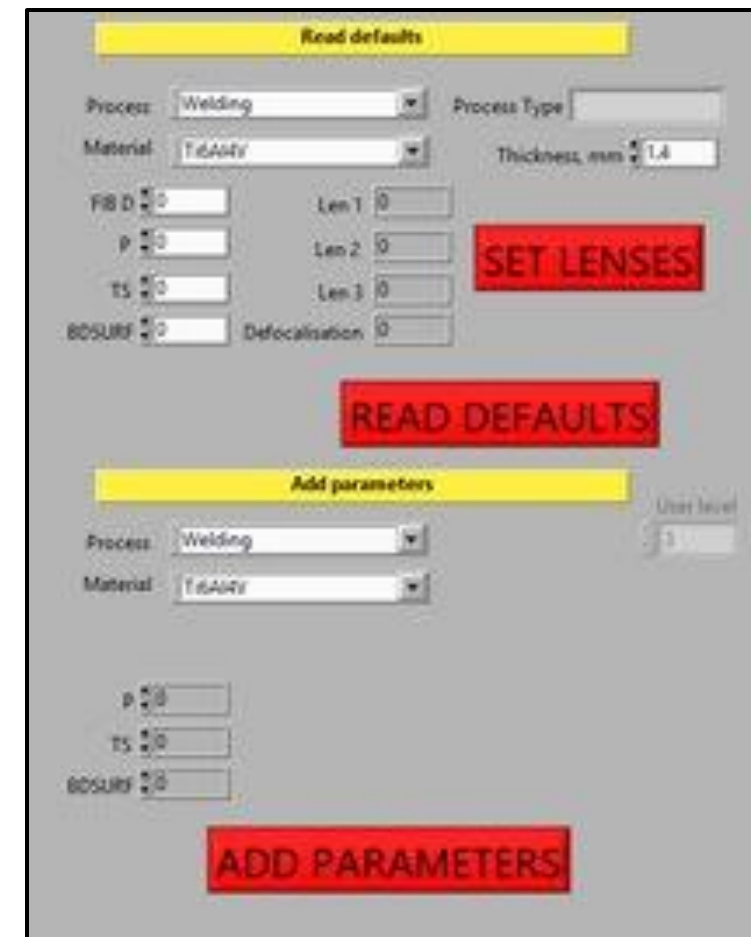
The Basic User level interface features a yellow 'Read defaults' bar at the top. Below it, a red dashed box highlights the 'Process' (Cutting) and 'Material' (DP600) fields. A green dashed box highlights the 'Process Type' (CUTPEN) field. Further down, another green dashed box highlights the 'P' (3.5) and 'TS' (2) fields. A red 'SET LENSES' button is positioned to the right of the lens parameters (FIB D, THICKEN, Len 1, Len 2, Len 3, Defocalisation). A red 'READ DEFAULTS' button is located below the 'SET LENSES' button. At the bottom, a yellow 'Add parameters' bar is present, followed by a 'User level' dropdown set to '1'. A legend at the bottom right indicates that a red dashed box represents 'User Input' and a green dashed box represents 'User Output'.

