Introduction to OPeraTIC

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AIMEN – Project Coordinator

OPERATIC

Laser-based technologies for green manufacturing

Funded by the European Union

OPeraTIC is a project funded through the European Union's Horizon Europe programme to **boost the adoption of high-power ultra-short-pulsed lasers**, bringing all the benefits of high-power, ultrafast lasers into large scale industrial applications.

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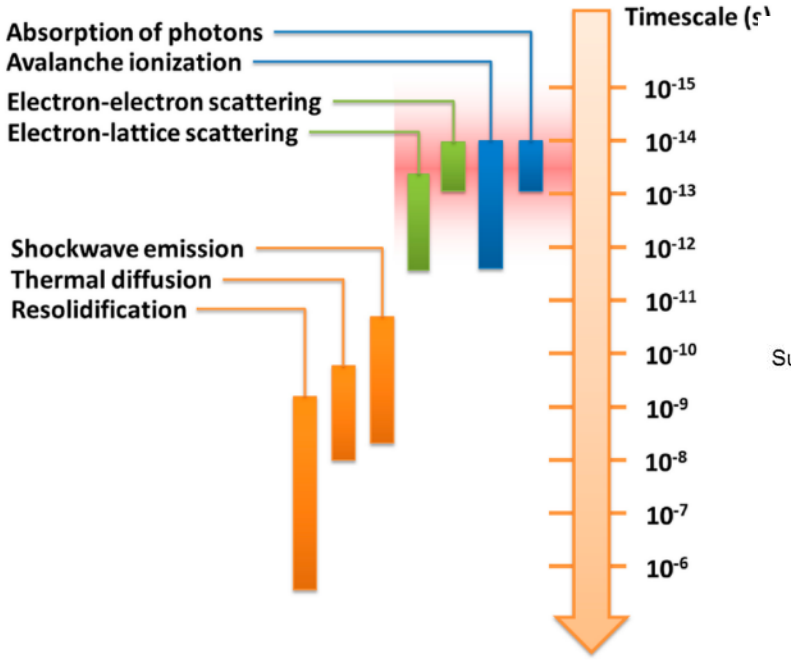
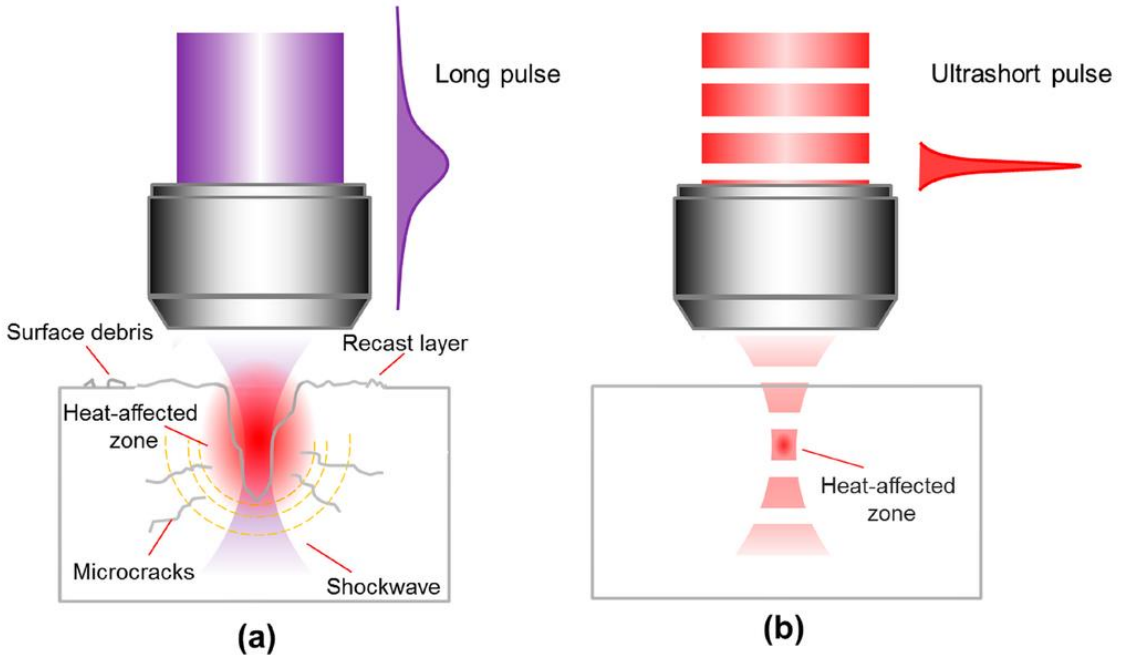
Why Ultrafast Laser

Timescale affects the physics of light-matter interaction.
Reduces the interaction volume, improves efficiency and resolution.





