LASER WELDING FOR MEDICAL DEVICE MANUFACTURING

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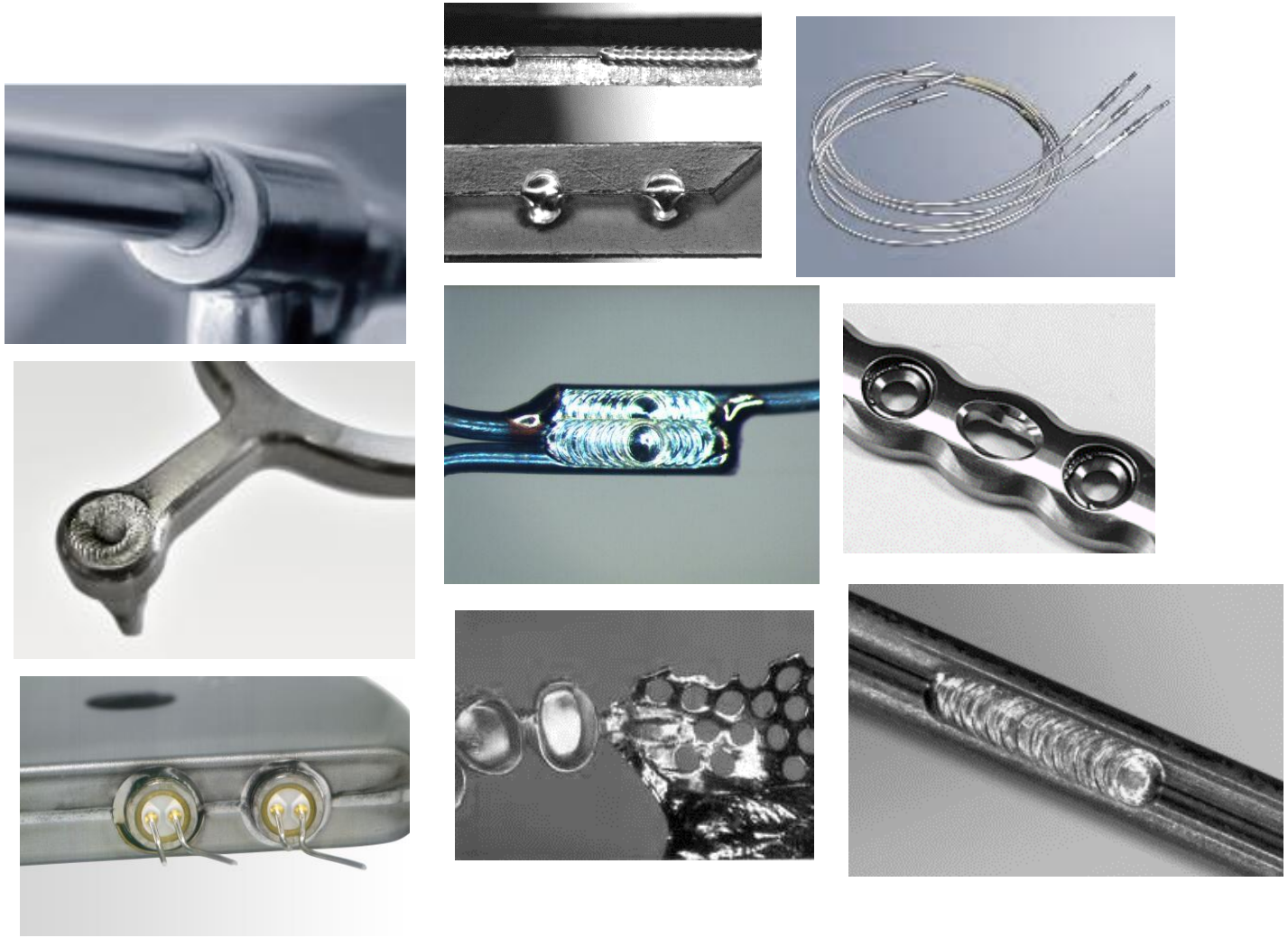
COHERENT

AGENDA

- **Laser Welding Fundamentals**
  - Introduction to Laser Welding – What to Know
    - Laser basics
    - Laser Parameters
    - Materials
    - Cover Gas
    - Joint Geometry, Fit-up & Tooling
  - Welding solutions
- **Weld Monitoring**

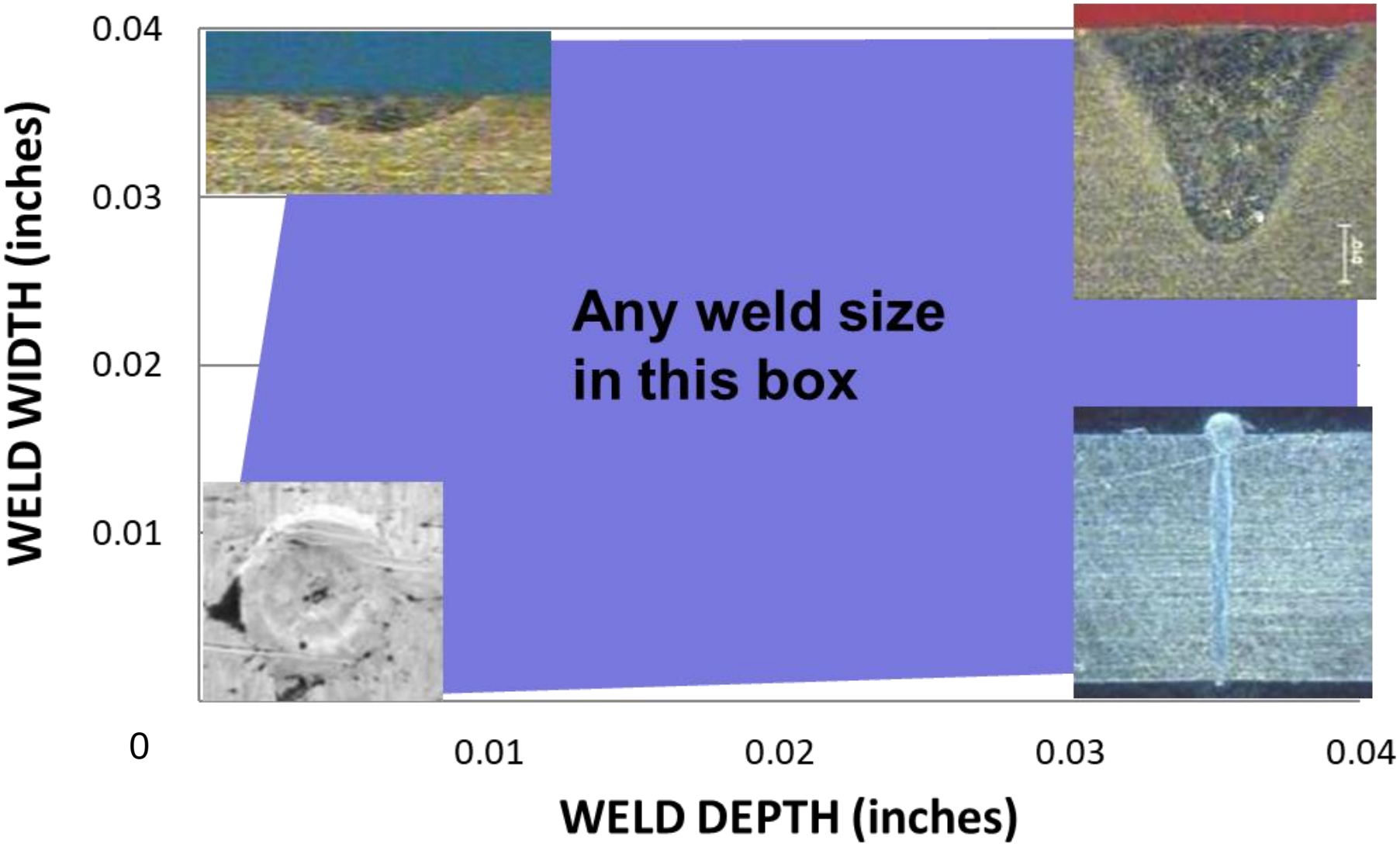
LASER METAL WELDING FUNDAMENTALS

LASER WELDING APPLICATIONS



- Many medical device laser welding applications
- Laser welding aligns well with MDM
  - Non-contact
  - Low thermal input
  - Small spot size
  - Flexible
  - Reliable