Intermediate User level



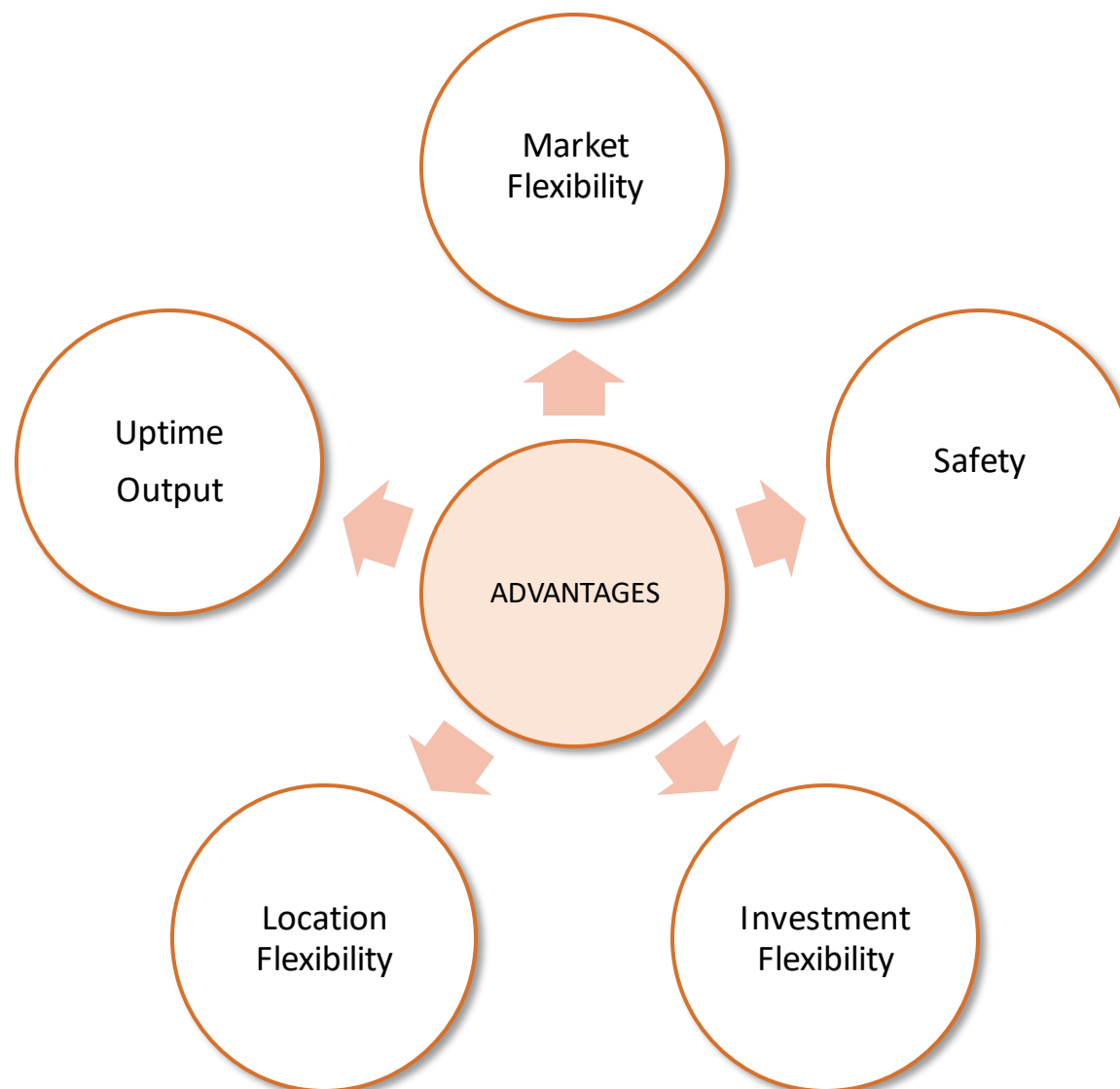
The Intermediate User level interface is similar to the Basic level but with a 'User level' dropdown set to '2'. The red dashed box highlights the 'Process' (Cutting) and 'Material' (S420) fields. The green dashed box highlights the 'Process Type' (CUTPEN) field. Another green dashed box highlights the 'P' (3) and 'TS' (2) fields. The 'SET LENSES' and 'READ DEFAULTS' buttons are present. The 'Add parameters' bar is at the bottom, with the 'User level' dropdown set to '2'. The legend at the bottom right remains the same.

Administrator User level

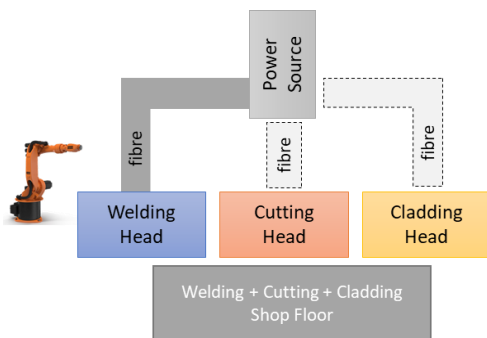


The Administrator User level interface has a 'User level' dropdown set to '3'. The 'Process' is set to 'Welding' and 'Material' is 'Ti6Al4V'. The 'Thickness, mm' is set to '1.4'. The 'SET LENSES' button is present. A red 'READ DEFAULTS' button is located below the 'SET LENSES' button. The 'Add parameters' bar is at the bottom, with the 'User level' dropdown set to '3'. The legend at the bottom right indicates that a red dashed box represents 'User Input' and a green dashed box represents 'User Output'.

