LASER MARKING & ENGRAVING

From application to solution

Coherent Laser Seminar
San Jose, Costa Rica, June 19, 2024

Dr. Roland Mayerhofer, Product Marketing Manager
Dr. Tissa Gunaratne, Product Line Manager

COHERENT

CONTENT

- **Introduction: from application to solution**
- **How to select the right laser:**
  - Fundamentals: most important parameters for marking and engraving
  - Optical configurations
  - Available laser sources
- **Laser marking processes and applications**
- **Laser micro processes and applications**
- **How to control the complete process chain?**
- **System and automation options for complete solutions**

FROM APPLICATION TO SOLUTION

Laser source

\+

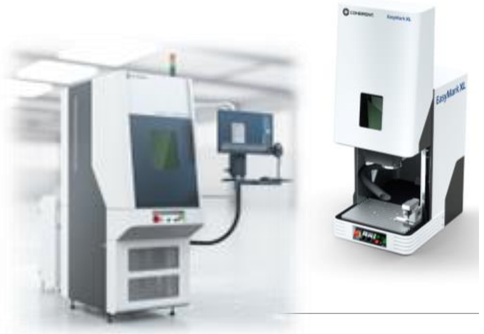
1

Optical configuration, accessories and features

Sub-system

2

System



Subsystem delivered to integrator

STEP 1 : APPLICATION LAB

- Various laser systems or sub-systems for process development
- Comprehensive measurement equipment for process qualification

Wavelengths:

UV (355nm), VIS (517, 532nm), NIR (1030-1070nm), IR (9.35-10.6µm)

Pulse durations:

350fs - cw

Power levels:

Up to 1.5kW (IR)

HOW TO SELECT THE RIGHT LASER FOR A SPECIFIC APPLICATION?

NO. 1-6 IMPORTANT LASER PARAMETERS

- **Order of importance**
  - Light absorption and heat input optimization:

    Wavelength | Pulse width

  - Beam quality and optical configuration determine achievable spot size

    Beam quality | Beam shape

  - Parameter, that help to scale throughput

    Pulse repetition rate | Laser average power

NO. 1 MOST IMPORTANT LASER PARAMETER: LASER WAVELENGTH

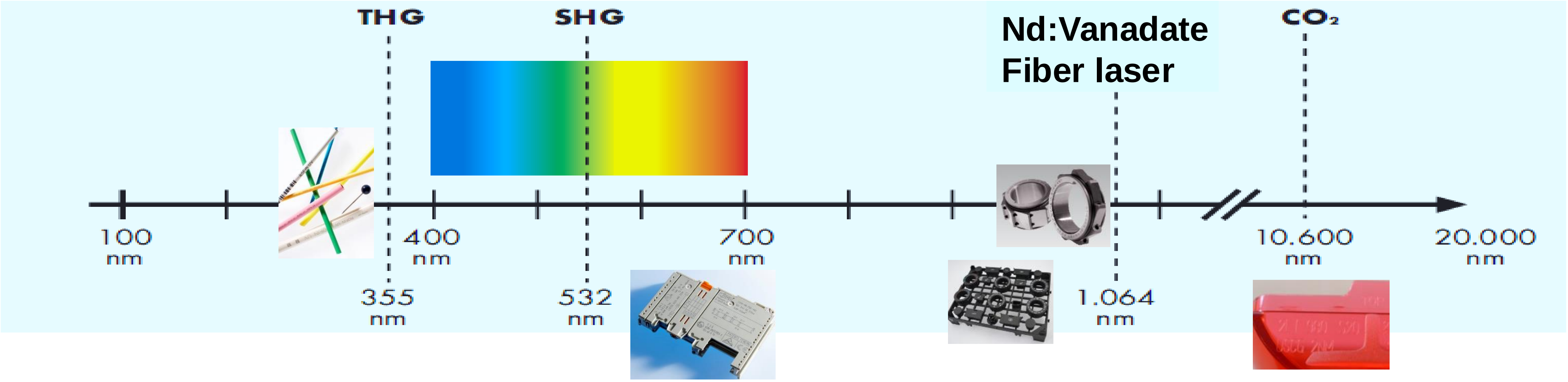
- Laser wavelength determines initial absorption in the material

Third choice UV:
Even no absorption in VIS
or smallest spot required

Fourth choice IR:
Typically used for organic
materials

Second choice VIS:
No absorption in IR or small
spot diameter needed

First choice NIR:
Suitable for many
materials



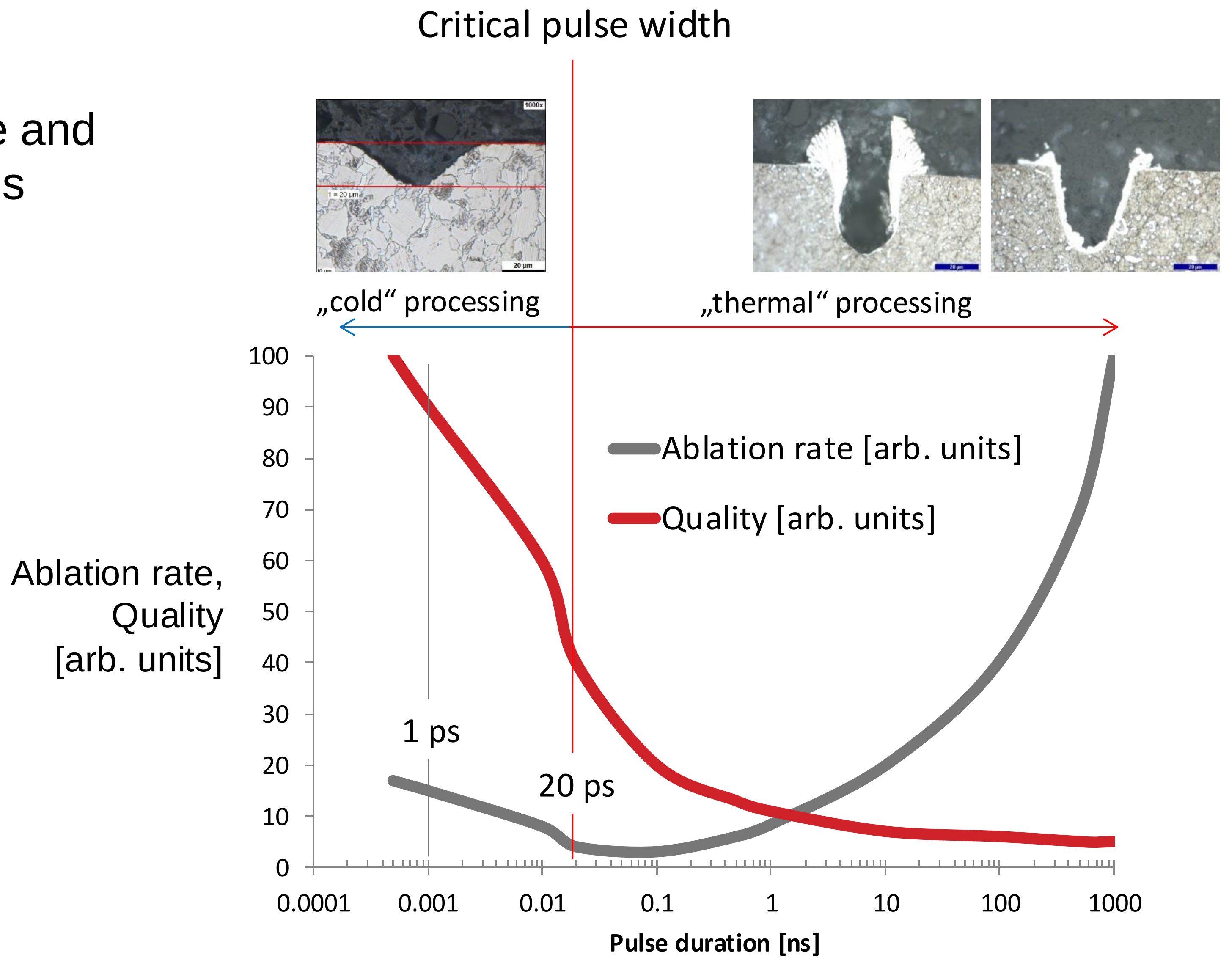
COHERENT

NO. 2 MOST IMPORTANT LASER PARAMETER: PULSE WIDTH

- Pulse width determines ablation rate and quality in surface engraving of metals

Critical pulse duration:
determined by lattice heating time

Material	critical pulse duration [ps]
Iron	1.1 – 1.8
Copper	26
Aluminium	7
Titanium	2.6
Nickel	0.3
Platinum	5
Gold	14

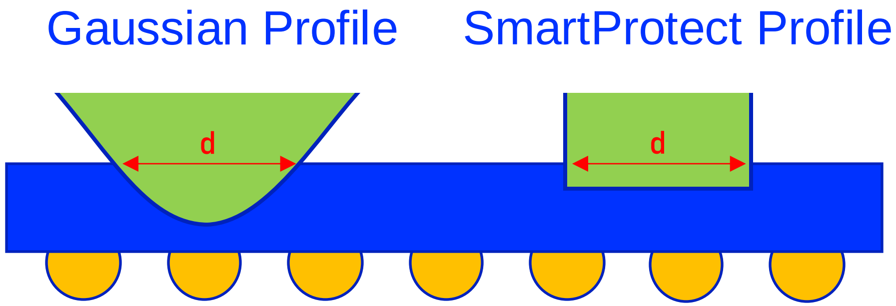


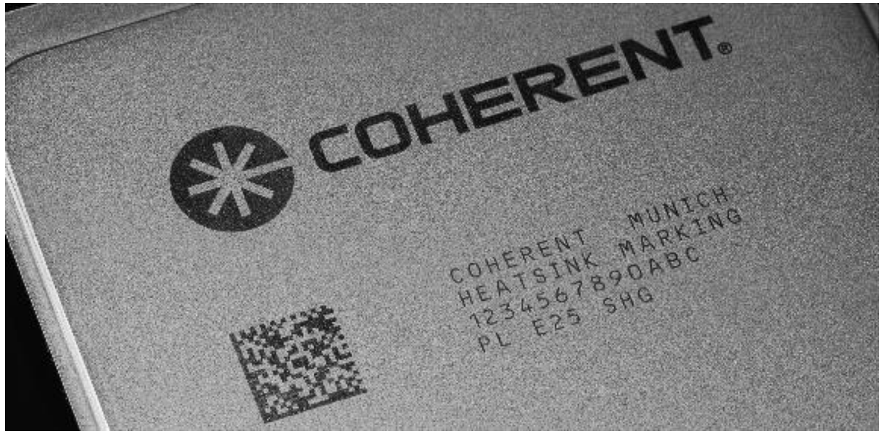
COHERENT

PARAMETER BEAM SHAPE: SMART PROTECT TECHNOLOGY

- **I.e. for semiconductor devices with:**
  - Very thin mold compound encapsulation
  - IC substrates with thin laminated solder stop layers
  - Dark marking of heat spreaders
  - More effective and selective thin film removal