LASER MICRO-WELDING GEOMETRY WINDOW



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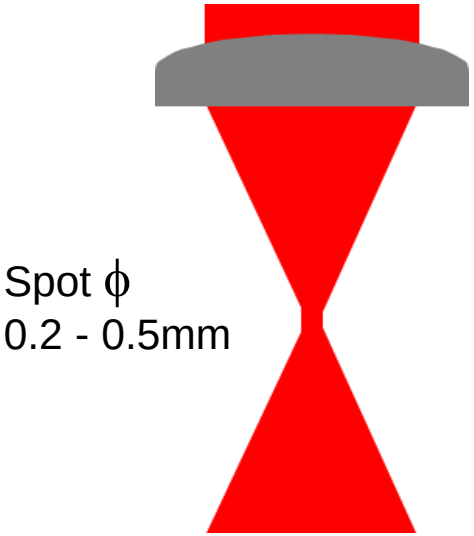
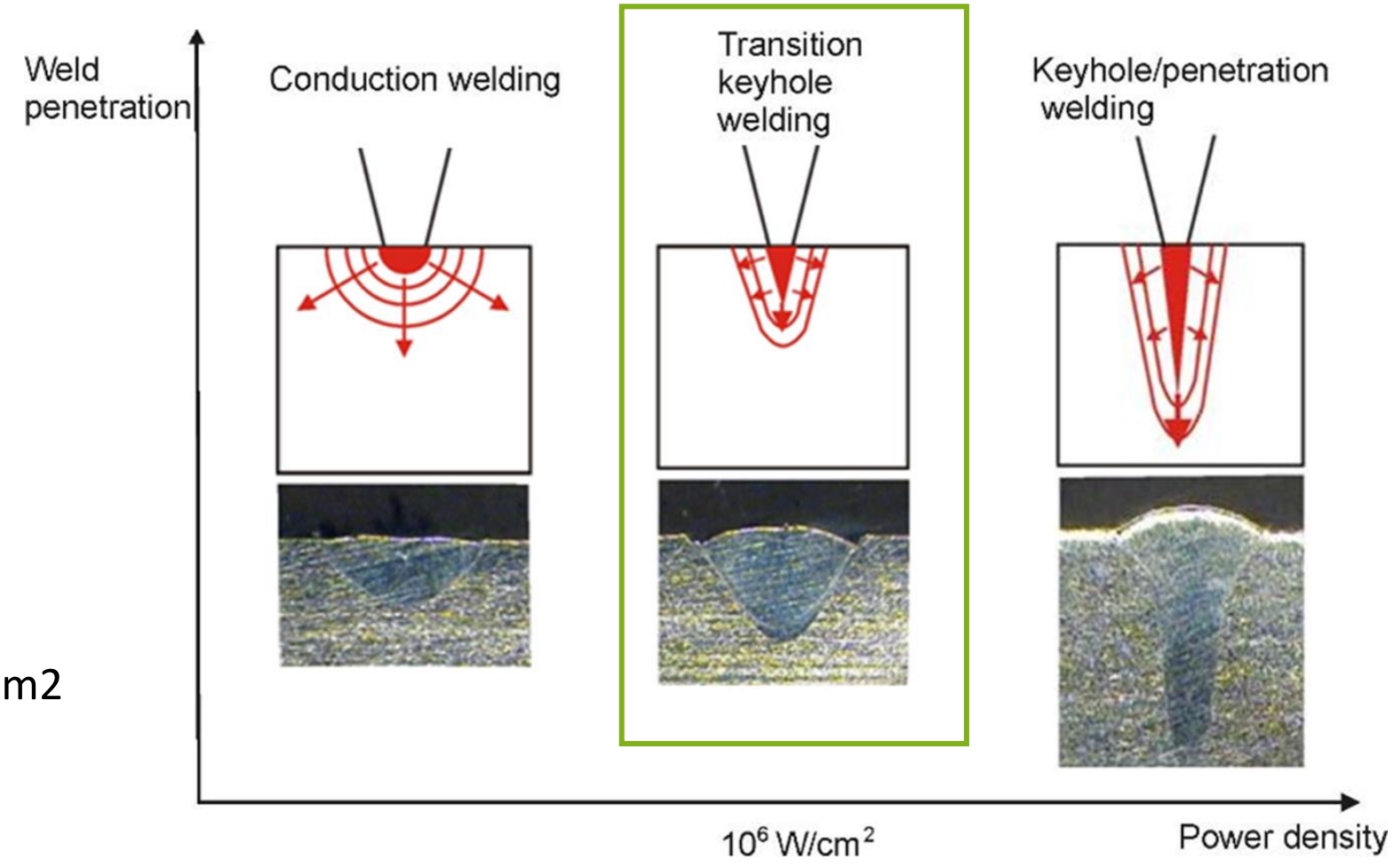
THE BASICS

Laser focus



- Soldering Iron 100 W/cm2
- MicroTIG 10,000 W/cm2
- Focused laser 1,500,000+ W/cm2

Welding modes



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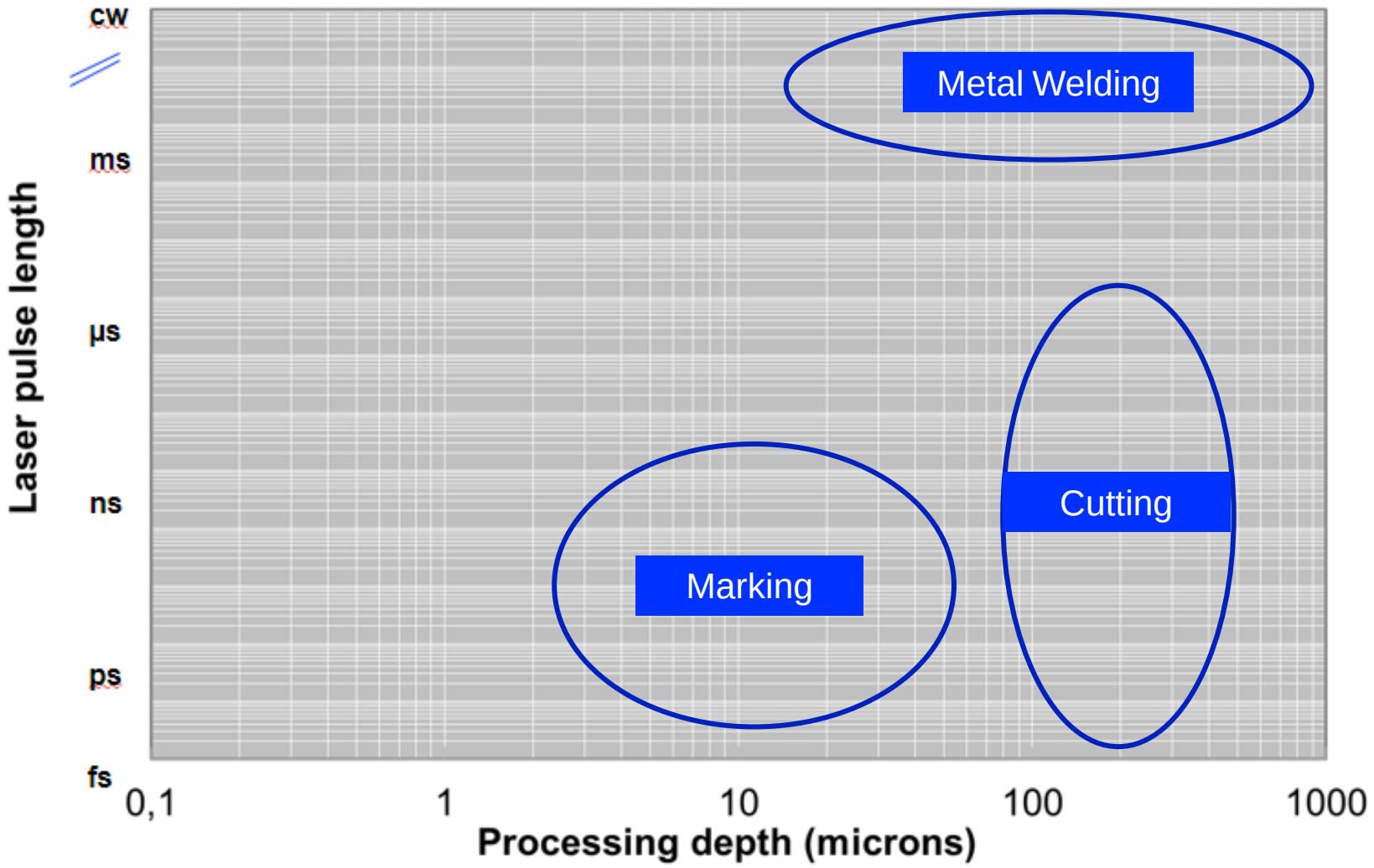
LASER WELD PARAMETER REGION