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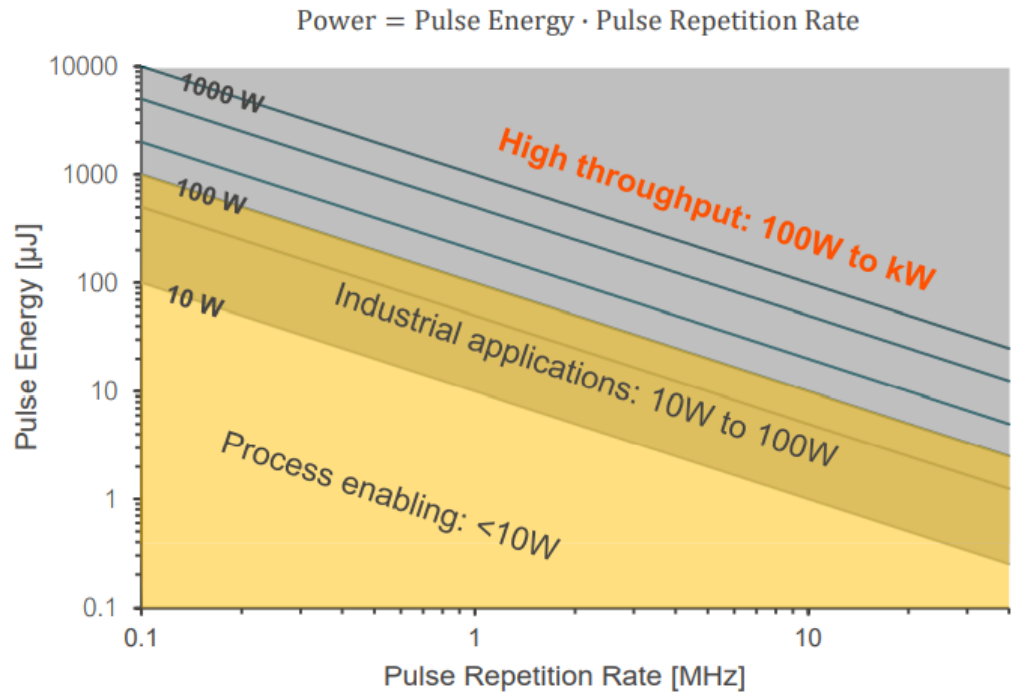
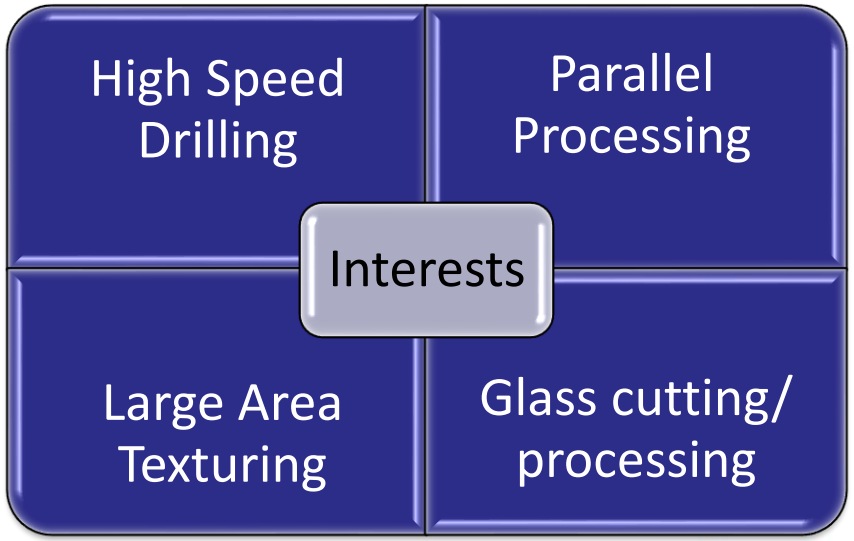
Why High Power

Benefits of ultrafast sources are also their weakness.
High resolution limits productivity, solutions: pulse power or rep.rate





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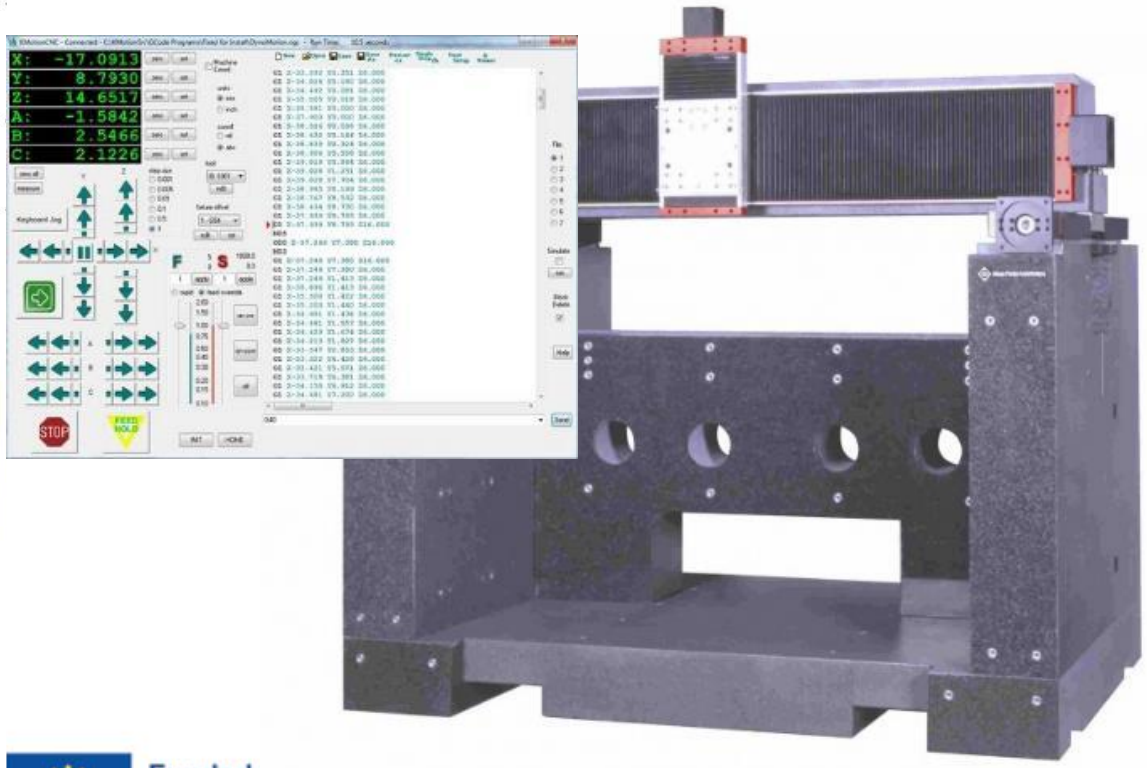
Why OPeraTIC

It’s not all about the laser. Good advances in high power sources.
Only in clean, controlled environment, flat support, 3 ton granites, G-code axis-by-axis control… need for flexible automation. SYSTEM needs R&D.



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High-power (>200 W), ultrashort pulse (< 30ps) lasers to become **fully industrial tools for 3D surface treatment**, bringing their advantages in terms of **quality, efficiency, emissions (avoidance of chemicals and waste), flexibility, and functionality**.

- **the machine architecture (optics and mechatronics),**
- **the digital architecture (electronics and data),**
- **the Machine Intelligence (AI),**
- **the adaptive processing of complex 3D parts.**

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Project Objectives

Modular Laser System	We will develop all the components to take maximum advantage of high-power ultrafast lasers and make them work together, as plug-and-play elements, thanks to a new machine architecture.
Data driven pipeline	We will enable the real time transmission of critical information within the system to allow closed loop control.
Zero Defect Manufacturing	Using AI and real time signals, we will enable the reduction of deviations and target a zero-defect operation, even in complex pieces with dimensional inaccuracies.
Demonstrate the approach	On the basis of four very different and demanding use cases from real industry, the project will demonstrate the effectiveness of the results and the benefits against competing technologies.