- **For IR, green and UV laser markers**

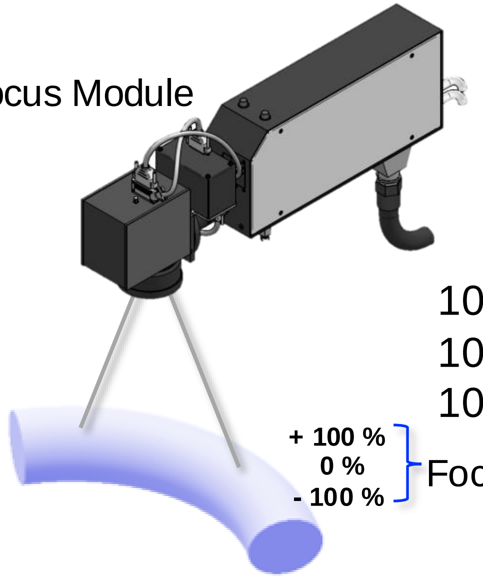




PROCESSING 3-DIMENSIONAL PARTS

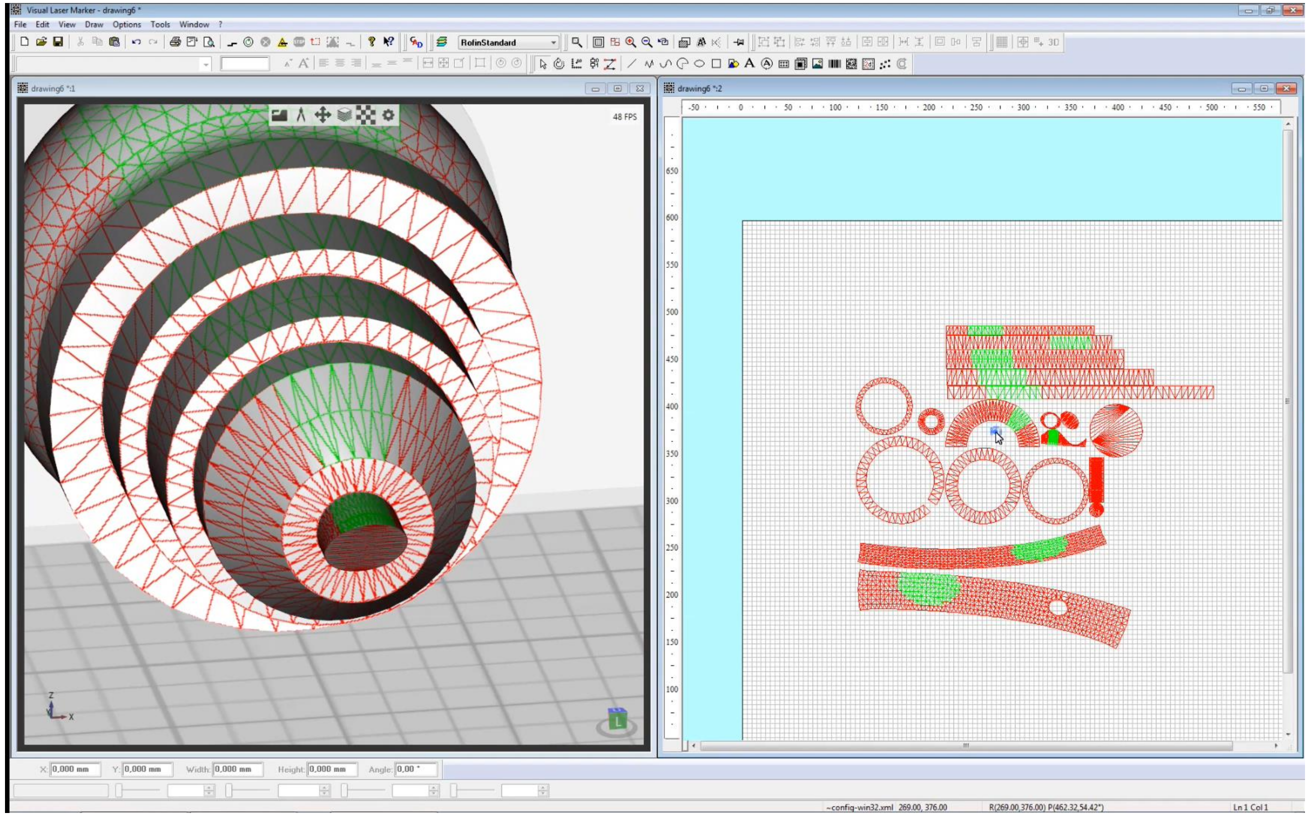
- **Fast Focusing module (FFM)**
  - Dynamic focus shifter
  - Recipe controlled focus setting
  - Enables 3D free form marking
  - Travel range depends on F-Theta objective

Fast Focus Module



1064nm, f-160mm: ± 4.5mm
1064nm, f-255mm: ± 12.5mm
1064nm, f-350mm: ± 24.0mm

+ 100 %
0 %
- 100 %
Focus range



COHERENT

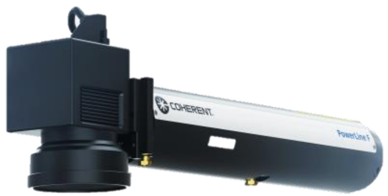
TYPICAL LASER TYPES FOR MARKING AND ENGRAVING

- **Powerline E**
  - End-pumped, solid state Nd:Vanadate lasers
  - Short ns-pulses at high peak power

1,064 nm
532 nm
355 nm

PowerLine E Air 25-1064	
Wavelength	1,064 nm
Average power	18 W (20 kHz)
Frequency	cw, 0 – 200 kHz
Pulse width	20 ns (20 kHz)
Beam quality M^2	1.3

- **Powerline F**
  - Q-switched fiber laser
  - Fixed or variable pulse width at decent peak power



1,070 nm

PowerLine F 20-1064 Varia	
Wavelength	1,060 - 1,070 nm
Average power	19
Frequency	2 – 1,000 kHz
Pulse width	1.5 – 350 ns
Beam quality M^2	2.0

- **Powerline USP**
  - Ps- or fs-lasers hybrid MOPA lasers
  - Pulse width ranging from 350 fs to 10 ps, burst mode

1,064 nm
517 nm

PowerLine PS30	
Wavelength	1064 nm
Average power	28 W
Frequency	50 – 5000 kHz
Pulse width	<10 ps
Beam quality M^2	< 1.3

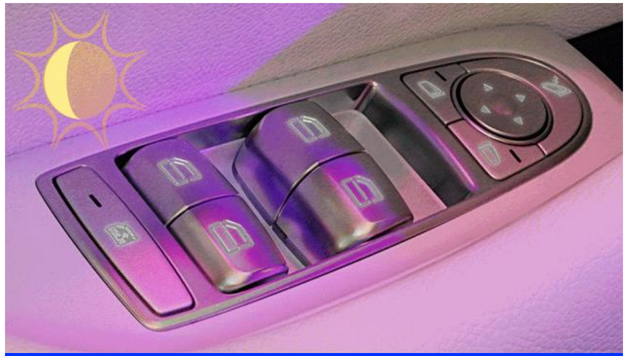
LASER MARKING PROCESSES

Annealing/black marking

Ti-dioxide effect

Color change, foaming

Carbonization

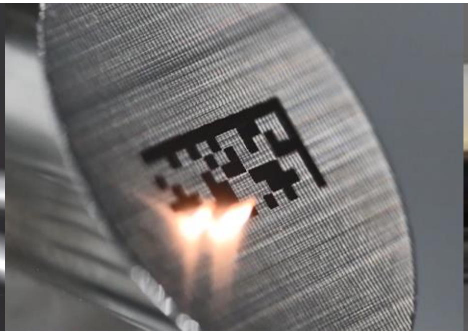


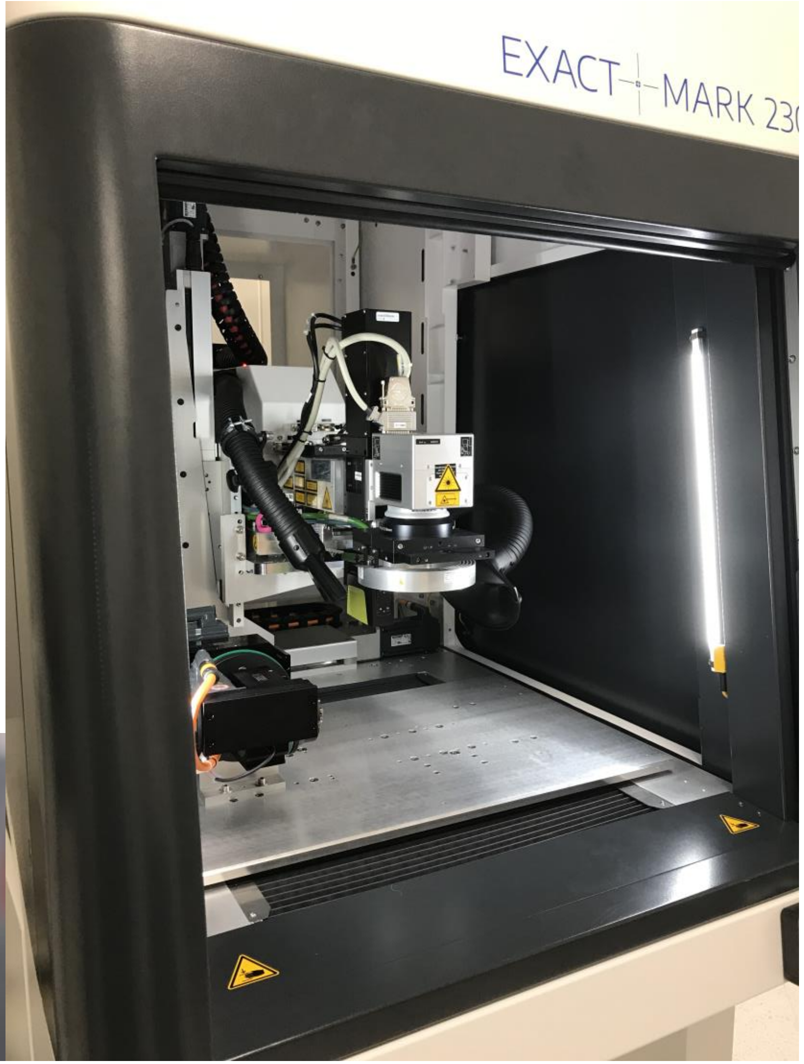
Layer removal

Engraving

EXACTMARK 230 WITH PS30 LASER - BLACK MARKING

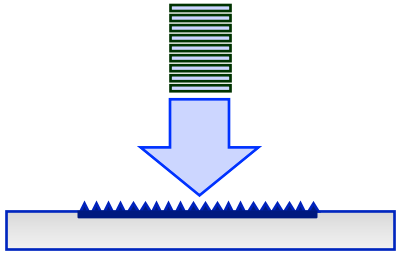
- High-contrast mark, not sensitive to angle of view
- Indestructible and non-corrosive marking of a broad range of metals
- No fading after multiple autoclaving cycles
- Contamination-free sub-surface mark
- Minimal thermal stress extends applicability on fragile and/or small parts
- No need for post processing, e.g., passivation



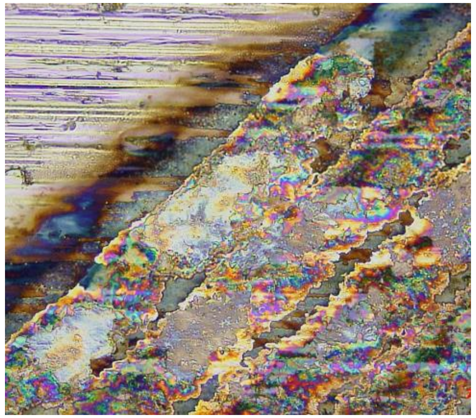


CORROSION RESISTANT MARKING - BLACK MARKING

- Short laser pulse durations limit heat affection
- Diffusion of alloy elements is reduced
- Surface oxidation of Cr and Fe significantly reduced
- Formation of nano-structures due to USP laser pulses
- Changes in metal alloy structure minimized