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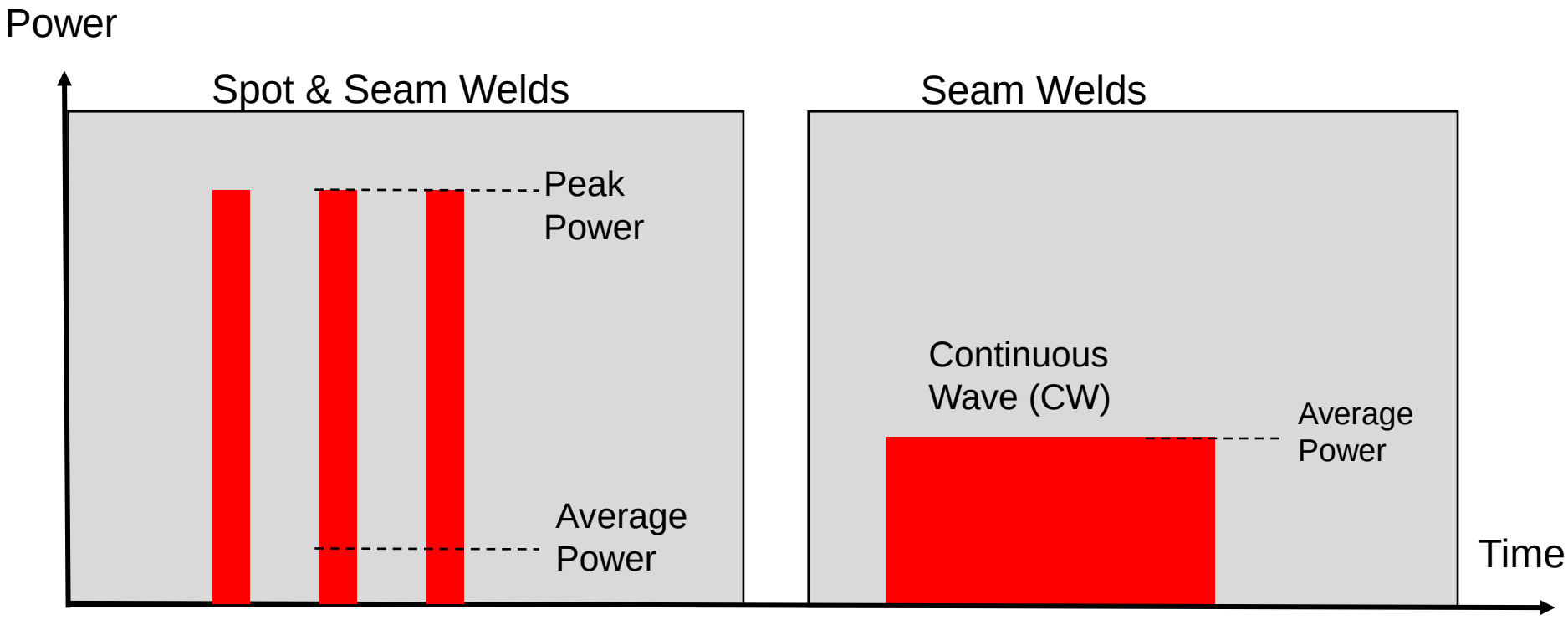
LASER WELD PARAMETERS



LASERS FOR MICRO WELDING

- **Pulsed Nd:YAG**

Applications

- **Fiber laser**

- **“The original” laser for micro welding**
- **Pulsed operation only**
- **Large parameter envelope**
- **Spot diameter ~ 200 to 400 microns**
- **Can be field repaired**
- **Higher cost of ownership**
  - Flash lamps
  - Cavity optics & alignment
  - Water cooling

- **Latest laser technology**
- **Pulsed or continuous wave operation**
- **OK parameter envelope**
- **Spot diameter ~ 50 – 300 microns**
- **Cannot be field repaired**
- **Lower cost of ownership**
  - Air cooling
  - No consumables

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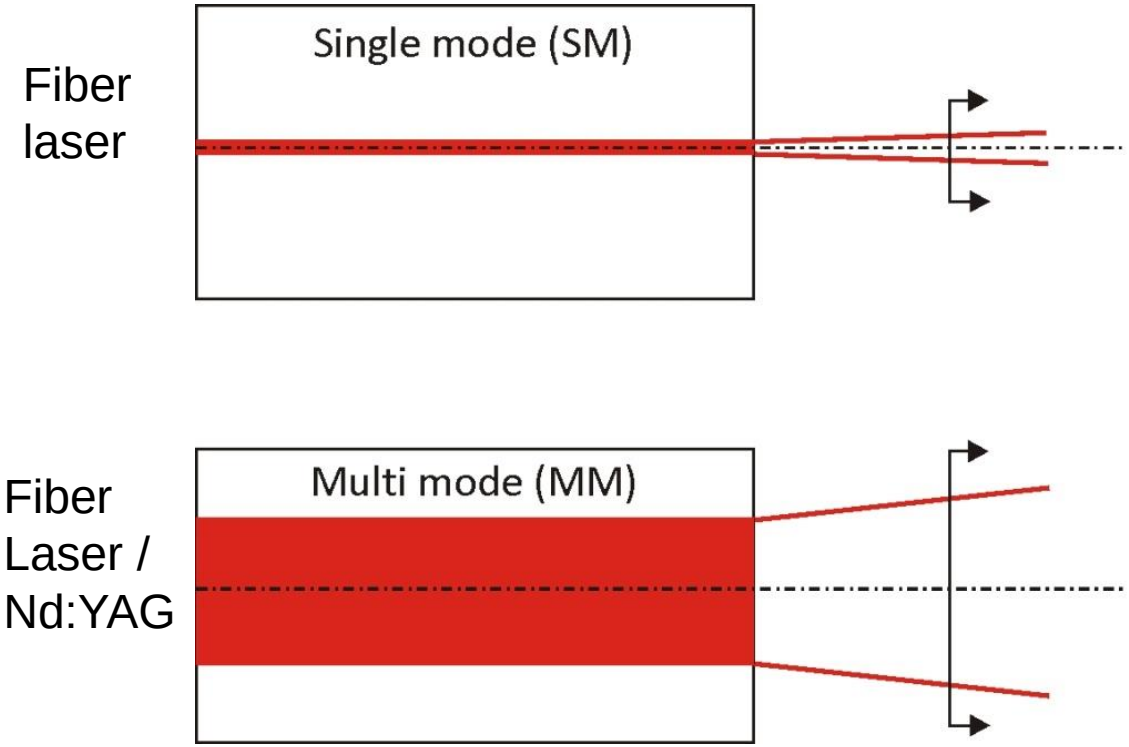
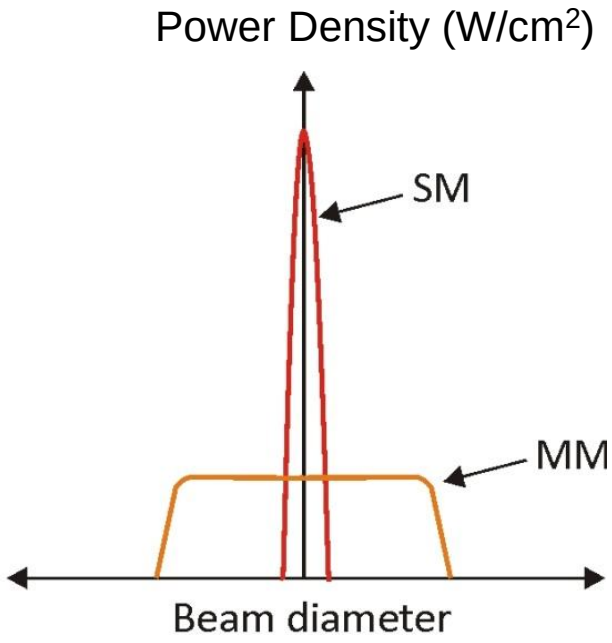
SINGLE MODE VS MULTI MODE (BEAM QUALITY, M^2)

- Based on laser/delivery fiber diameter
  - Single mode fiber laser ~ 15μm, M^2 ~ 1.2 best for cutting
  - Multi-mode delivery fiber ≥ 50μm, M^2 > 5 best for welding (mostly)





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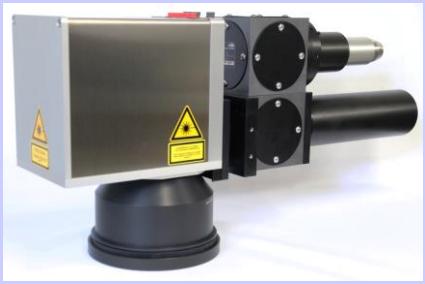
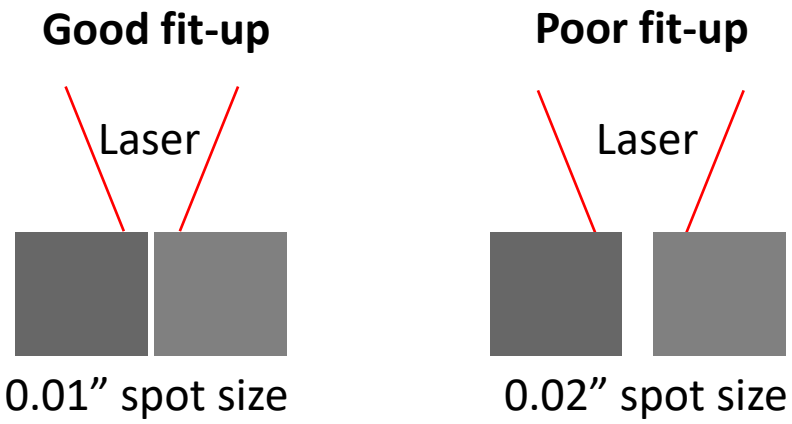
LASER FOCUSING SOLUTIONS