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Sci-Tech Developments

Beam Management	Delivering the high energy beam through an intricate mechanical configuration
System Architecture	Physical layer: development of the complete optical and mechanical chain
Digitization/ Connectivity	I4.0 compatible digital architecture to provide interoperability and reconfigurability
Machine Intelligence	AI for rule extraction and robust adaptability

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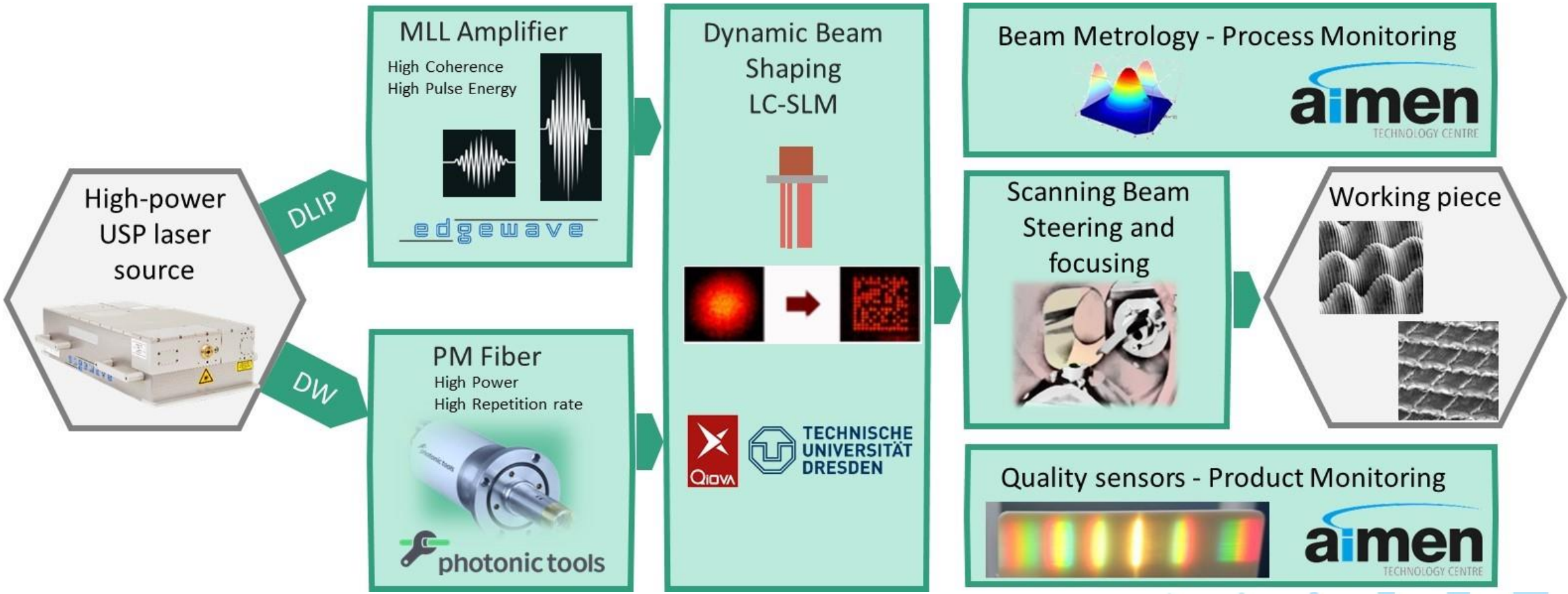
Sci-Tech Developments