Modular cells for laser processing

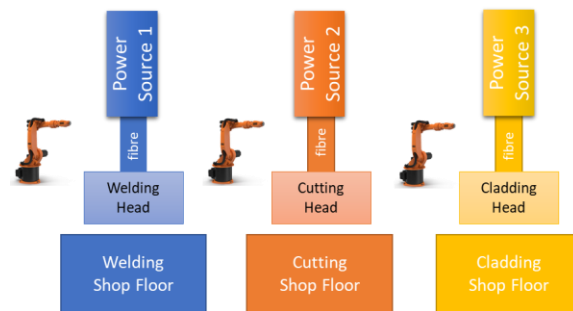


ModuLase vs. Conventional Technologies



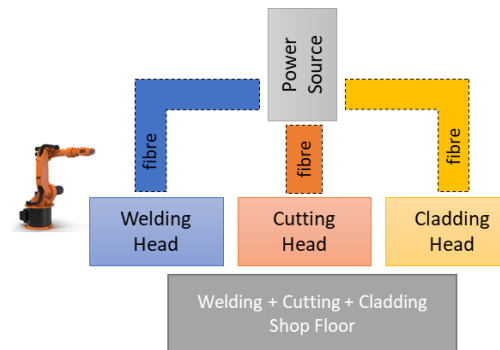
Industrial Scenario 1

1 power source
1 manipulation system
3 heads
1 fibre
Changing of the head



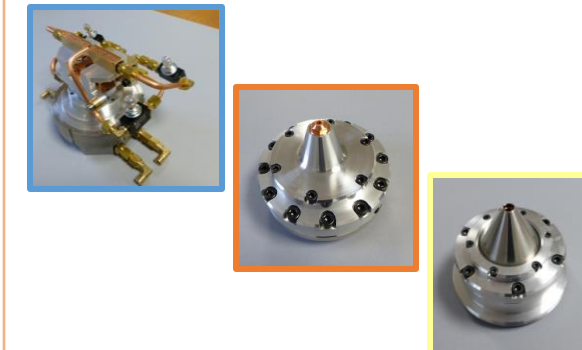
Industrial Scenario 2

3 power sources
3 manipulation systems
3 heads
3 fibres
3 processes working at the same time