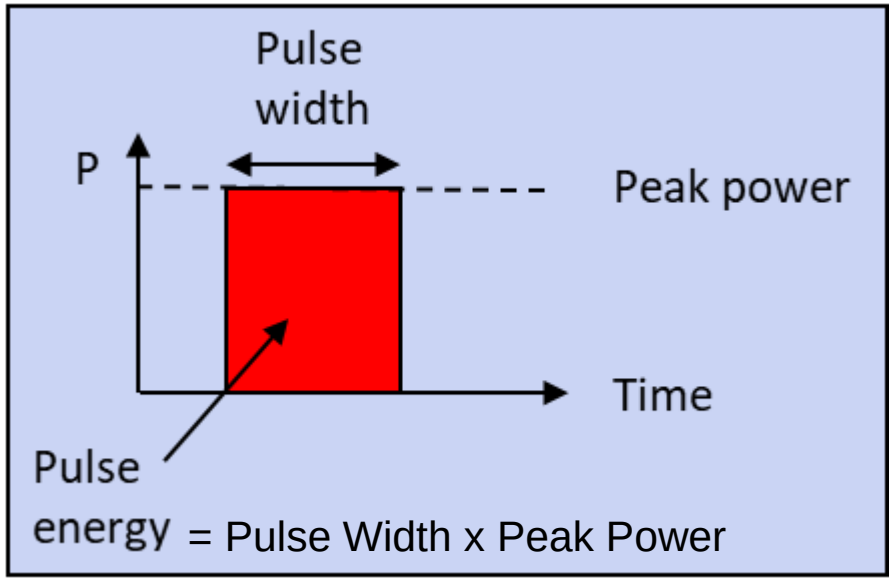
Fixed head	Scan head	Smart wobble head
		
Stages provide motion	Motion included	Stages provide motion
Applications: Used for all applications	Applications: High speed linear seam welds, multi position spot welds	Applications: Specialized welding – dissimilar metals
Pulsed Nd:YAG & Fiber laser	Fiber Laser	Fiber Laser

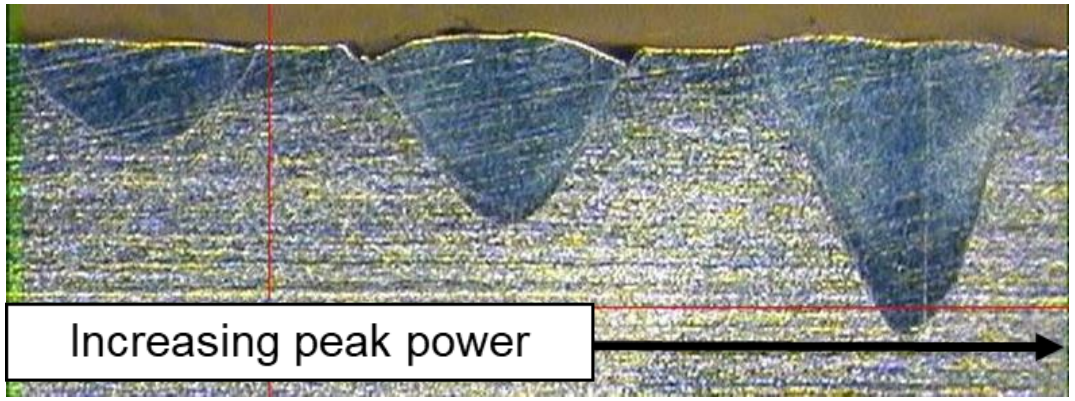
PARAMETERS - SELECTING FOCUS SPOT SIZE

- 0.01 – 0.02” spot size ok for many pulsed applications
- ~0.004” continuous wave seam applications
- Poor fit-up requires larger spot size
- Smaller, thinner parts need smaller spot sizes
- Maximize focal length for tooling access and spatter protection

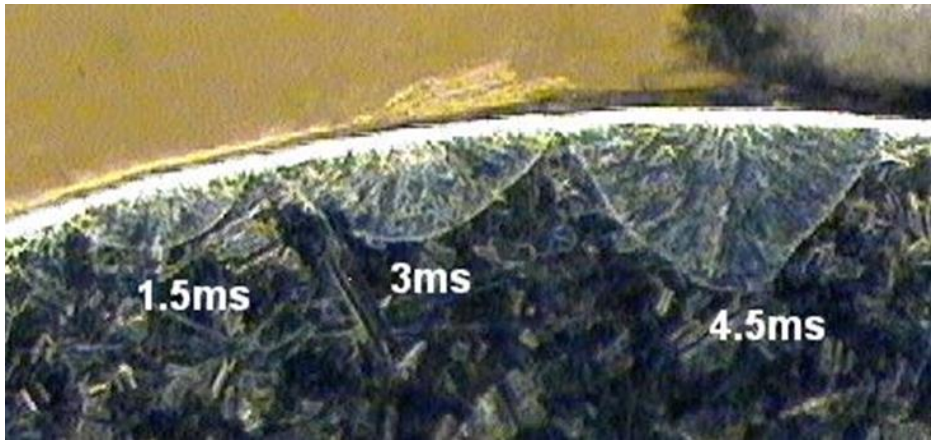


PULSE PARAMETERS – PEAK POWER & PULSE WIDTH





PEAK POWER
- Increases depth
- Too high causes porosity



PULSE WIDTH
- Increases width and depth
- Controls the thermal cycling of delivering power to the workpiece

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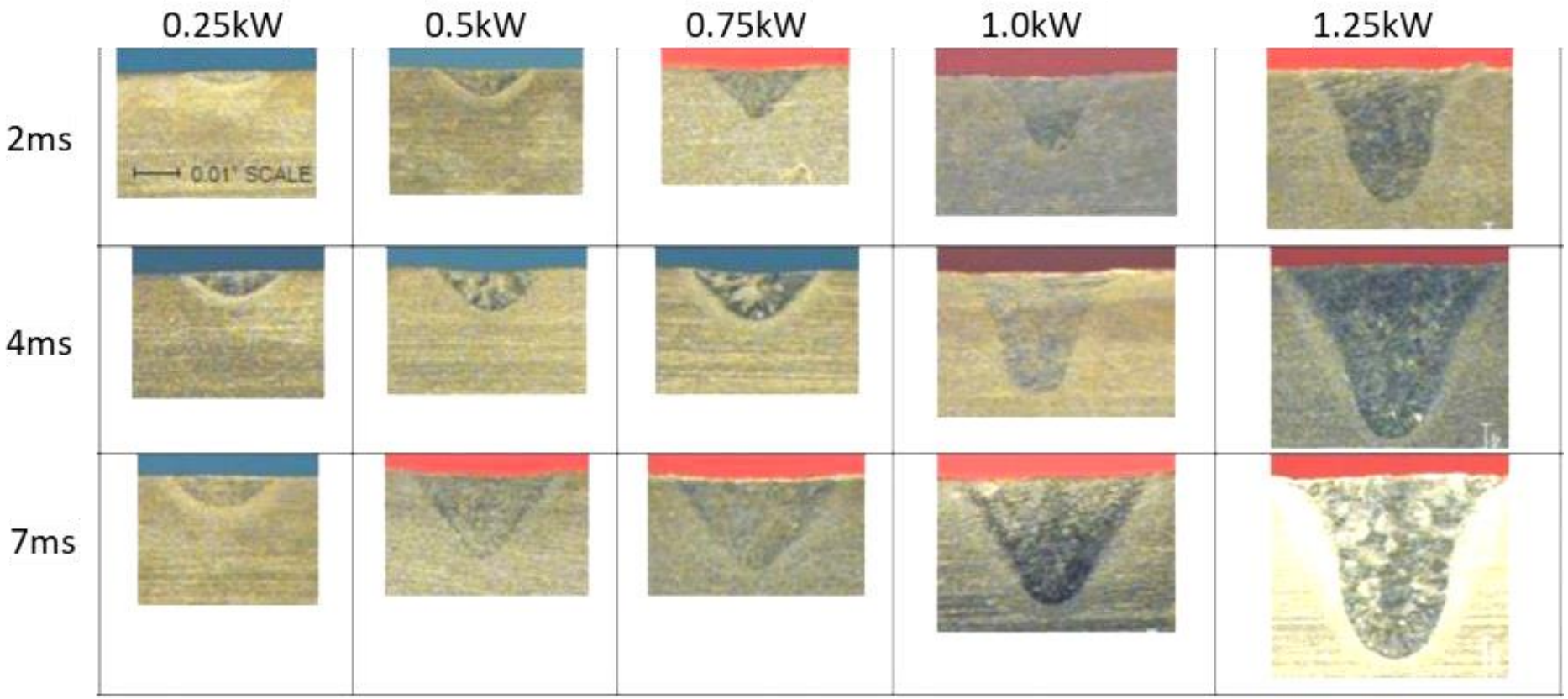
TYPICAL PULSED WELDING PARAMETERS