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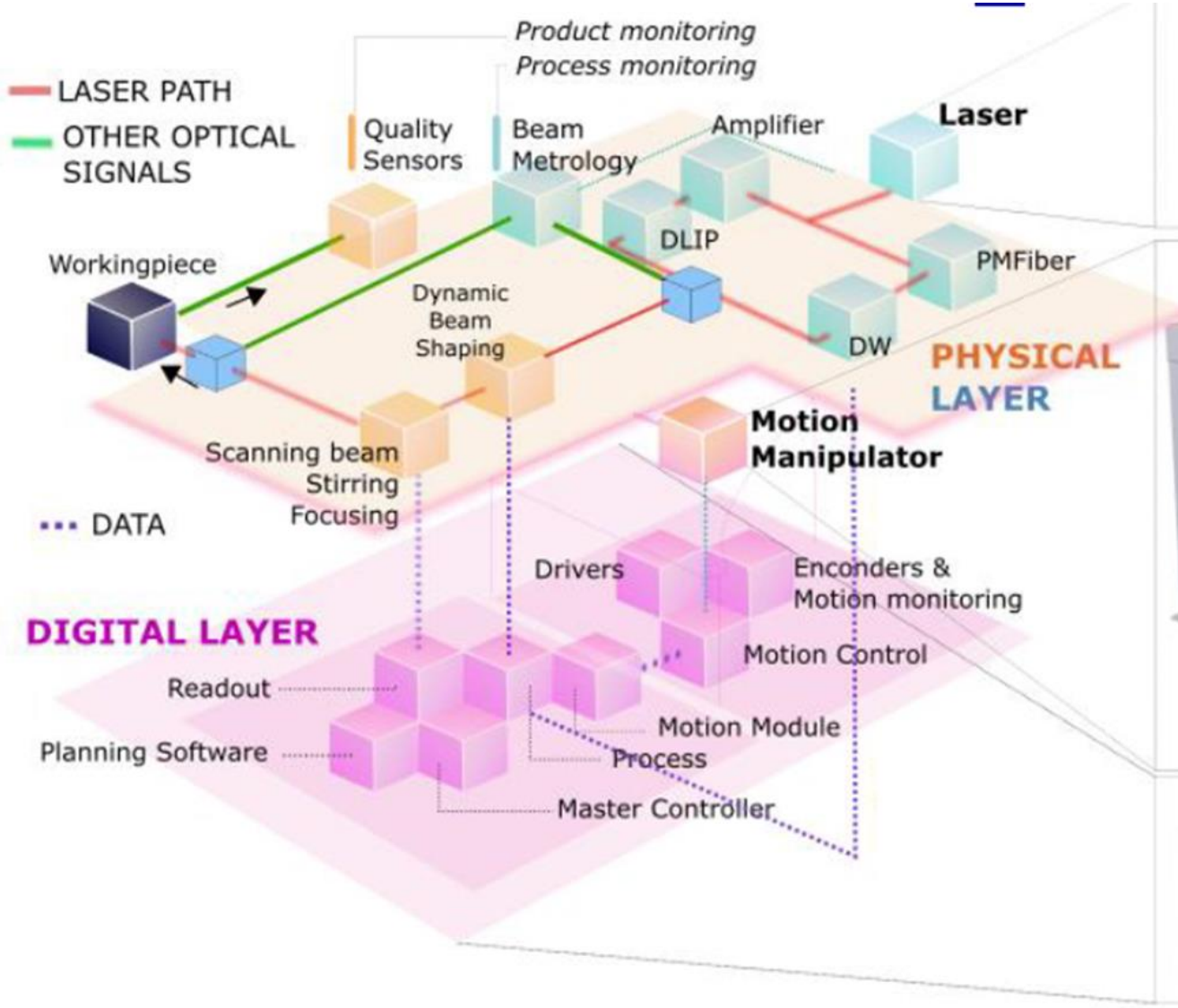
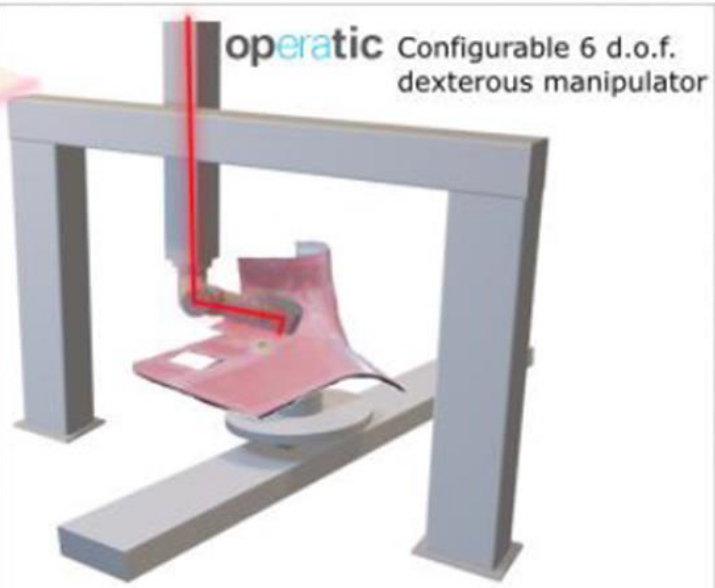
Multilayer architecture





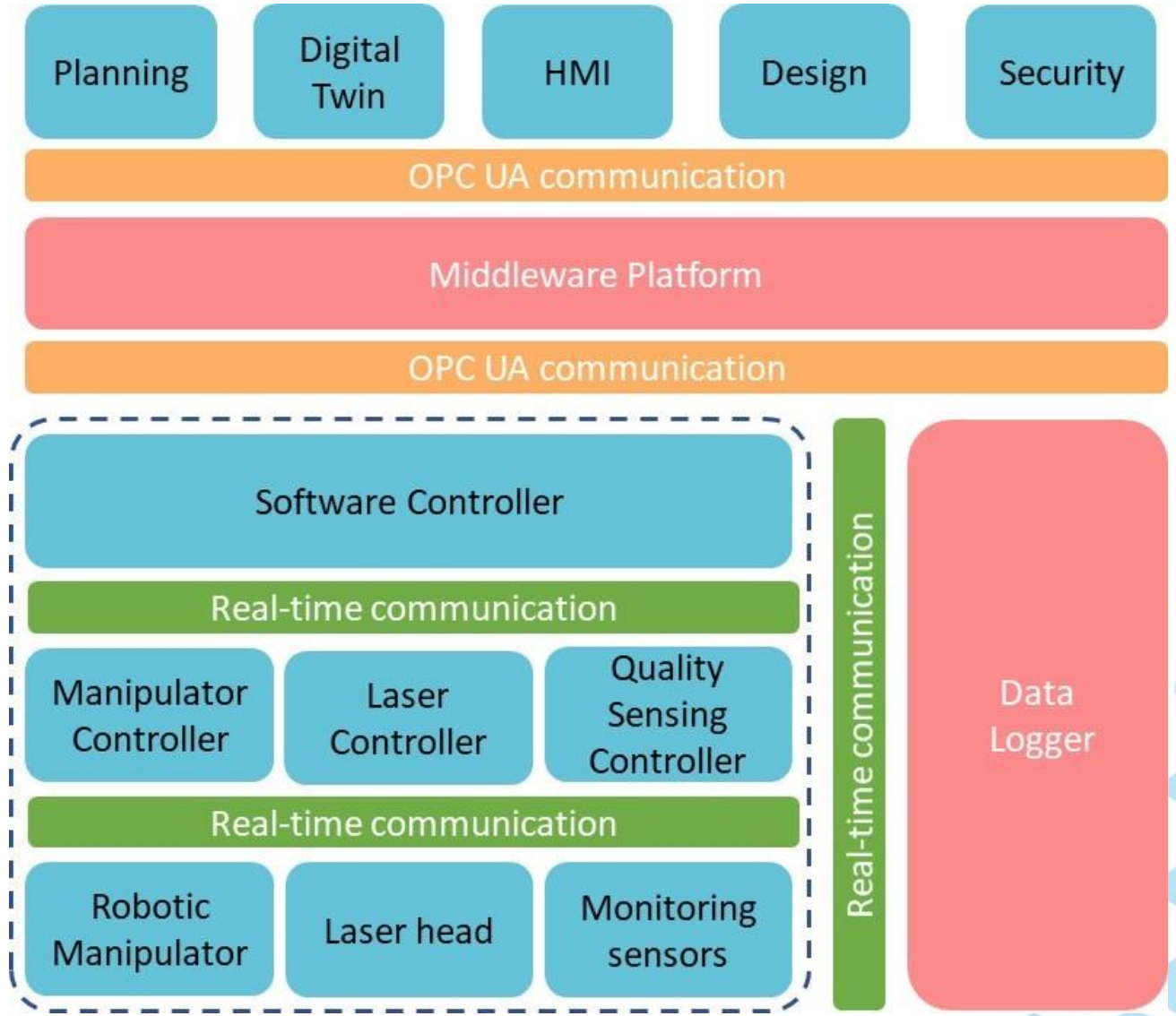
Connectivity and I4.0

RAMI compliant: Not standard in micromachining equipment

Real Time: Hard real time connection among system components and distributed control.