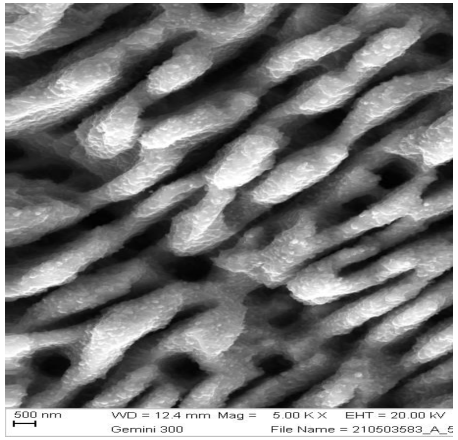


Nanosecond mark



Nanosecond laser marking after corrosion test (72h in 50°C warm 5% NaCl salt-water spray test)

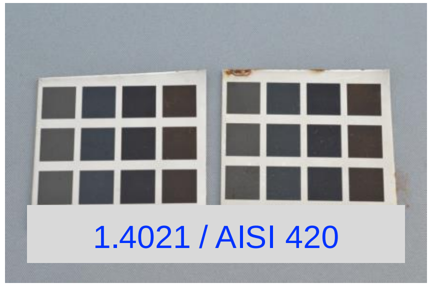
Picosecond mark



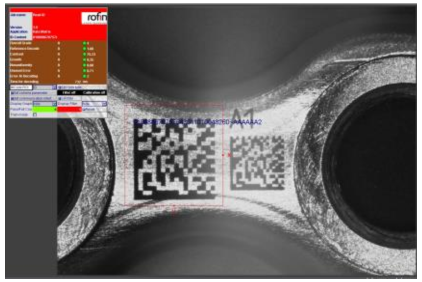
Black-marking LIPSS (laser induced periodic surface structure) under SEM

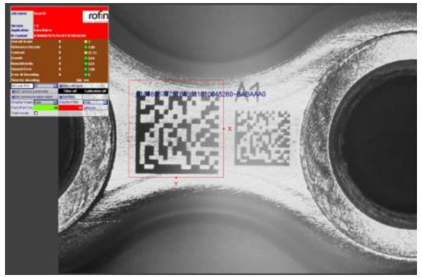
CORROSION RESISTANT MARKING - USP BLACK MARKING

Salt spray test	Passivation	Autoclaving



72h in 50°C warm 5% NaCl salt-water spray test





7% Citrisurf 2250, 20 min @ 50°C

35x

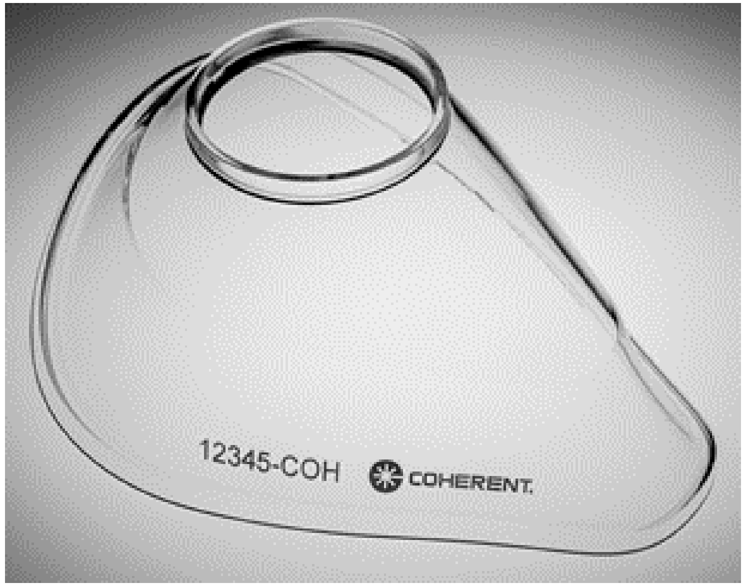
50x

Steam, >120 °C, 60 min

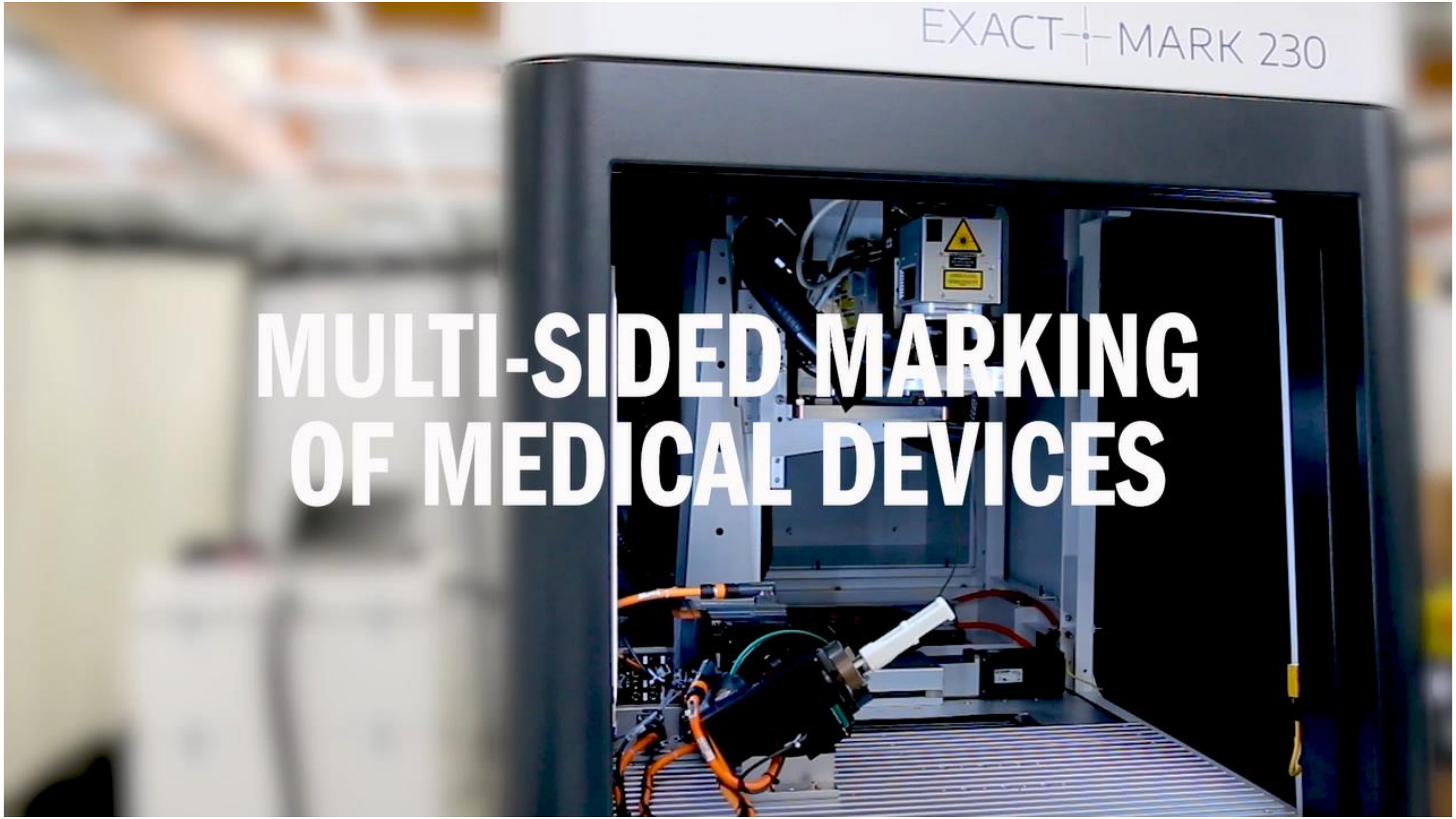
COHERENT

MARKING OF GLASS AND POLYMERS W/ UV NS-LASERS

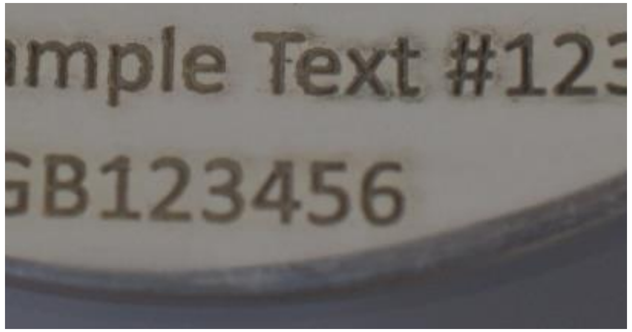
- Permanent, direct part marks are mandatory for tracking and traceability.
- Increases patient safety, enhances quality control, improves counterfeit safety



MULTI-SIDE MARKING

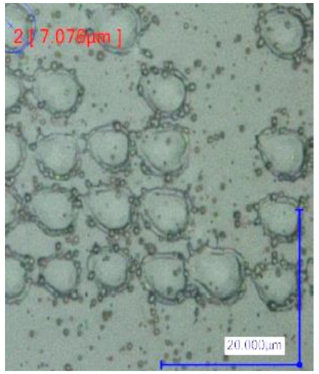


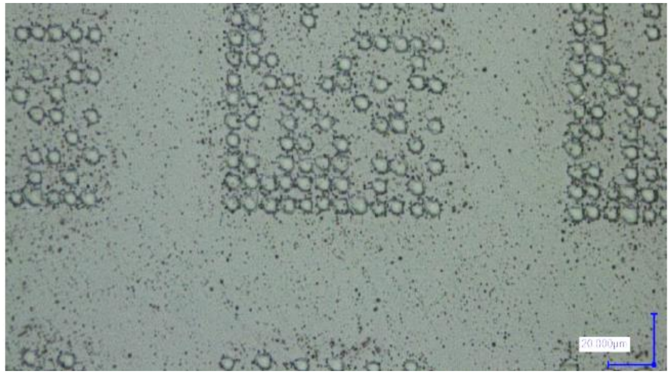
MARKING BY ENGRAVING

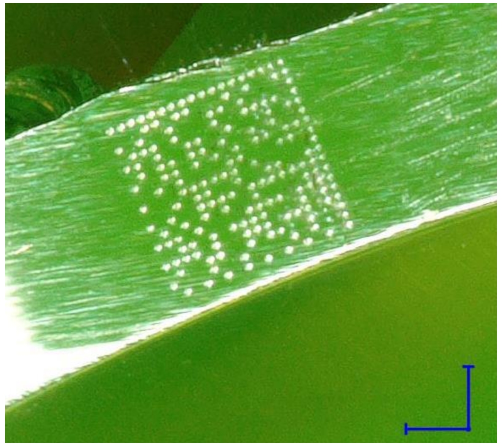
Nanosecond	Picosecond	Femtosecond
 		
Post processing mandatory due to the high amount of debris. Discoloration visible due to the heat impact.	Only slight cleaning required, rougher surface structures within the marking.	No post processing or cleaning required, least amount of discoloration.