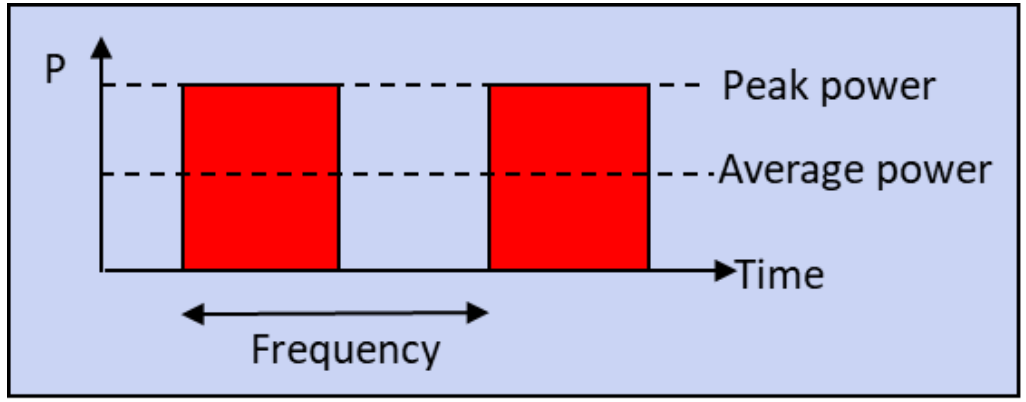
Peak Power (kW): 0.2 - 1.25kW
Pulse width (milliseconds): 1 - 5ms

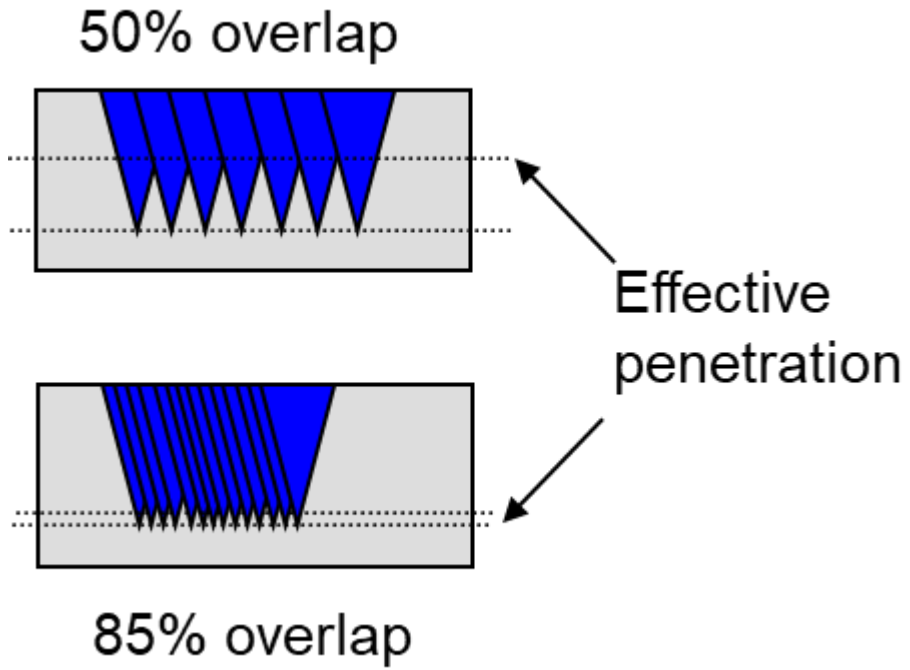
0.5 – 5 Joule



In house weld sectioning equipment is a must!

PULSED SEAM WELDING





- Overlap % = 1- (speed/spot size x frequency)
- Rule of thumb settings
  - 50-60% spot overlap for strength
  - 80-90% spot overlap for hermeticity

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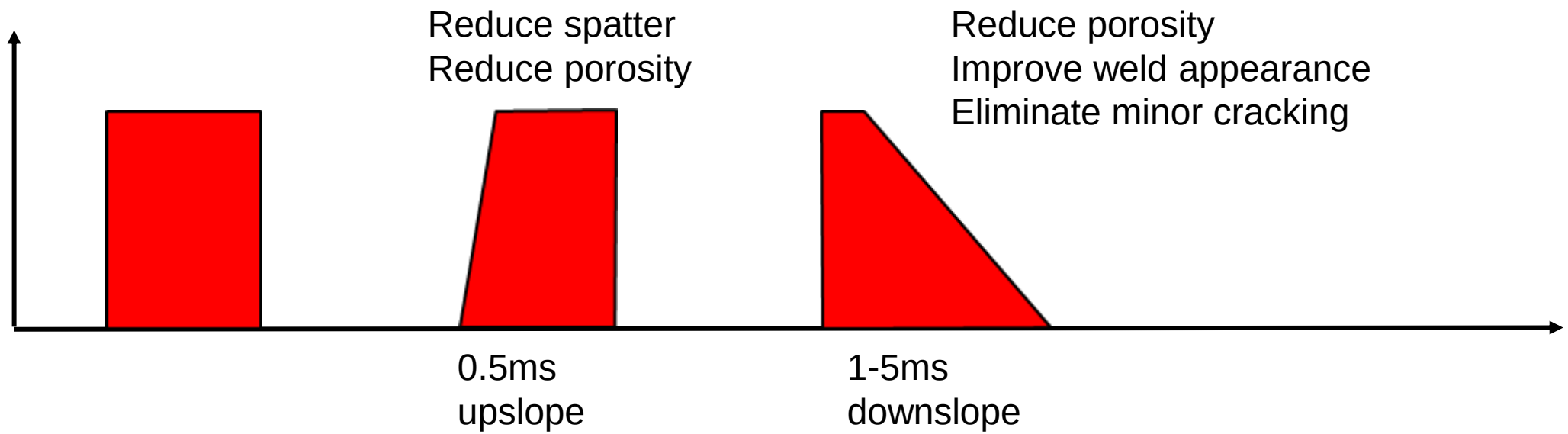
TUNING THE WELD WITH PULSE SHAPING

- Many welds are ok with square pulse
- Only use when you have an issue, and keep it simple
- For seam welding CW laser mitigates weld cracking



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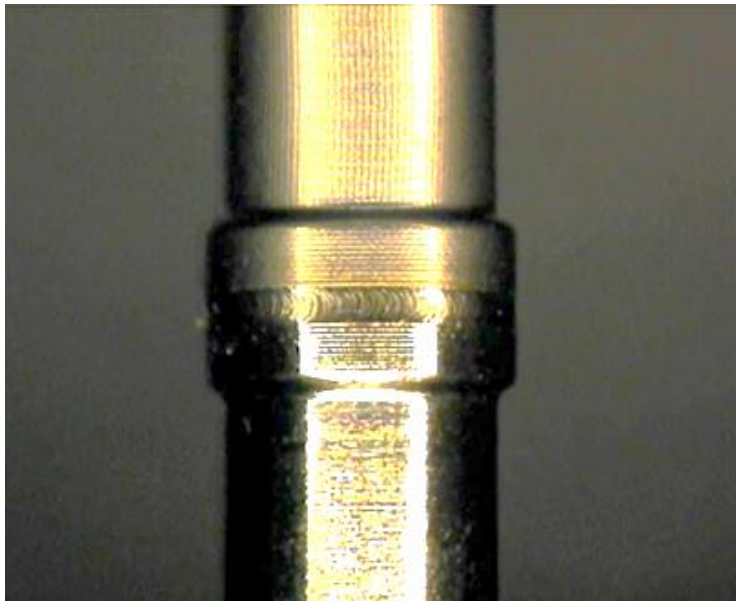
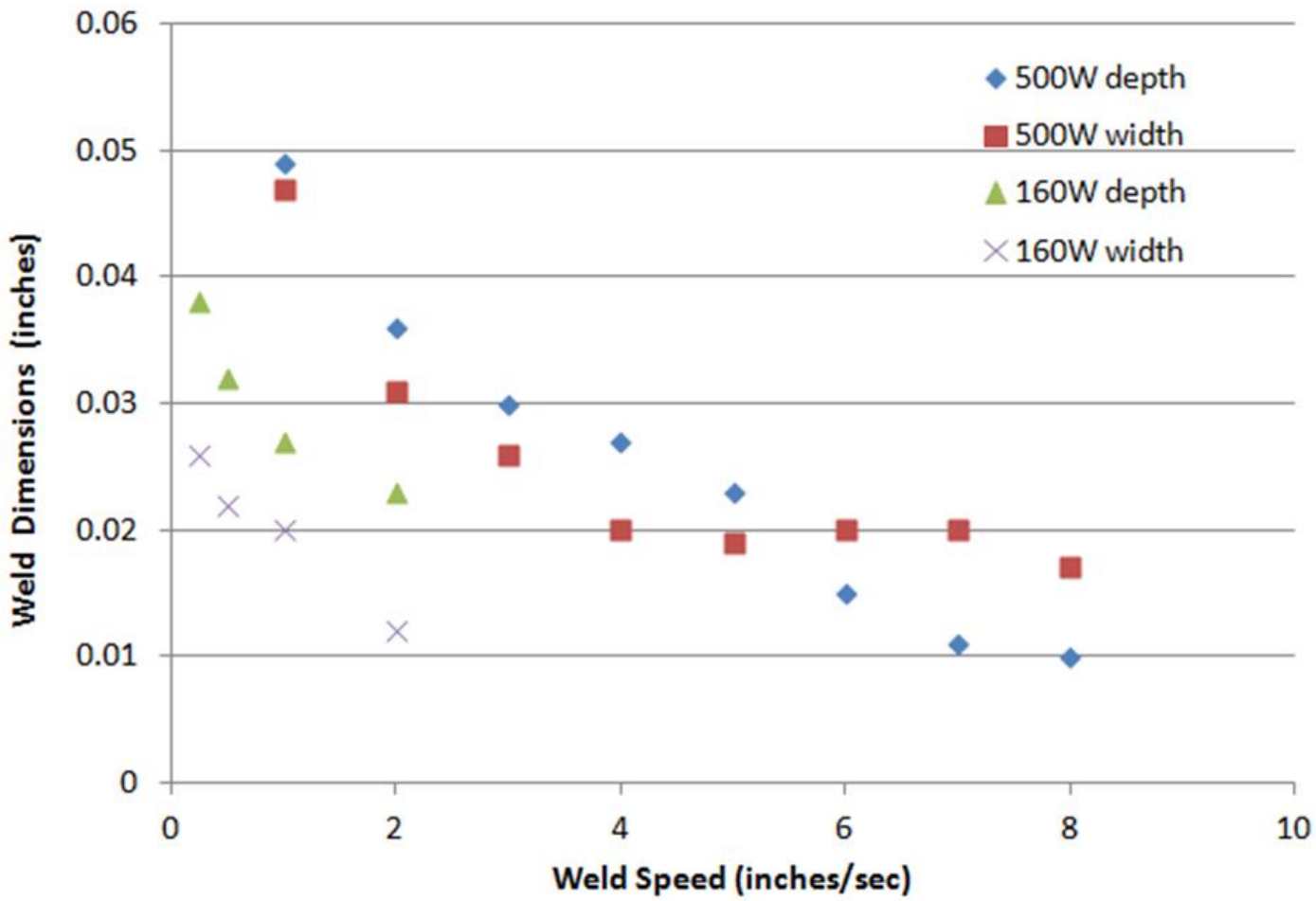
CONTINUOUS WAVE SEAM WELDING