Industrial Scenario 3

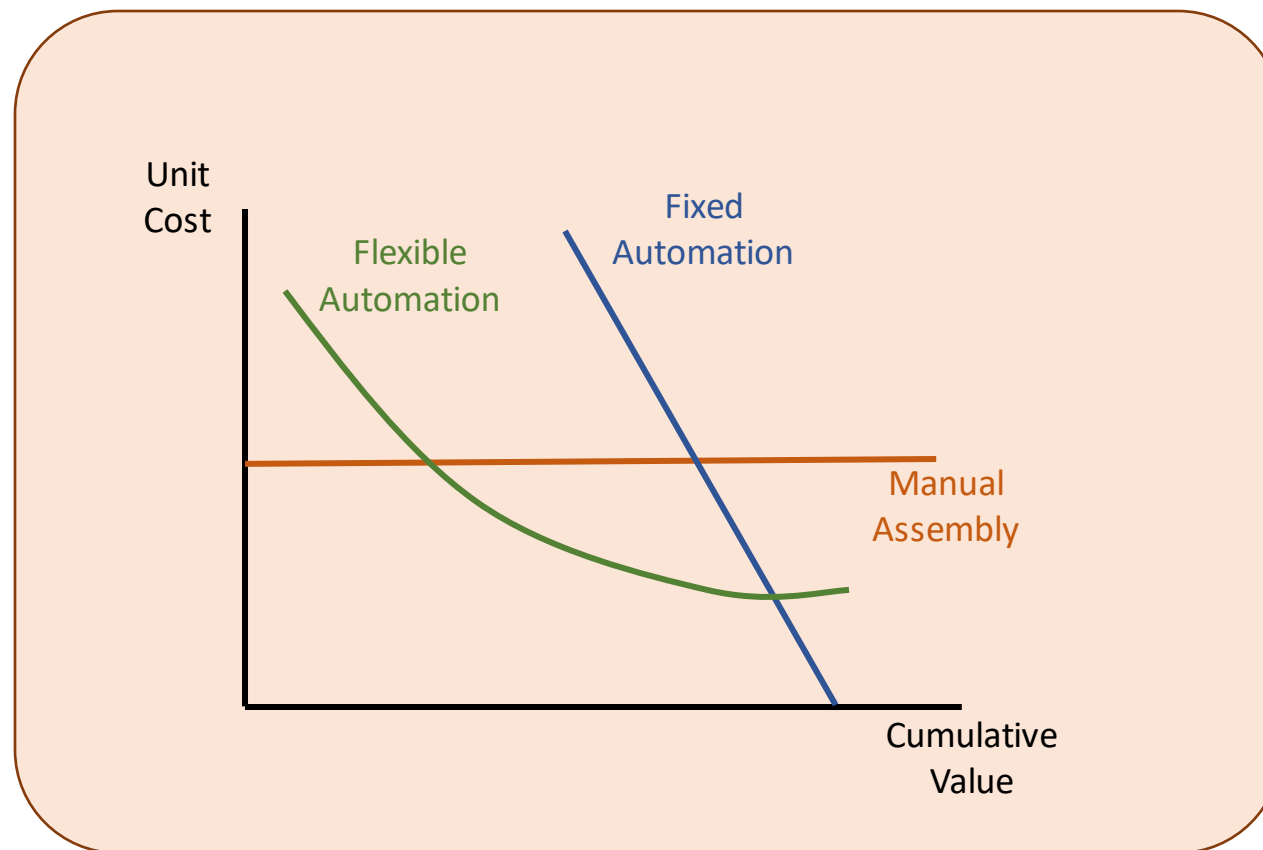
1 power source
1 manipulation system
3 heads
3 fibres



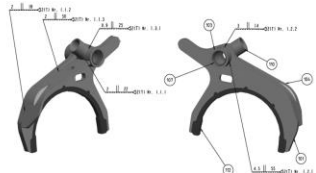
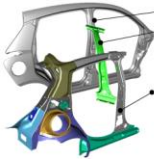
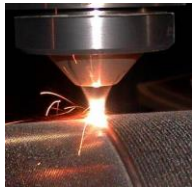
ModuLase System

1 power source
1 manipulation system
1 head with 3 end-effectors
1 fibre

Modular cells for laser processing



End-use Cases to validate the Technology

End-user	Component	Applications	Demonstrative Images	Outcomes
	Guard for a composite turbine engine blade	Welding Cutting		Time: -9,74% Initial Investment: -69,25% Shop floor usage: -71,83% Rejection Rate: -60%
	Gear box forks of a car	Welding Cladding		Time: -% Initial Investment: -40,52% Shop floor usage: -54,54% Rejection Rate: -33,33%
	Component of the body in white of a car	Welding Cutting		Time: -% Initial Investment: -% Shop floor usage: -% Rejection Rate: -%
	General Application	Cladding		Time: -% Initial Investment: -% Shop floor usage: -% Rejection Rate: -%

Modulase in action

Summary

- ModuLase project was able to develop a re-configurable system that allows to perform three different laser processes within a unique facility.
- The ModuLase system has great potential to boost the flexibility of fibre-delivered laser sources and address a number of arising industrial challenges. Including:
 - The rising need for flexible manufacturing systems, to support an increasing variety of product mixes.
 - The need to maximise equipment utilisation rates, by eliminating down-time associated with changing of laser, processing heads and equipment stoppages and reducing capital investment costs.

Thank you

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The project is an initiative of the Photonics and Factories of the Future Public Private Partnerships.



PHOTONICS PUBLIC PRIVATE PARTNERSHIP



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