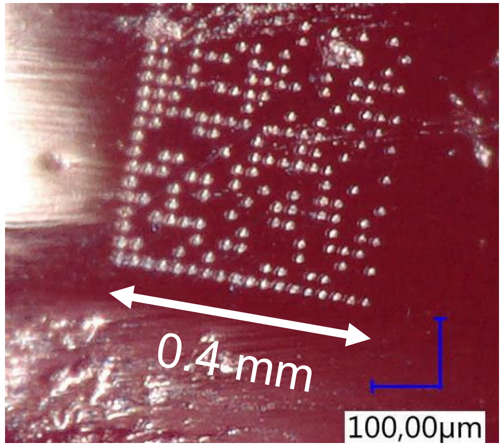
MARKING BY ENGRAVING – SMALLEST FEATURES

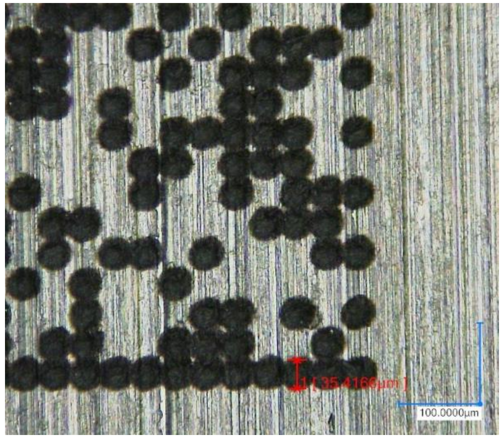
- **Security features, DMC and traceability marks on various materials (anti-counterfeiting)**







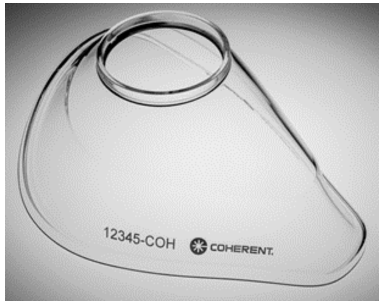




Very small codes with cell sizes down to ~5µm can be marked on various materials like metal or glass.

Codes can be marked on glass to be close to invisiblility with bare eye but still readable.

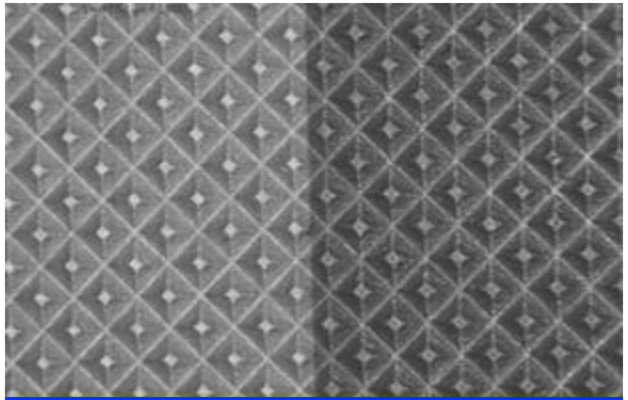
APPLICATION MATRIX – LASER MARKING



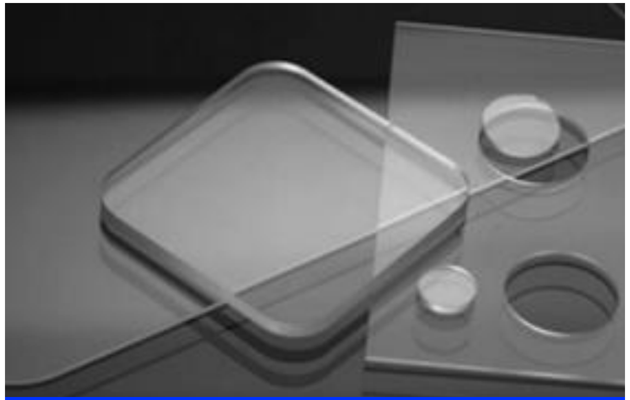
	λ = 1,064 nm									λ = 532 nm			λ = 355 nm	
	PL E Air 10	PL E Air 25	PL F 20	PL F 30	PL F 50	PL F 100	PL F 20 Varia	PL F 50 Varia	PL PS 30	PL E 6 QS	PL E 12 QS	PL E 25 SHG	PL E 20 THG	PL E 30 QT
Plastic Marking (Carbonization)		●	●	●	●		●	●	●				●	
Plastic Marking (Foaming)	●	●	●	●	●		●	●	●					
Plastic Marking (Bleaching)													●	●
PEEK, PA 6, Nylon											●	●	●	●
Day and Night Design		●					●							
Metal Marking & Engraving			●	●	●	●	●	●	●					
Copper Marking												●		
Annealing Marking							●	●						
USP Black Marking									●					
Glass Marking									●		●		●	●

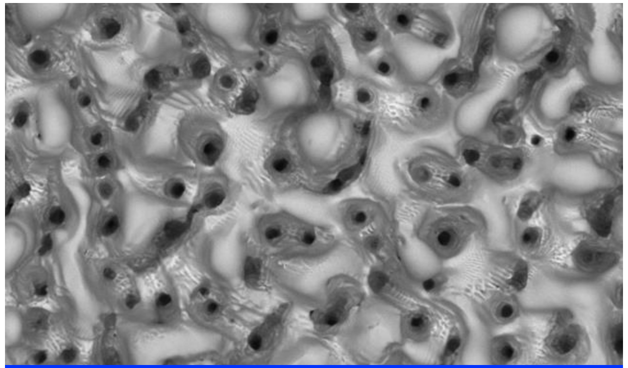
Rough guideline only – application test recommended

LASER MICRO PROCESSING APPLICATIONS

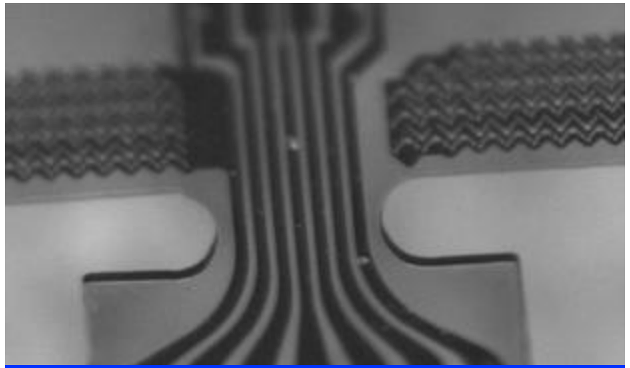

Cleaning


Coating removal


Glass filamentation


Surface structuring

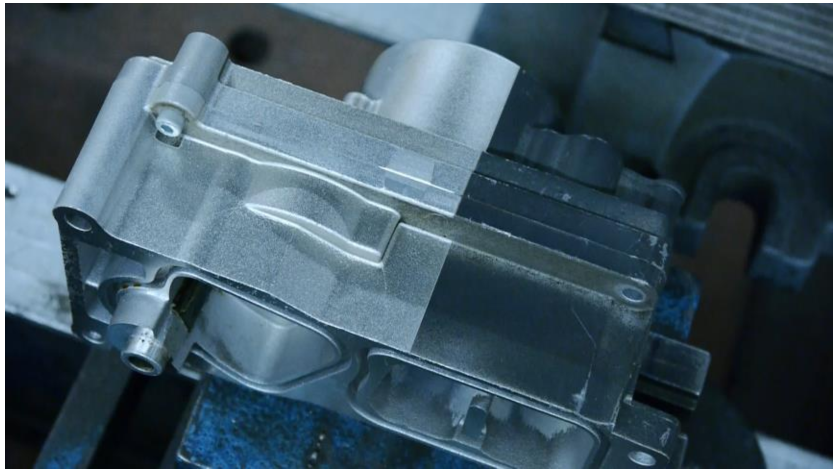

Multipass - drilling

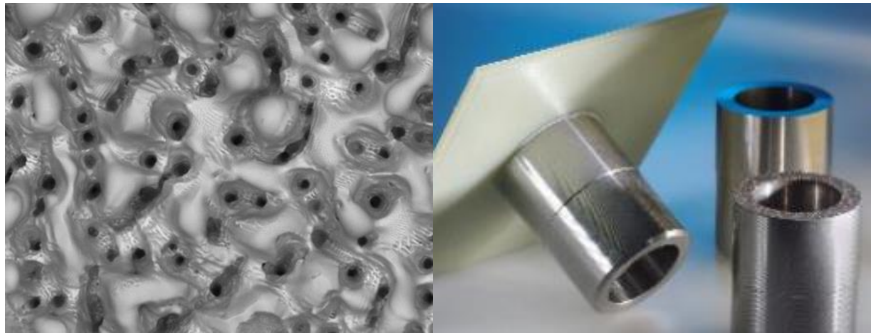

Multipass - cutting

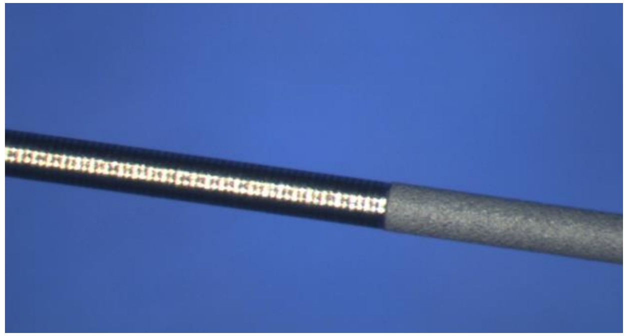
COHERENT

SURFACE CLEANING AND STRUCTURING

- **Laser ablation of coatings**
  - Paint or organic contaminations
  - Residual material from molding processes
- **Laser pre-treatment for adhesion improvement**
  - Removal of contaminants (grease, oil, …)
  - Nano-structuring of metals for improved joining properties with organic materials





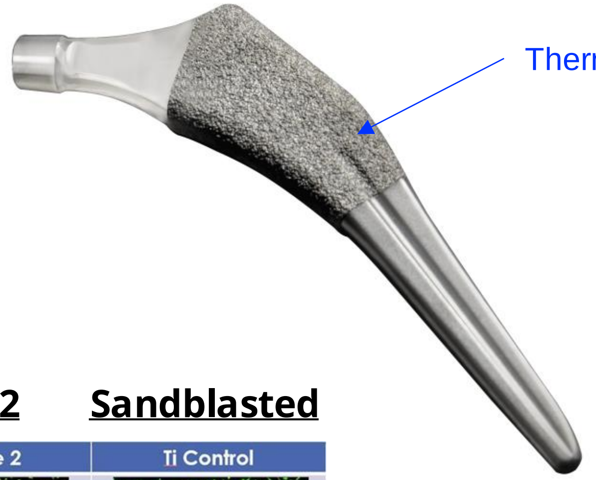


SURFACE STRUCTURING JOINT IMPLANTS

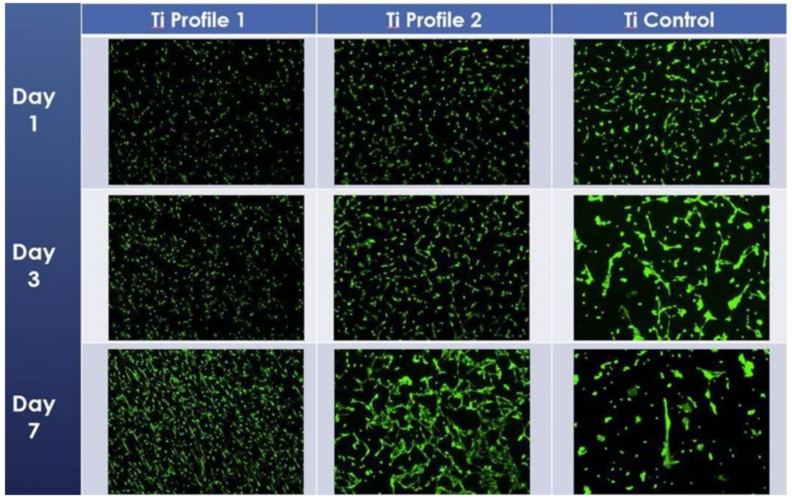
- **Replace Media Blast for Improved Thermal Spray Coat Adhesion**
  - No masking
  - Reduce handling damage
  - Consistent control
  - Minimal strength impact
  - Improved coating adhesion