Data acquisition and logging: use of Edge devices and newly crafted data models and pipelines.

Data exploitation: Development of a specific Middleware for data use.



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Use cases

Arçelik

Product: Dishwasher

Sector: Home Appliances

Targeted function: Hydrophobicity Re-manufacturing

Aim: to reduce water and energy consumption in dishwasher drying cycles.

Objective: Enhance the contact angles of the interior component parts.

OPeraTIC solution: use hierarchical micro-nano topographies to achieve Ultra-Short-Pulsed Lasers (USPL) micro-structuring of the injection moulding tool, transferring the texture to the actual part.

Impact: Reduction of water and energy consumption, improved drying process, extended lifespan of product, avoid plasma coating, achieve better environmental impact, and improve the Restriction of Hazardous Substances (ROHS) compatibility.

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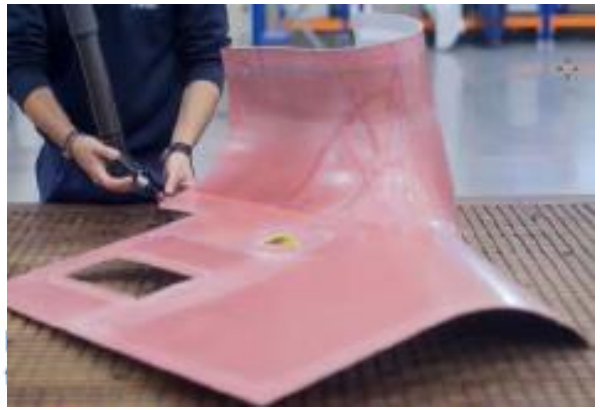
Use cases

Product: Aircraft composite parts

Sector: Aeronautics

Targeted function: Improved adhesion/paintability



Aim: Reduce time consuming and harmful sanding process in current preparation processes.

Objective: Improve the paintability of components while improving the process yield, repeatability, flexibility, and decreasing rejection rates through use of lasers.

OPeraTIC solution: Surface texturing through customised energy distribution of high-energy USPL on the component, ensuring optimal adhesion between composite and paint, as well as avoiding pores.

Impact: Damage avoidance to Kevlar matrix and provision of a functional surface within a competitive process cycle time, high repeatability, reduction in rejection rates and increased yields, improved worker health and safety conditions.

Use cases

Product: Texturized die component

Sector: Automotive

Targeted function: Improved lubrication and re-manufacturability

Aim: Reduce wear, adhesion, and defects in steel blank stamping and deep drawing.

Objective: Improve lubrication and homogeneous gripping, thus also improving formability of intricate shapes, speed of processes and reducing forming steps.

OPeraTIC solution: Utilise USPL machining of microreservoirs in a stamping tool.

Impact: Reduction in energy use, oil, and feedstock, extension of die lifespan, reduction in process downtime, and enabling manufacturing of complex geometrics and difficult materials, and reducing forming steps from 7 to 4.

Use cases

Product: Advanced backlighting

Sector: Lighting/HMI

Targeted function: Functional structuring of backlit panels

Aim: Reduce LED power and energy use in LED Backlit Units (BLU)

Objective: Increase visible light transmissions and lower dielectric permittivity, increasing integration capacities with BLUs and/or capacitive sensing electrodes.

OPeraTIC solution: Use direct laser selective patterning to allow mass customisation in design and function.

Impact: Meet the next wave in automotive design through creating high-quality 3D light emitting surfaces, with dynamically addressable luminance.

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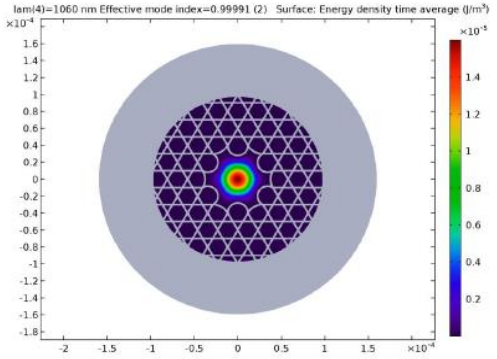
Advances so far

Polarization Maintaining Optical Fibre

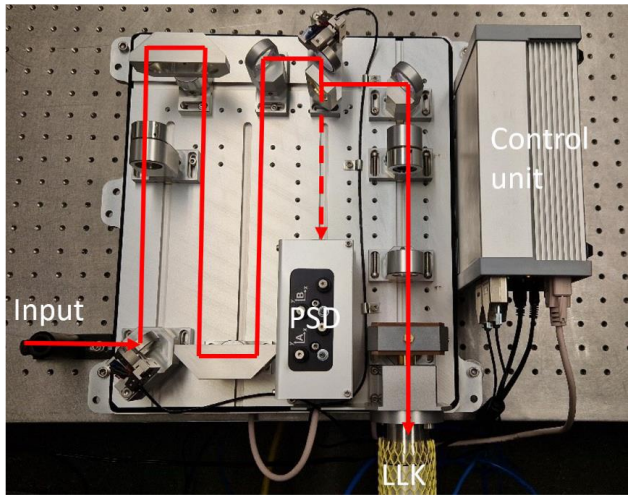
photonic tools

Features

- Hollow core fibre for IR
- Self-stabilized coupler
- High extinction ratio
- >1 mJ per pulse
- Mode field: 22 microns
- Down to 250 fs
- Low dispersion (<1.5 ps/nm/km)
- Reduced losses up to 4 m
- >75% total transmission (upgrade during OPeraTIC)



Microstructured Hollow Core Kagome Fibre



Advantages

- Light-cable concept: simplified machine
- Easier setup of 3D systems
- Transmitting linearly polarized beams:
  - Direct use in interference-based patterning
  - Use in SLM based parallelisation
  - Reduced losses compared with non-PM fibres