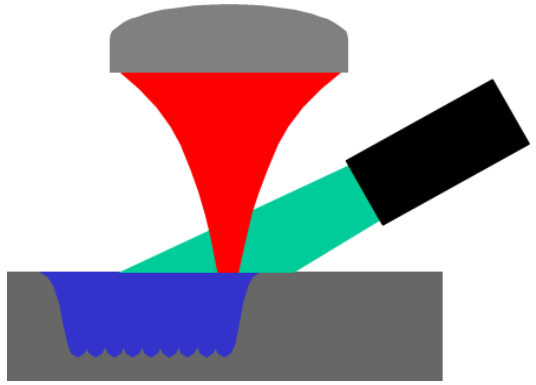
- Match power, speed to penetration
- Circumferential seam welds



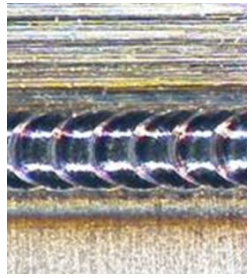


COVER/SHIELD GAS

- Argon used
- Prevents oxidation
- Produces aesthetic shiny weld
- Required for titanium
- Laminar flow (5-10 l/min.)
  - Avoid using too much flow
- Fix position rigidly



No Gas



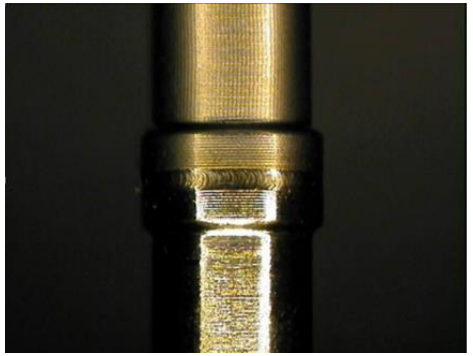
Gas

MATERIAL SELECTION

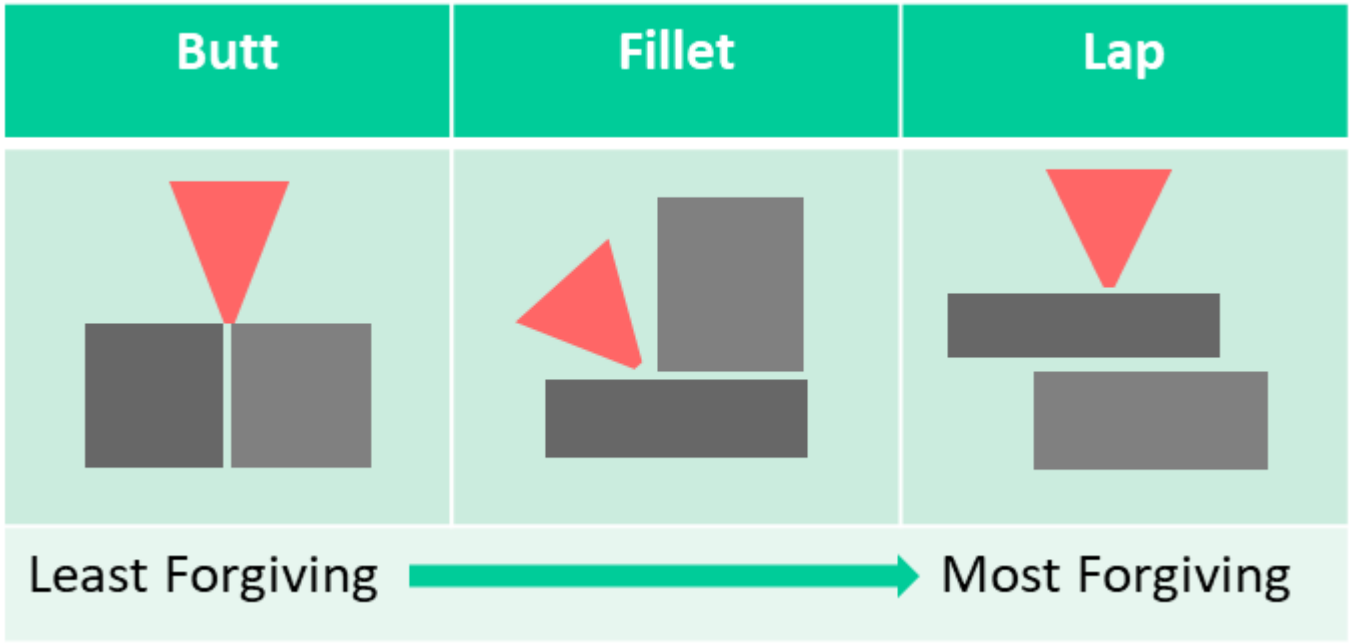
Materials	Weldability	Comment
304/304L		Best stainless steel to weld
316/316L		ok provided Cr/Ni ratio > 1.7
303		Weld only with CW laser
3xx		Require testing
4xx		Cracking tendency, CW laser may help, testing required
Nitinol		Brittle welds, cracking
Copper		Needs high peak power, weld repeatibility can be an issue
Nickel		Good welds
Platinum		Need high peak power

Mix Grades for Weldability

440 to 304, CW laser weld



JOINT GEOMETRY, FIT-UP & TOOLING



- **You can’t weld air!**
- Tooling is a critical part of the welding process
- Considerations;
  - Clamp as close to the weld joint as possible
  - Clearance for the laser
  - Access for gas shielding
  - Datum points for vision + access for illumination
- Iterative process for complex designs
  - Rapid prototype concepts
  - Plan for several design cycles

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DESIGN FOR LASER WELDING SUCCESS

The parts
- materials & plating
- joint geometry
- edge preparation

Know the toolbox
- Lasers
- Focus/motion
- Lean on vendors ☺

Understand
- How to test?
- Process window
- Avoid over specifying

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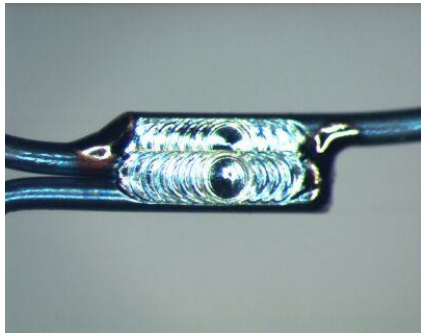
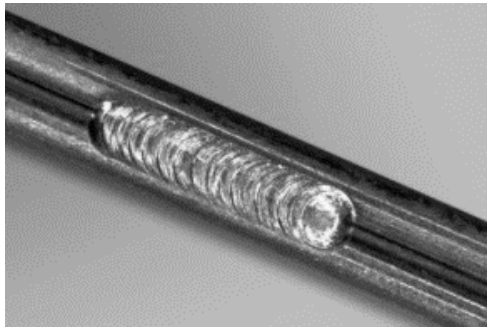
WELDING SYSTEM SOLUTIONS