- **Functionalize Surface**
  - Promote bone growth
  - Anti-bacterial
  - Modified surface chemistry

Hip Implant



USP 1 **USP 2** **Sandblasted**



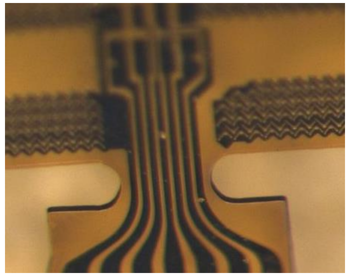
USP processed samples promote bone growth

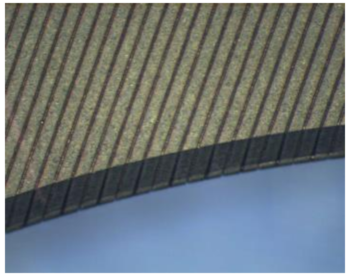
MULTI-PASS CUTTING OF POLYMER COATINGS ON MEDICAL IMPLANTS AND DEVICES

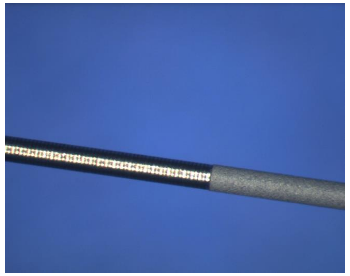
- Some medical implants or devices have got a polymer coating or shrink tubing applied to the metal structure
- This coating/shrink tube needs to be cut precisely at specific locations in relation to the strut layout

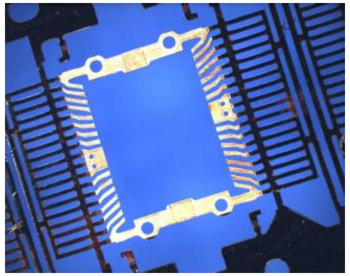
- Two different Coherent solutions available for such an application, using **30W CO_2 laser (10.6 µm) or fs-Laser SHG (517 nm)**
- Vision and pattern recognition sytem required

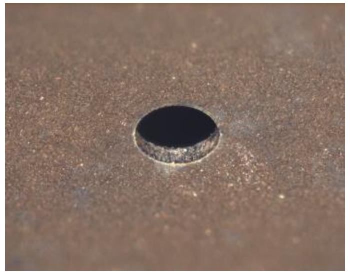
APPLICATION MATRIX – LASER MICRO PROCESSING











	λ = 10,6 µm	λ = 1,064 nm										λ = 532 nm				λ = 355 nm	
	PL C30	PL E Air 10	PL E Air 25	PL F 20	PL F 30	PL F 50	PL F 100	PL F 20 Var	PL F 50 Var	PL PS 30	Monaco fs-subsist.	PL E 6 QS	PL E 12 QS	PL E 25 SHG	Monaco fs-subsist.	PL E 20 THG	PL E 30 QT
Deep engraving						●	●	●	●	●	●				●		
Polyimide cutting/drilling															●	●	●
Polymer cutting/drilling	●									●	●				●		
Coating ablation								●	●	●	●	●	●		●	●	●
Metal surface structuring										●	●				●		
Polymer structuring										●	●		●		●	●	●
Tools surface cleaning				●	●	●	●	●	●	●	●						
Thin film ablation										●	●		●		●		●
Ceramic structuring	●									●	●				●		●
Glass polishing	●																

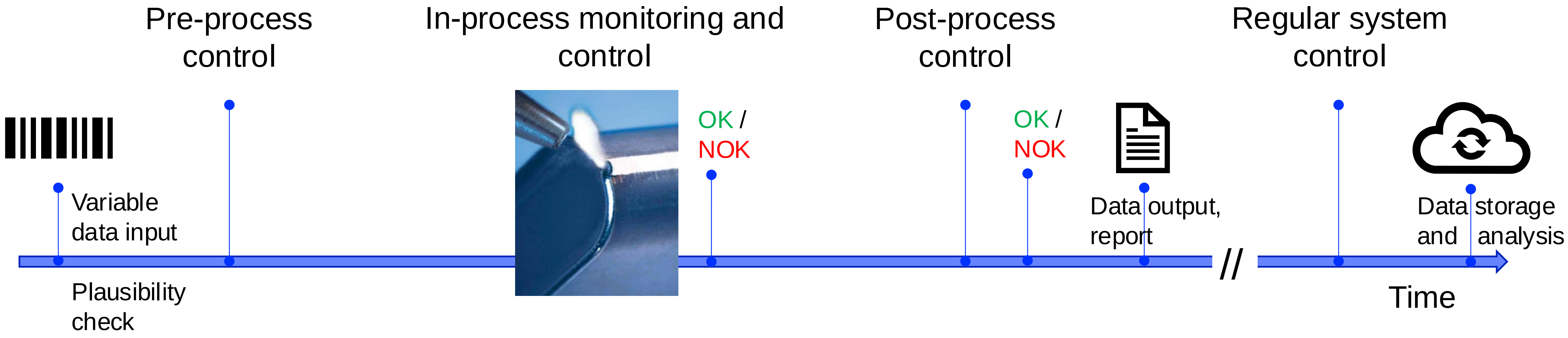
COHERENT

Rough guideline only – application test recommended

APPLICATION CONFIGURATION DONE

-> NEXT STEP IS TO LOOK AT THE COMPLETE PROCESS CHAIN

CONTROL THE LASER PROCESS AT VARIOUS STAGES

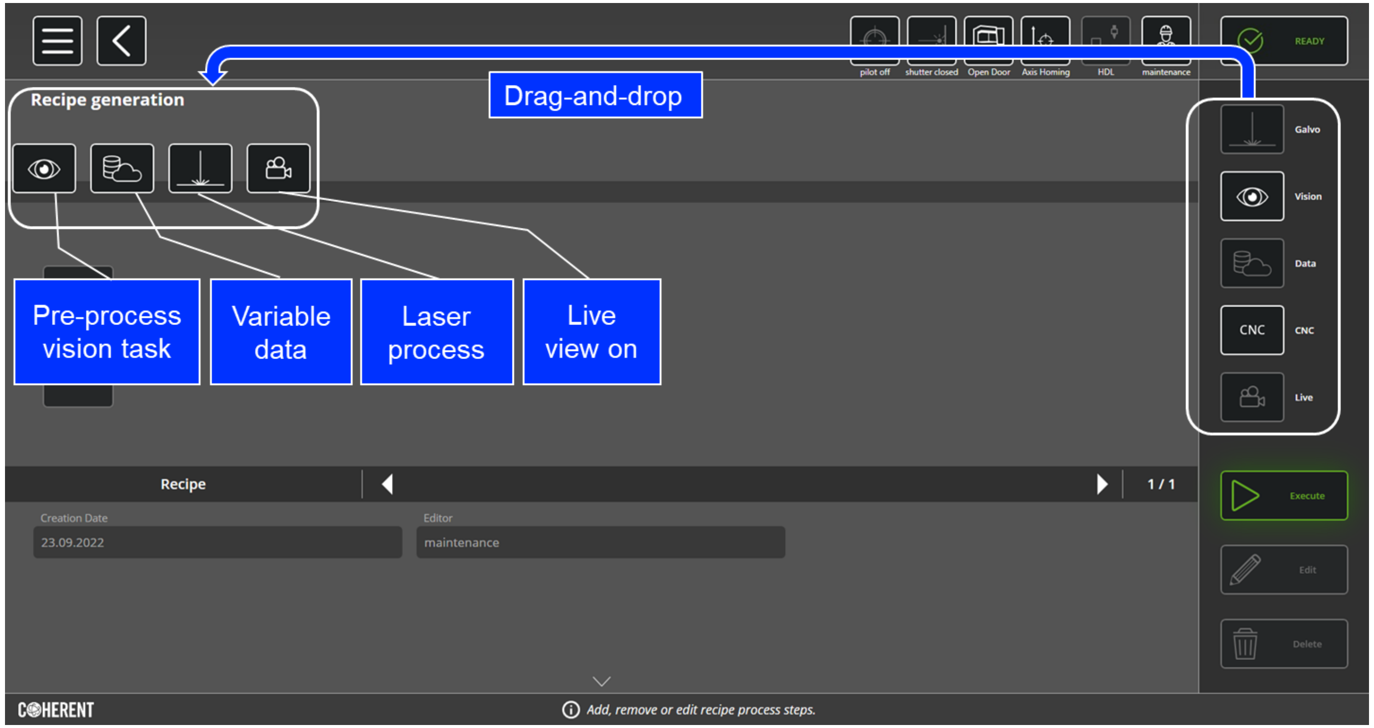


-> Needs a system software to let the process developer or operator set this sequence up in an intuitive way

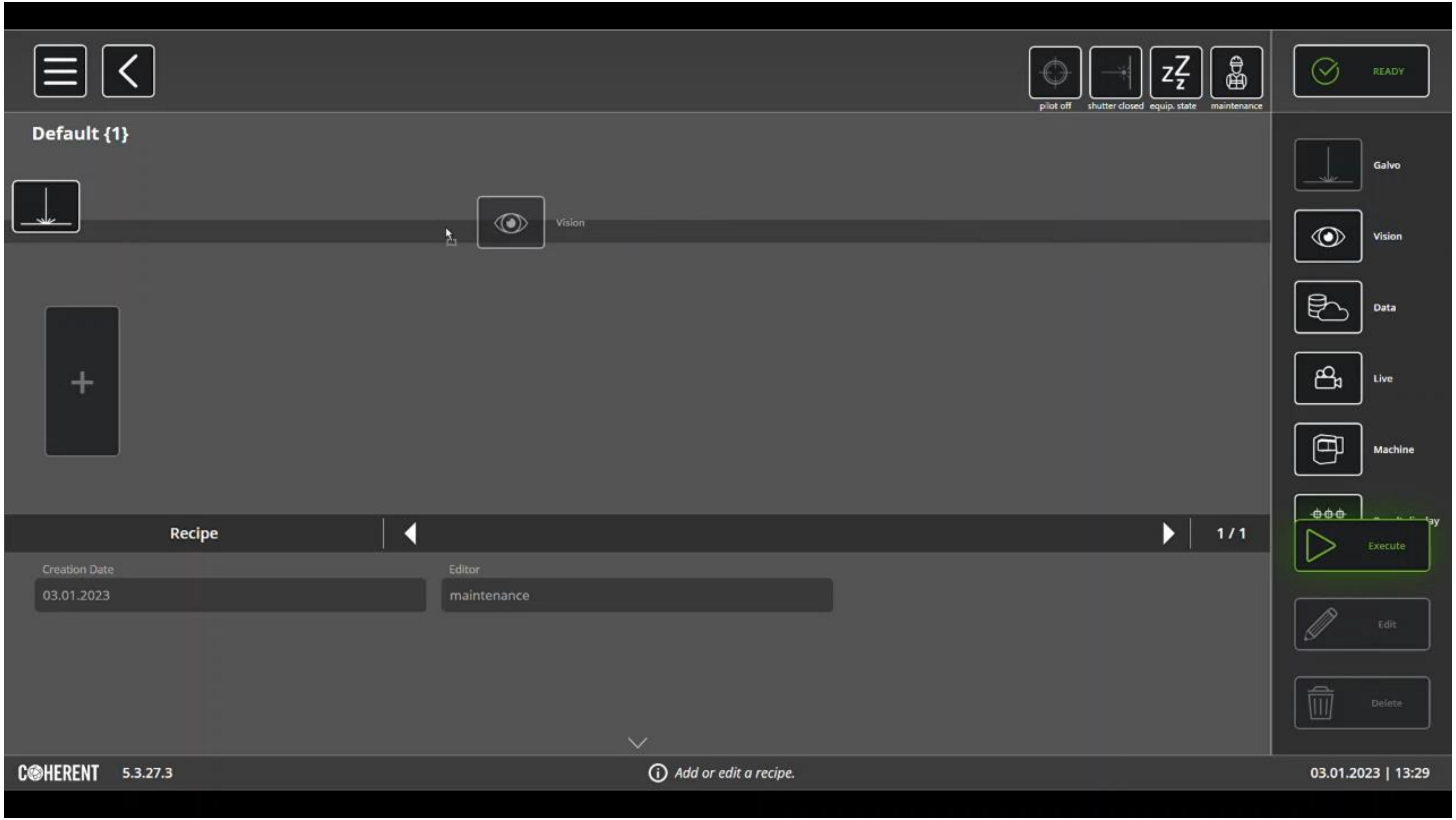
LASER FRAMEWORK SOFTWARE: SETTING UP AN APPLICATION

- The **Recipe** – is the center point of the new LFW concept and allows the process developer to create a sequence of process steps, that are necessary to fulfill a specific laser application.