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Advances so far

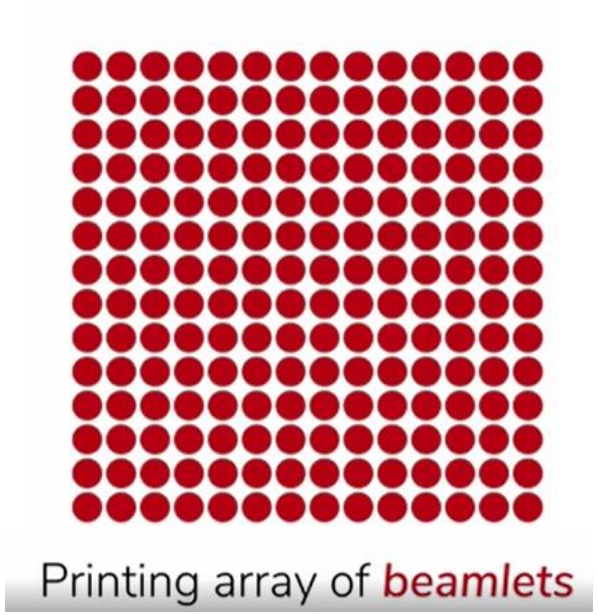
SLM-based direct writing system

QIOVA

Features

- Take advantage of newest Sapphire tech
- Pulse energy >1 mJ in 350 fs.
- Average power >250 W. New chip for >700 W, untested.
- Compact design, compatible with scanner optics

- In development: AI-based improved depth of field and correction of aberrations



Advantages

- “Stamp” mode concept: single laser exposition per pattern
- Parallel mode: beamlet
- Industrial design: easy integration, easy to handle software
- Self calibrating capabilities
- Excellent use of high power pulsed laser systems.

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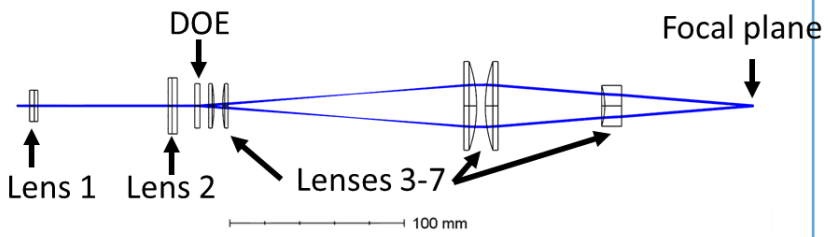
Advances so far

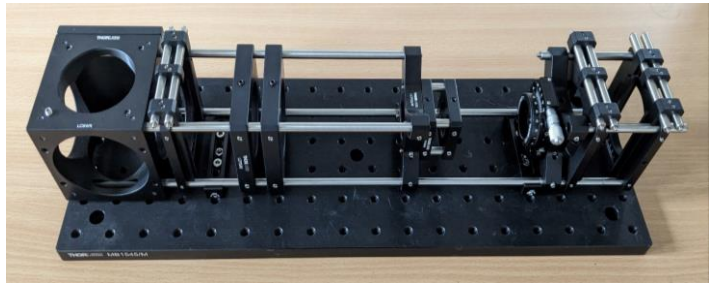
DLIP Interference patterning system

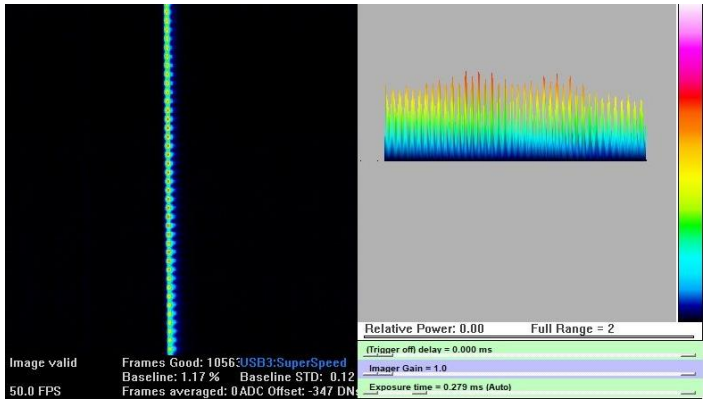
TECHNISCHE UNIVERSITÄT DRESDEN

Features

- Novel optical design
- No prism involved
- DOE-based splitter
- Large field of interference
- Very high energy density thanks to the line focusing.







Advantages

- Very compact design: lightweight and reduced space
- Easily integrable in robotic arm
- Demonstrated with optical fibre
- DOE allows for switchable periods, i.e. 5 um to 20 um
- Elongated beam is very adequate for raster patterning
- EXTENDED Depth of Focus makes it very robust!

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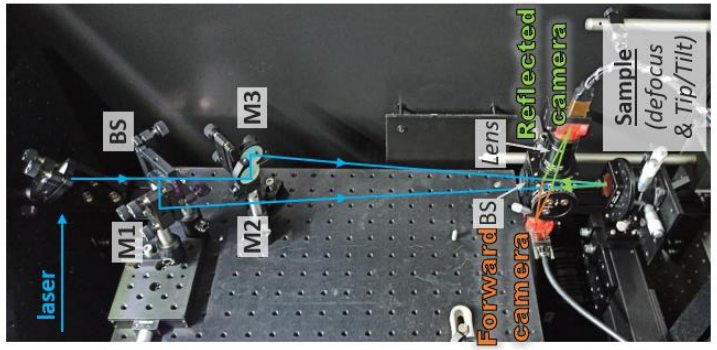
Advances so far