LASER WELDING SYSTEMS – SCALABLE SOLUTIONS



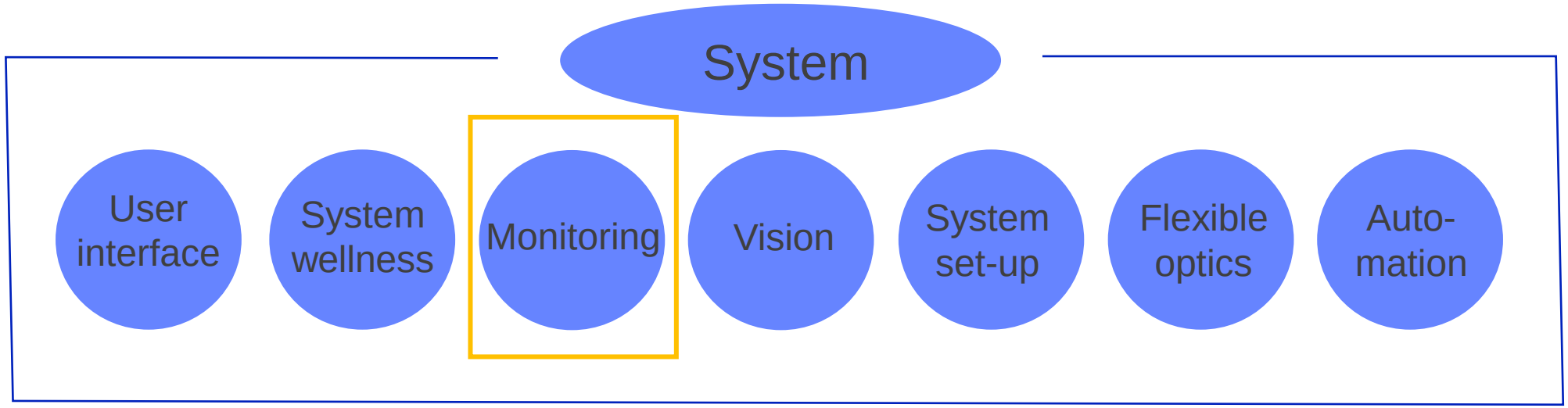


High Volume

Low Volume

COHERENT SYSTEM ROADMAP

- Smarter systems, easy to use software, modular hardware options
- Operator has no influence on process yield

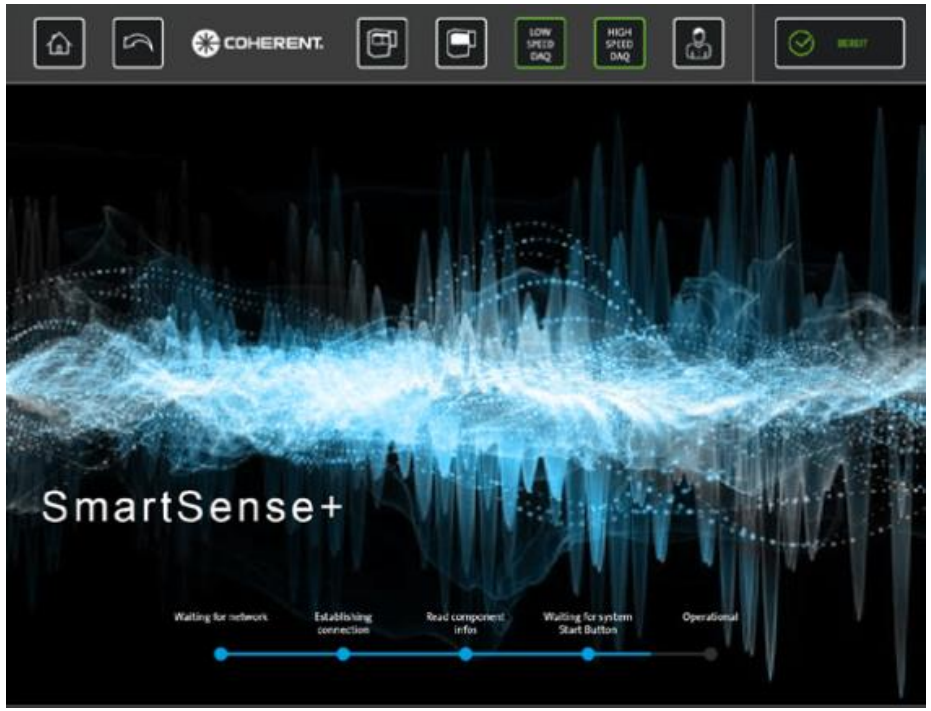


PROCESS MONITORING
Dr Roland Mayerhofer

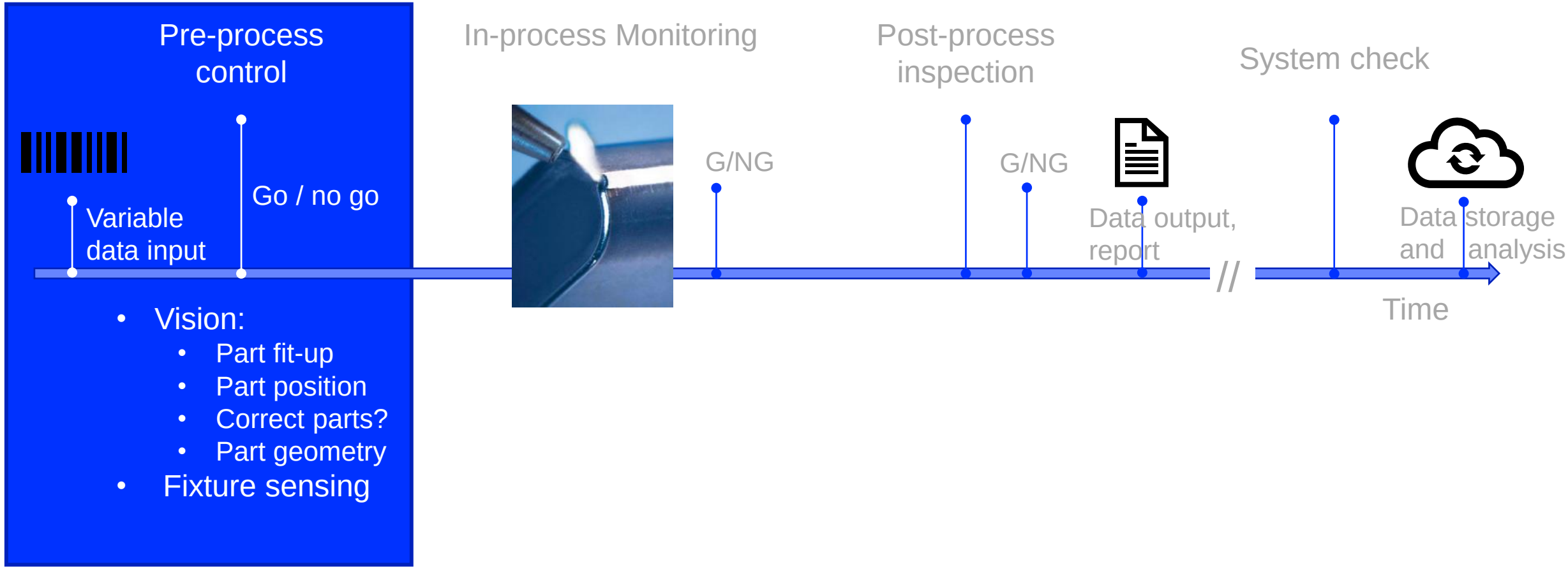
WELD PROCESS MONITORING

- **Issues will happen!**
  - Optics damage - dirty cover slide or lens
  - Material issues, fit-up / composition
  - Operator error - position of focus, alignment

- **Goal:**
  - Avoid making scrap!
  - Data available for a comprehensive documentation, analysis and optimization of the laser process (and to show to your customers)
  - Minimize downtime
  - Reduce or eliminate inspection