- The **Process step** – allows setting parameters for the individual steps of a recipe, for example:
  - laser parameter
  - Galvo scanner layout or CNC program
  - variables
  - vision tasks
  - machine I/Os
  - data exchange options
  - etc.

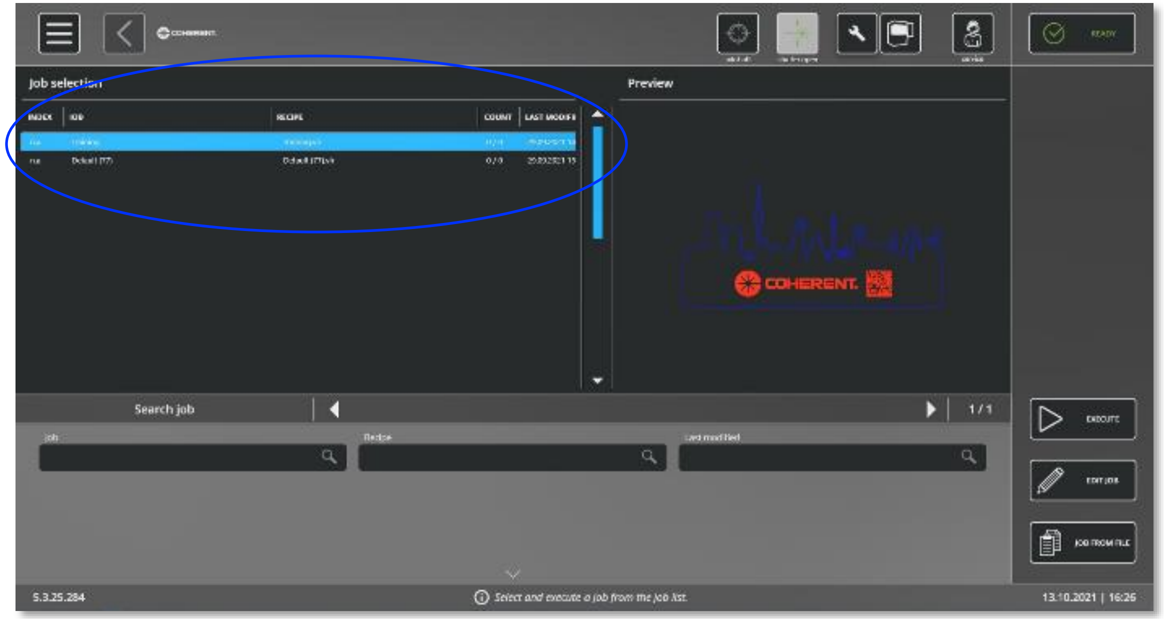


LASER FRAMEWORK SOFTWARE: GENERATE A RECIPE



LASER FRAMEWORK SOFTWARE: EXECUTING AN APPLICATION

- **The Job** – contains all necessary information for the execution of a certain laser processing application. A job includes a recipe and additional data, like number of executions or input variables. Each job has got a unique number assigned, that can also be selected or called by external I/Os.



Job list with layout preview

CONTROL THE LASER PROCESS: PRE-PROCESS CONTROL

Pre-process control

Variable data input

Plausibility check

- Visual sensing:
  - Part fit
  - Weld gap detection
  - Part position
  - Correct parts?
  - Part geometry
- Fixture sensing
- …

In-process monitoring and control

OK / NOK

- Weld depth monitoring (OCT)
- Diode-based monitoring
- Acoustic monitoring
- Pyrometer-based laser power control
- Thermal imaging
- Height sensing
- Path deviations
- …

Post-process control

Data output, report

- Weld geometry and alignment
- Visual process quality (w/ or w/o AI and machine learning)
- Marking code verification
- Thermography of the cool-down process
- Acoustic emissions
- …

Regular system control

Data storage and analysis

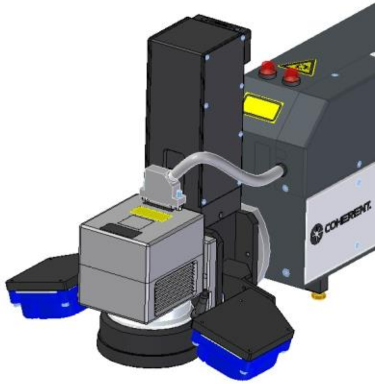
Time

- Laser power validation and regulation
- Beam quality check
- System utilization
- System-to-system equalization
- …

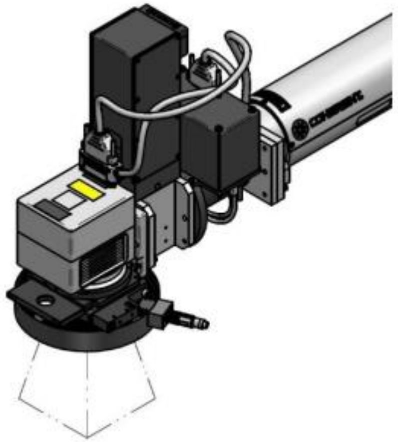
PARTVISION – PACKAGES

Vision and pattern recognition packages for all PowerLine Marking Sub-systems and Systems

BASIC



ADVANCED

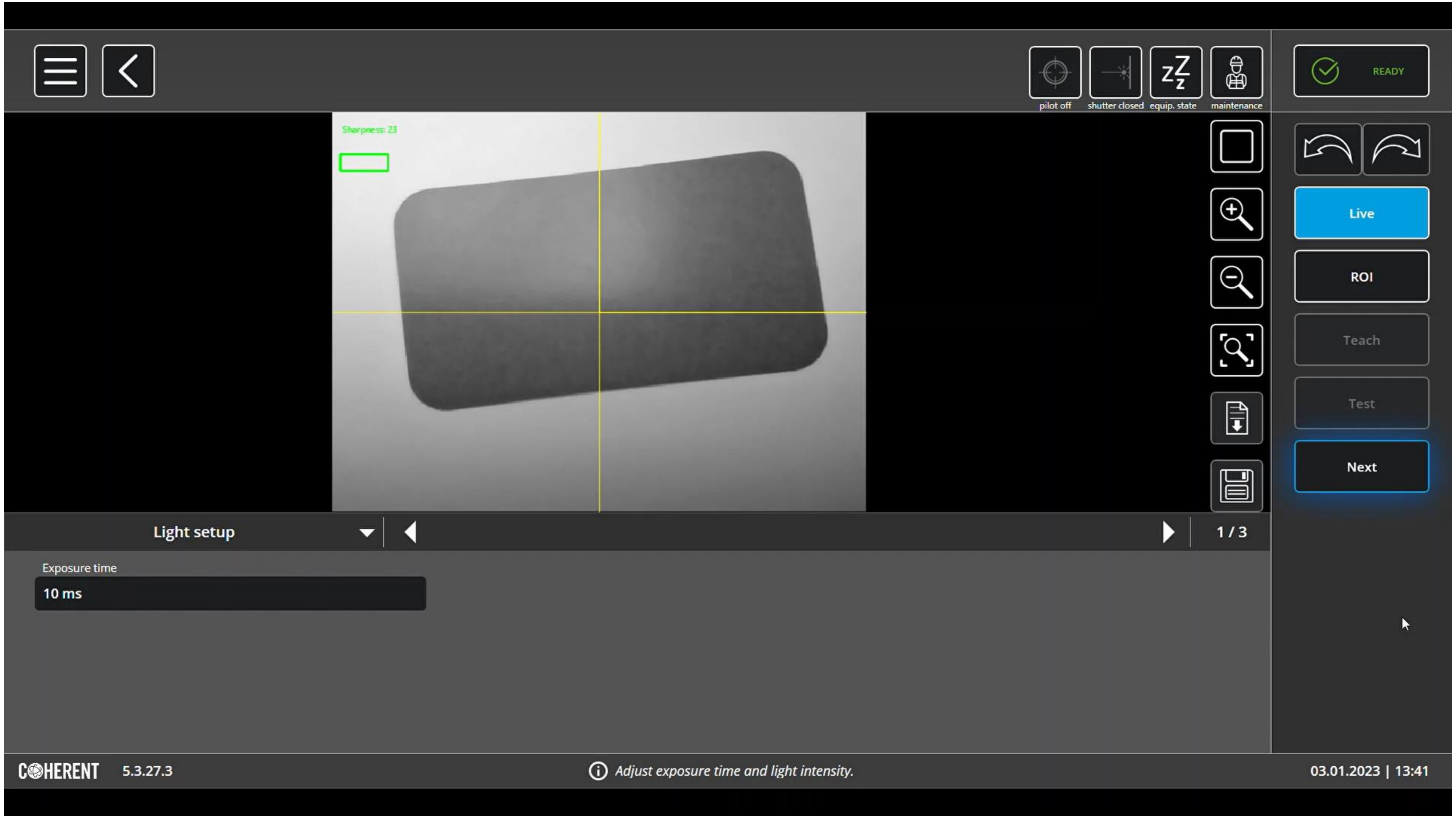


ADVANCED +

Consisting of hardware and software features:

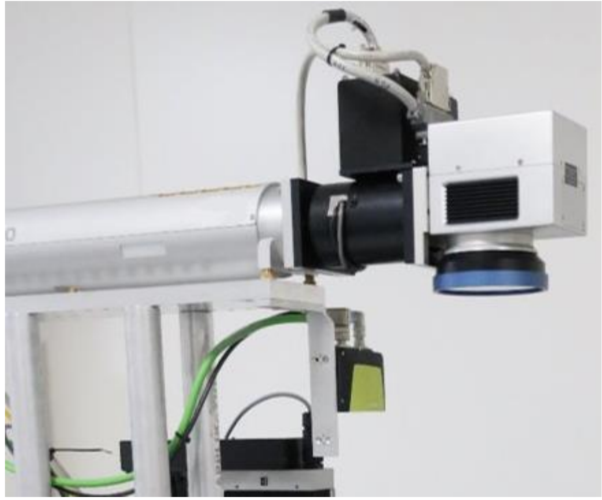
- Vision Cube
- Camera
- LED Illumination and controller (Advanced)
- Illumination adapted scanner mirrors
- Pre-assigned Laser FrameWork vision tasks (license-controlled)