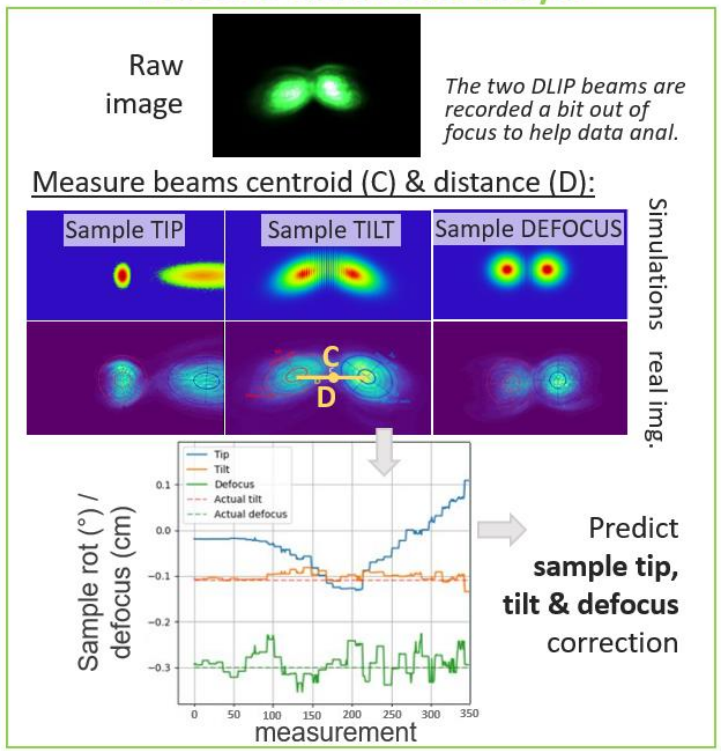
Features

- Imaging of the beam being projected to the sample
- Simultaneous imaging of the light reflected from the sample
- High sensitivity to misalignments and propagation issues
- Fitted for complex patterning such as three or four beam interference
- Few Hz currently (PC process). 100s Hz possible using hardware computing FPGAs/GPUs.

Monitoring system



Reflected camera data analysis



Advantages

- Geometric optics predictive models are able to extract deviations from single image
- Automatic discrimination between optical or sample misalignments, and identification of the
- Easily derived correction rules and algorithms.

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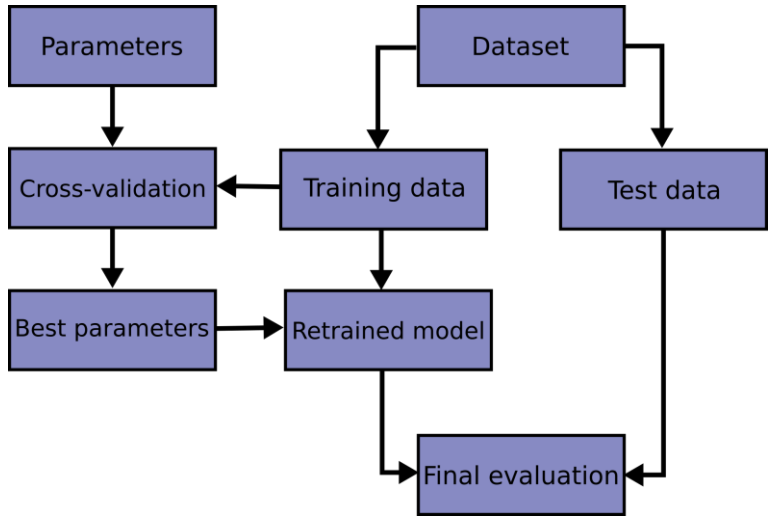
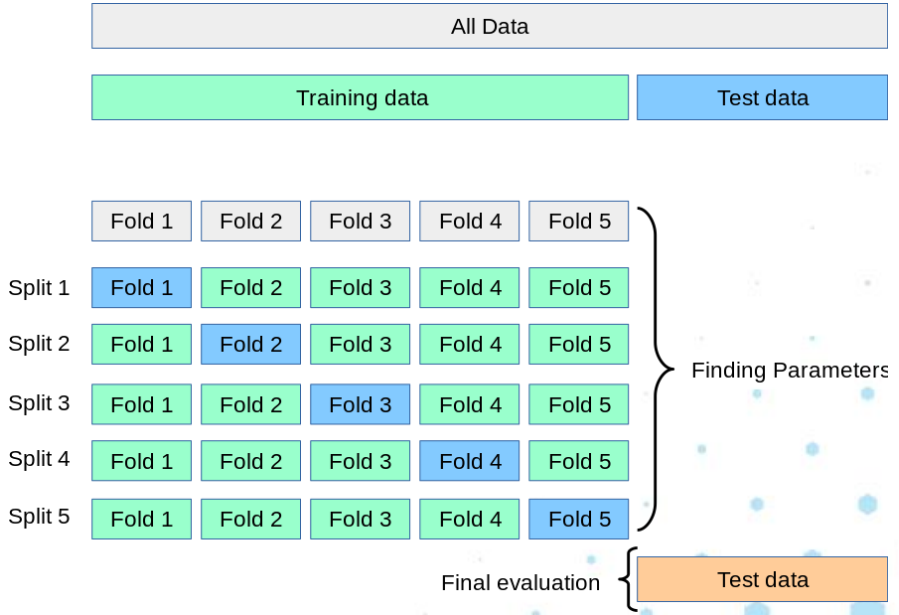
In progress

Artificial Intelligence Model

Features

- Hybrid model using mixed experimental and synthetic data for training.
- Multiple NN models evaluated and validated against real test data
- Capability to predict, for a given pattern, the resulting topography from the input parameters
- Inverse problem in progress
- New models in development for calculation of optical corrections and optimal optical setups for extended Depth of Focus





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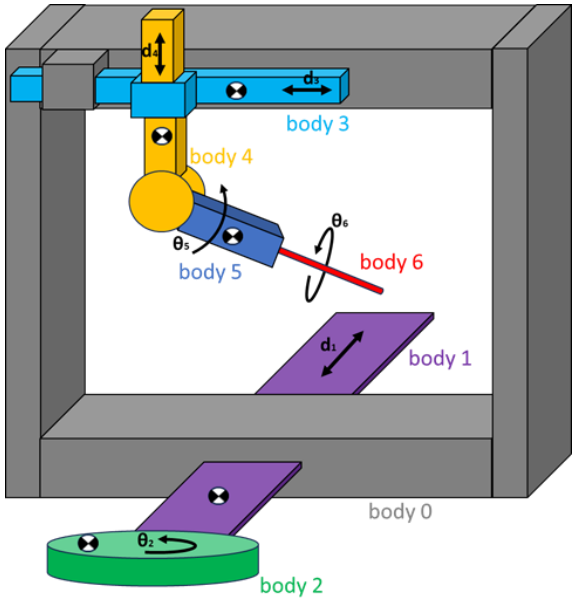
In progress

Robotic Manipulator and Motion Control

Features

- Decoupled design for improved reachability and dynamics
- Kinematic and dynamic modules coded from scratch for the project, for maximum performance
- Direct, inverse and differential kinematics integrated.
- Inertial and gravitational effect computation in advance, prediction of vibrations and motion inaccuracies. Precompensation in progress.



K-LOOPS

MECCANO

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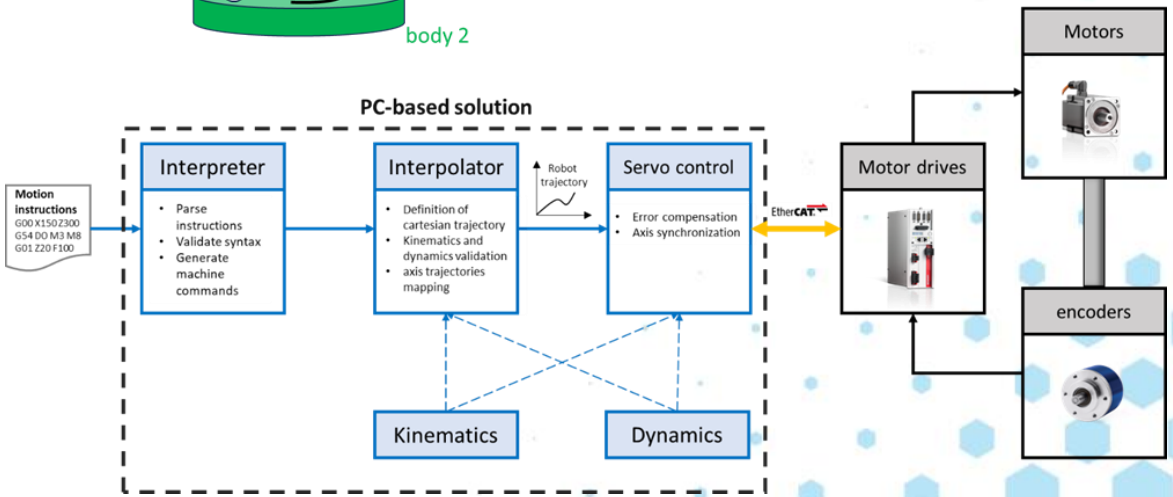

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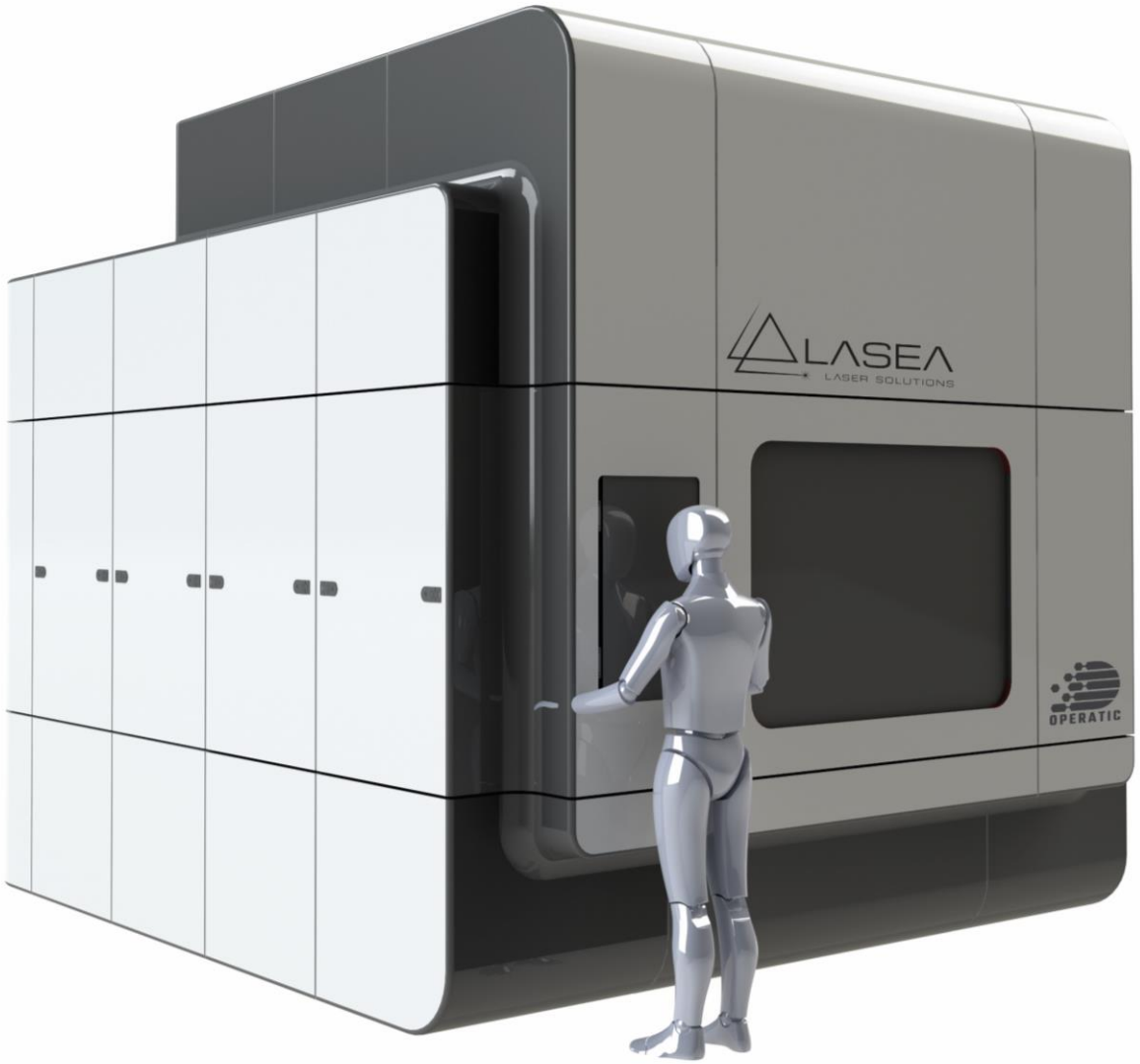
In progress

Machine concept and design

Features

- Single cabinet, compact machine integrating all systems
- >1m3 processing volume, high precision
- Ready for a wide range of laser systems from 100 W up to kW
- Plug’n’Play reconfigurable using Asset Administration Shell
- Software integration: process planning (DMC), system/motion control, monitoring, AI support… everything under a single HMI



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Thank you for your attention!

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