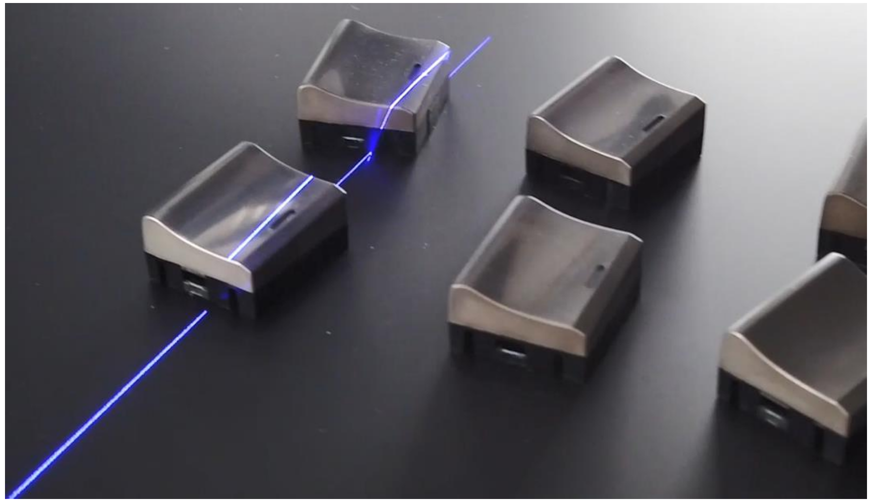
LASER FRAMEWORK SOFTWARE: DEFINE A VISION TASK

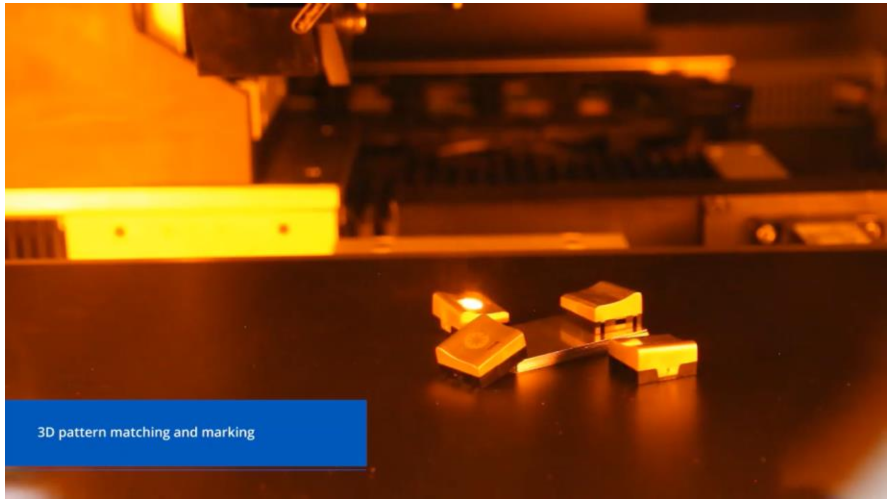


PRE-PROCESS CONTROL OPTIONS

- **3D part geometry shape detection** w/ line scan camera and x/z-axes
  - Precise distance measurement
  - Captures point cloud of object surface
  - Accurate detection of workpiece geometry and position
  - Automatic position adjustment of marking layout



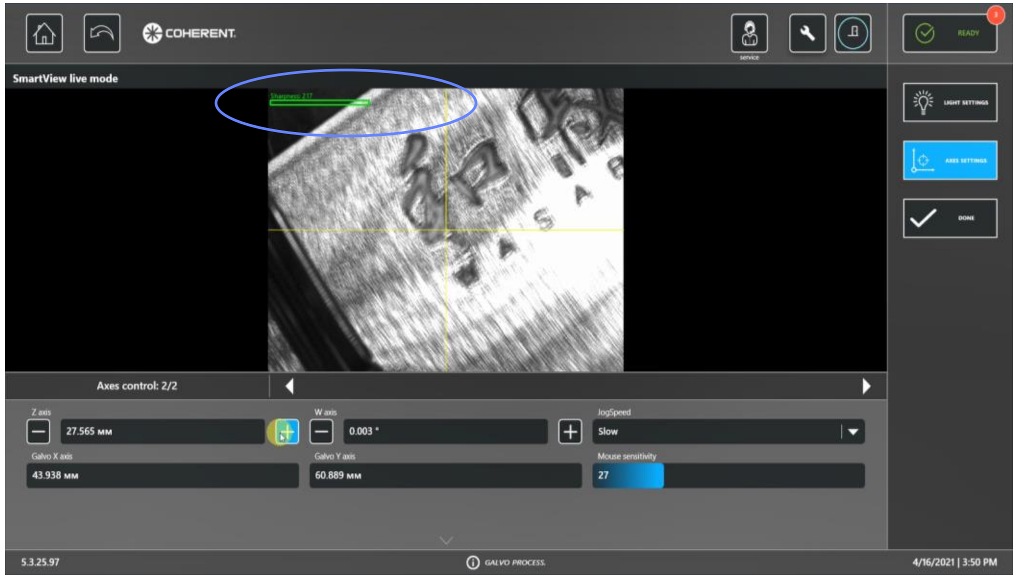




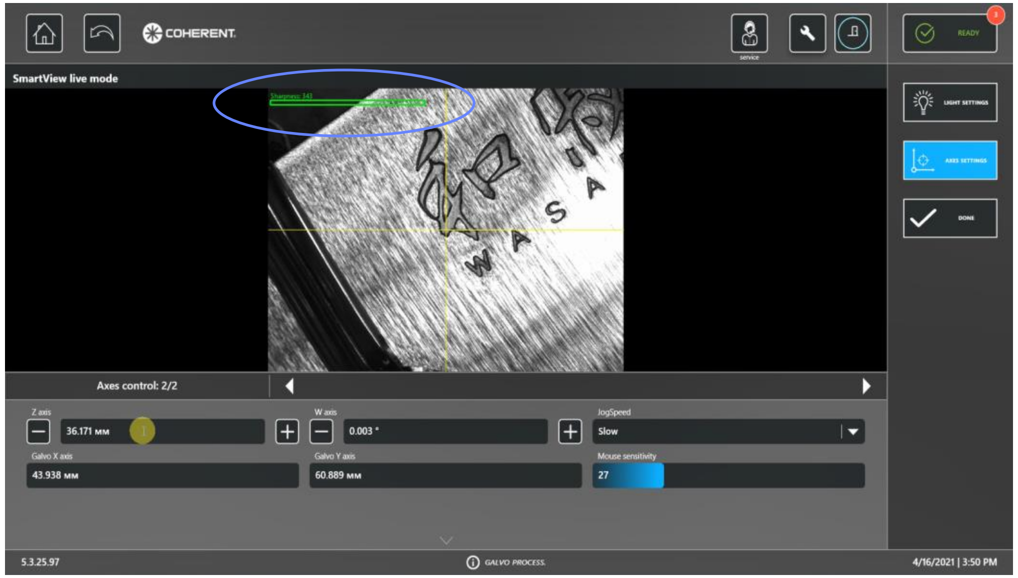
PRE-PROCESS CONTROL OPTIONS

- **Autofocus from image sharpness value**
  - For TTL camera calibration
  - For process developer
  - For automatic vision task

*requires LFW controlled z axis
** FoV = Field of View



Out of focus: blurry, live FoV**

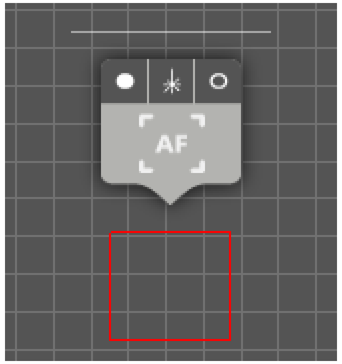


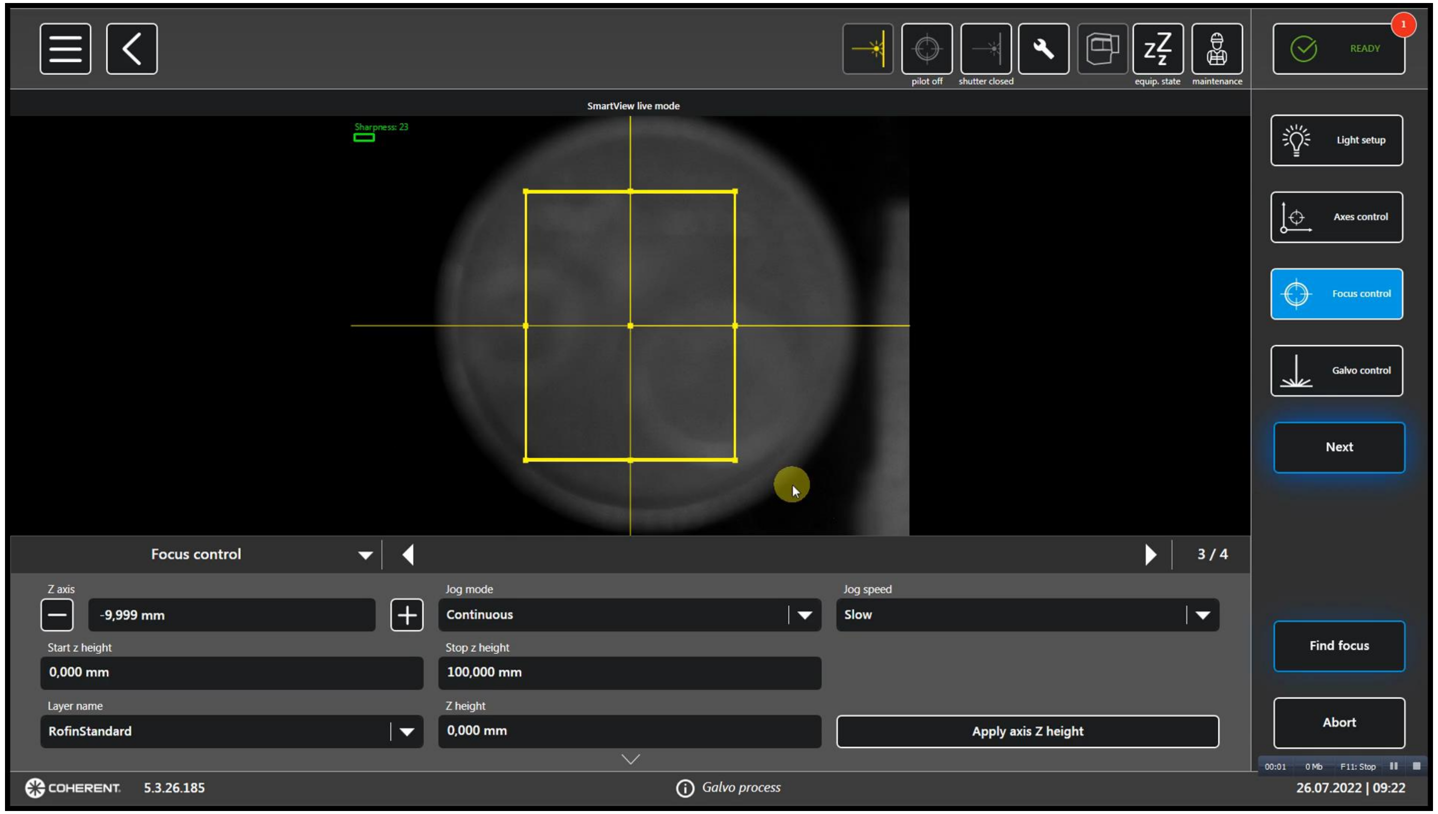
In Focus: sharp, crisp live FoV**

COHERENT

PRE-PROCESS CONTROL OPTIONS

- **Autofocus from image sharpness value**
  - For TTL calibration
  - For process developer
  - For automatic vision task





CONTROL THE LASER PROCESS: POST-PROCESS CONTROL

Pre-process control

Variable data input

Plausibility check

- Visual sensing:
  - Part fit
  - Weld gap detection
  - Part position
  - Correct parts?
  - Part geometry
- Fixture sensing
- …

In-process monitoring and control

OK / NOK

- Weld depth monitoring (OCT)
- Diode-based monitoring
- Acoustic monitoring
- Pyrometer-based laser power control
- Thermal imaging
- Height sensing
- Path deviations
- …

Post-process control

Data output, report

- Weld geometry and alignment
- Visual process quality (w/ or w/o AI and machine learning)
- Marking code verification
- Thermography of the cool-down process
- Acoustic emissions
- …

Regular system control

Data storage and analysis

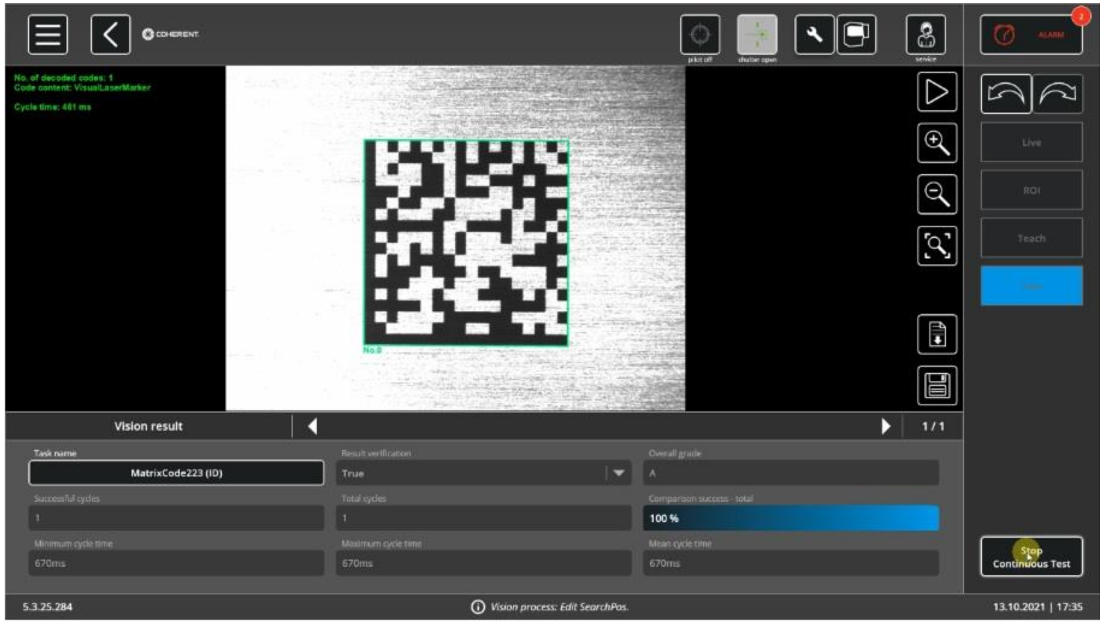
Time

- Laser power validation and regulation
- Beam quality check
- System utilization
- System-to-system equalization
- …

COHERENT

POST-PROCESS CONTROL OPTIONS

- **Vision:** code verification



- Log code reading results according to ISO standards or print a report

- **Vision:** OCR

- Check lasered clear text marking content

CONTROL THE LASER PROCESS WITH LASER FRAMEWORK

Pre-process control

- Variable data input
- Plausibility check

In-process monitoring and control

OK / NOK

Post-process control

OK / NOK

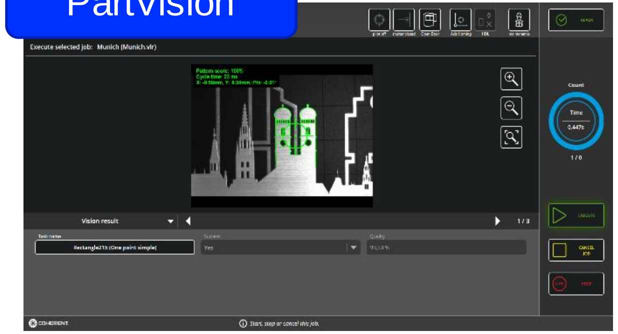
Data output, report

Regular system control

Data storage and analysis

Time

PartVision



SmartSense+

PartVision

System monitoring

MARKING PROCESS – VIDEO

SYSTEM AND AUTOMATION OPTIONS

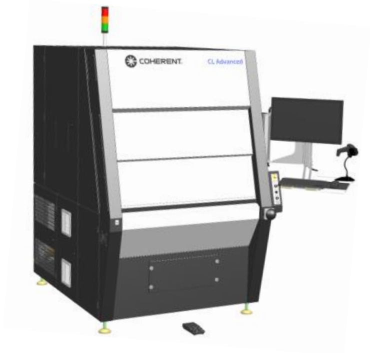
2

STANDARD SYSTEMS FOR MARKING AND ENGRAVING

EasyMark,
EasyMark XL

ExactMark 210
ExactMark 210 TL/R

ExactMark 230 USP
ExactMark 230 WT



CombiLine XL

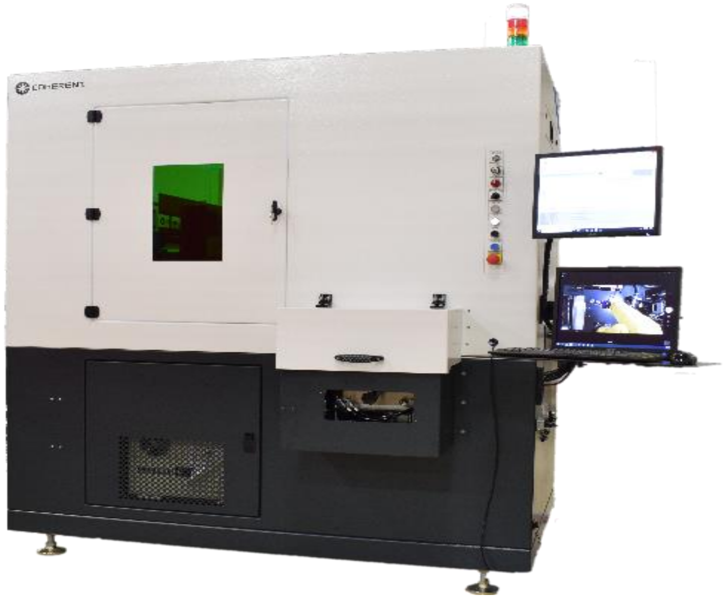
CombiLine RT800
CombiLine RT1000

LabelMarker

AP 530
(dedicated 3d micro processing system with internal robot)

AUTOMATED SYSTEMS - BASED ON UW180 PLATFORM

Advantages



Automation

- High Degree of Automation
- Better Utilization of Assets
- Lower Cycle Time
- Higher Throughput

Throughput

Human

- Minimize Operator Fatigue
- Longer Unattended Operation
- Eliminate/Minimize Human Error

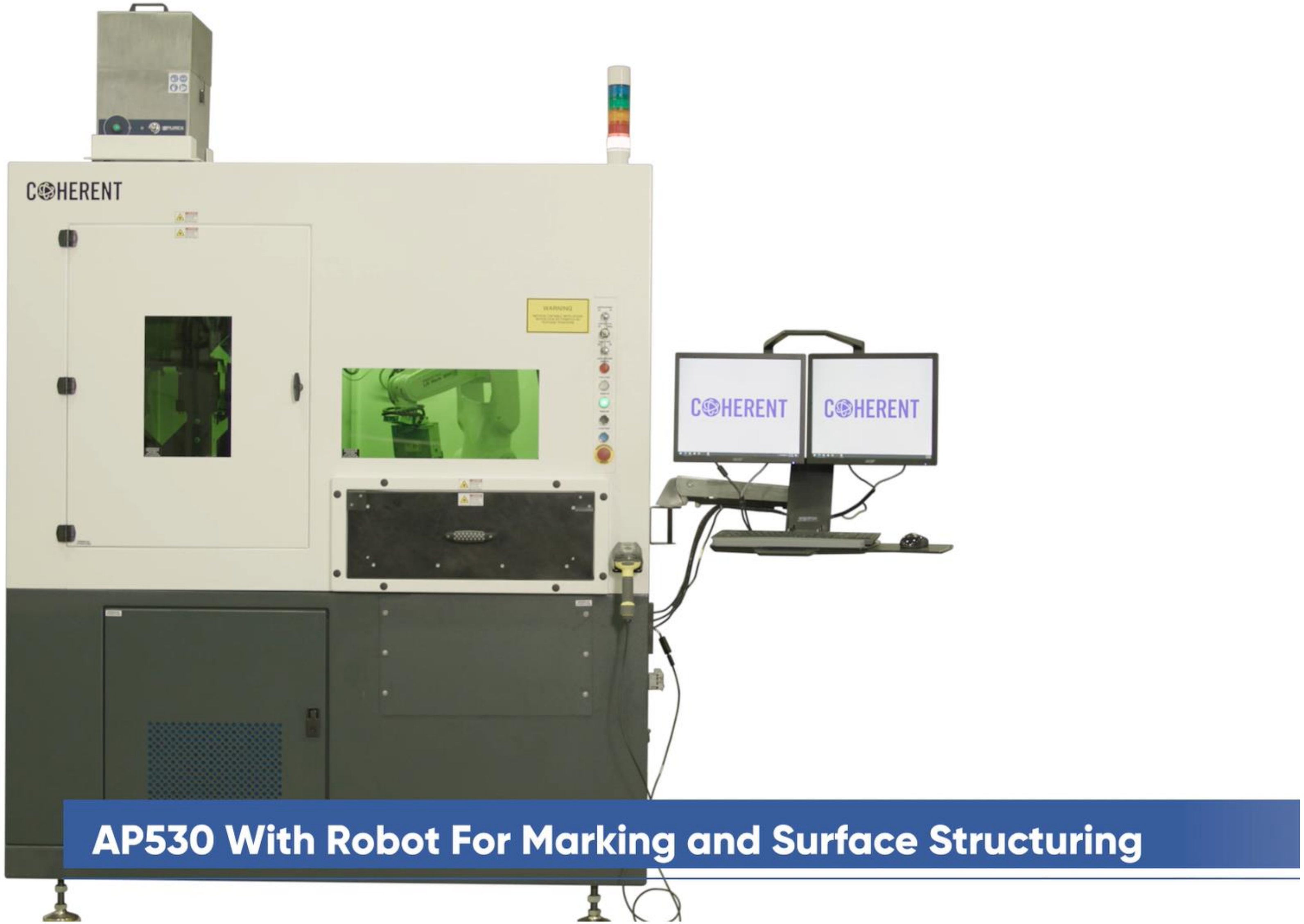
- Part Verification and Sorting
- Data Logging / Compliance

Compliance

Productivity
&
Value Creation

AUTOMATION AND PROCESS CONTROL: MARKING

AUTOMATION AND PROCESS CONTROL: MARKING



AUTOMATION AND PROCESS CONTROL: MARKING AND TEXTURING

AUTOMATION AND PROCESS CONTROL: MARKING

Automatic Tube
Processing System

COHERENT