CONTROL THE LASER PROCESS AT VARIOUS STAGES



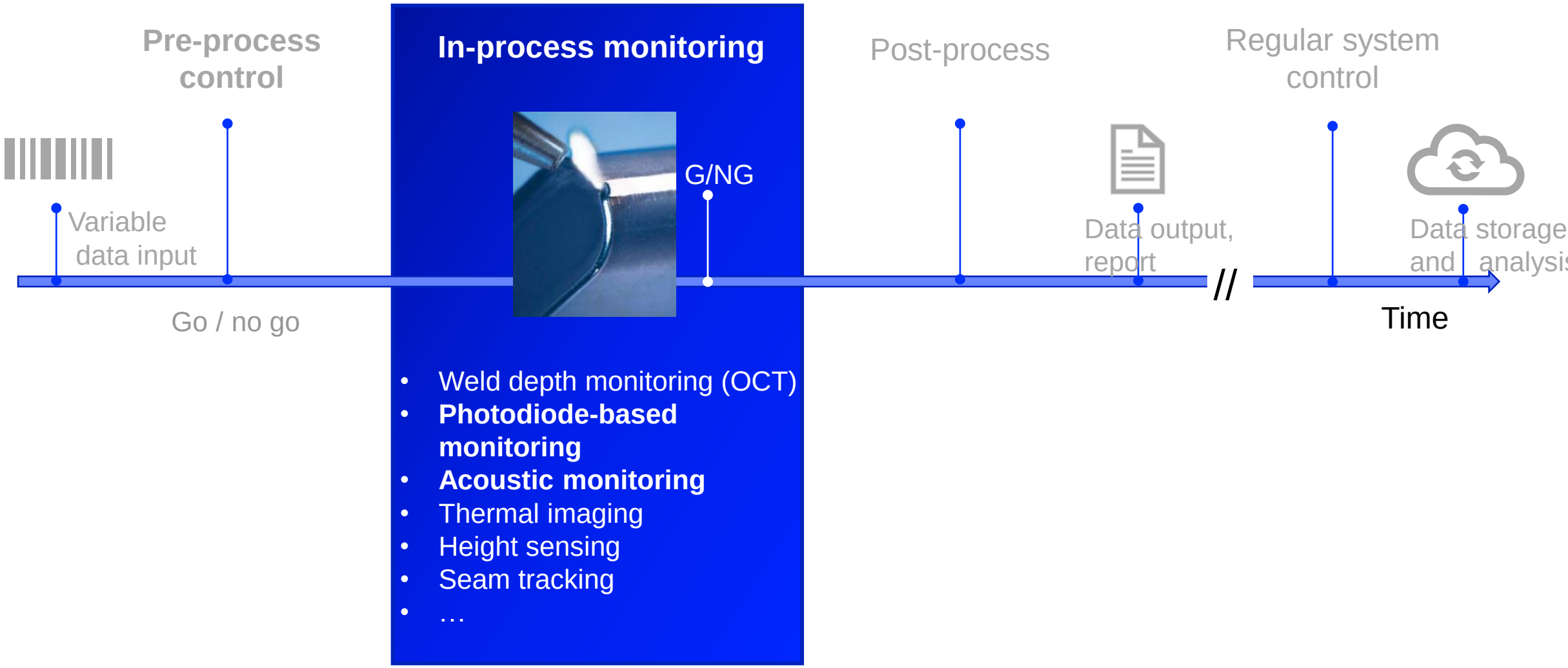
PRE-PROCESS CONTROL

System Check	Comment	Coherent Solution
Laser energy	Measurement with NIST traceable device.	✓
Focus diameter	Measure diameter	✓
Position of Focus	Measure position of focus	✓
Pre production part check	Laser Framework sample part option	✓

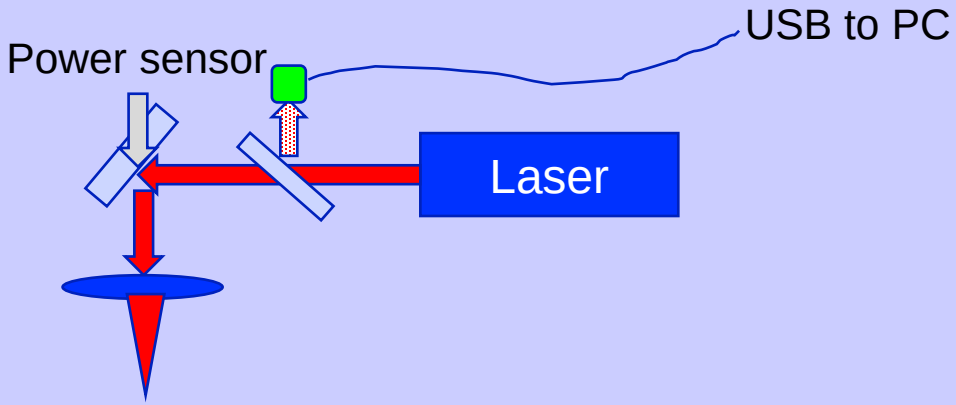
Job Preparation	Comment	Coherent Solution
Recipe	Ensure correct recipe selection, barcode/carrier	✓
Tooling	Identify correct tooling, barcode	✓
Part detection	Parts are present	✓
Part fit-up	Verify part fit-up	✓

LaserFramework
Integrated devices

CONTROL THE LASER PROCESS: IN-PROCESS CONTROL

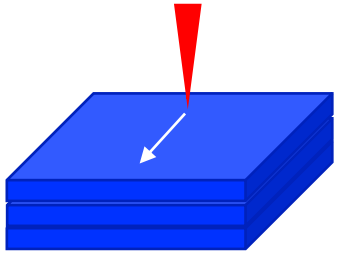


IN-PROCESS MONITORING

Monitoring	Comment	Coherent Solution
Laser energy	In line measurement for every pulse 	✓
Sensor signals are collected and interpreted for weld quality - SmartSense		✓

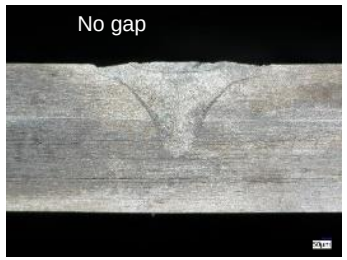
SMARTSENSE APPLICATION EXAMPLE: LAP WELDING STAINLESS STEEL SHEETS

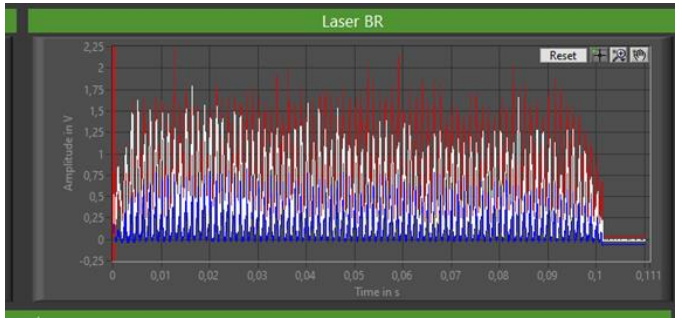
- Upper and lower sheet solid, middle layer with cutout (100 µm)
- CW seam weld 200W power

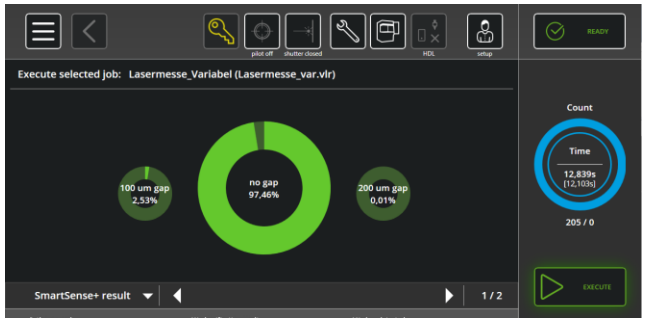


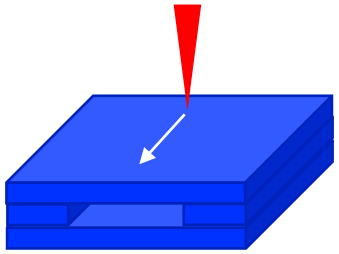
300 µm
100 µm
500 µm

No gap



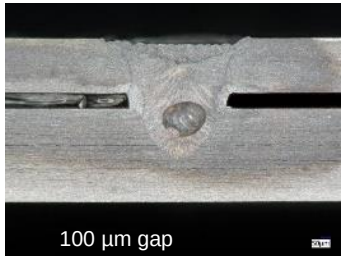


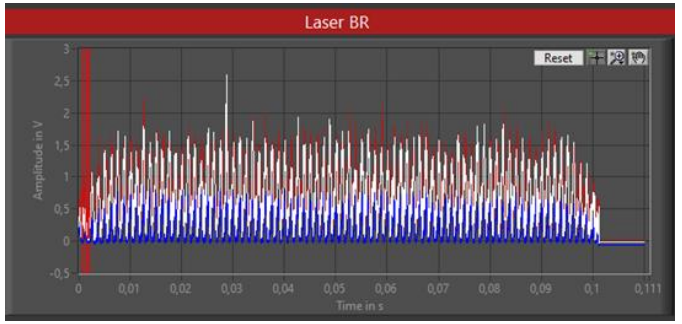




300 µm
100 µm
500 µm

Gap





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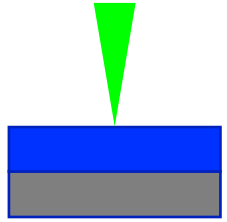
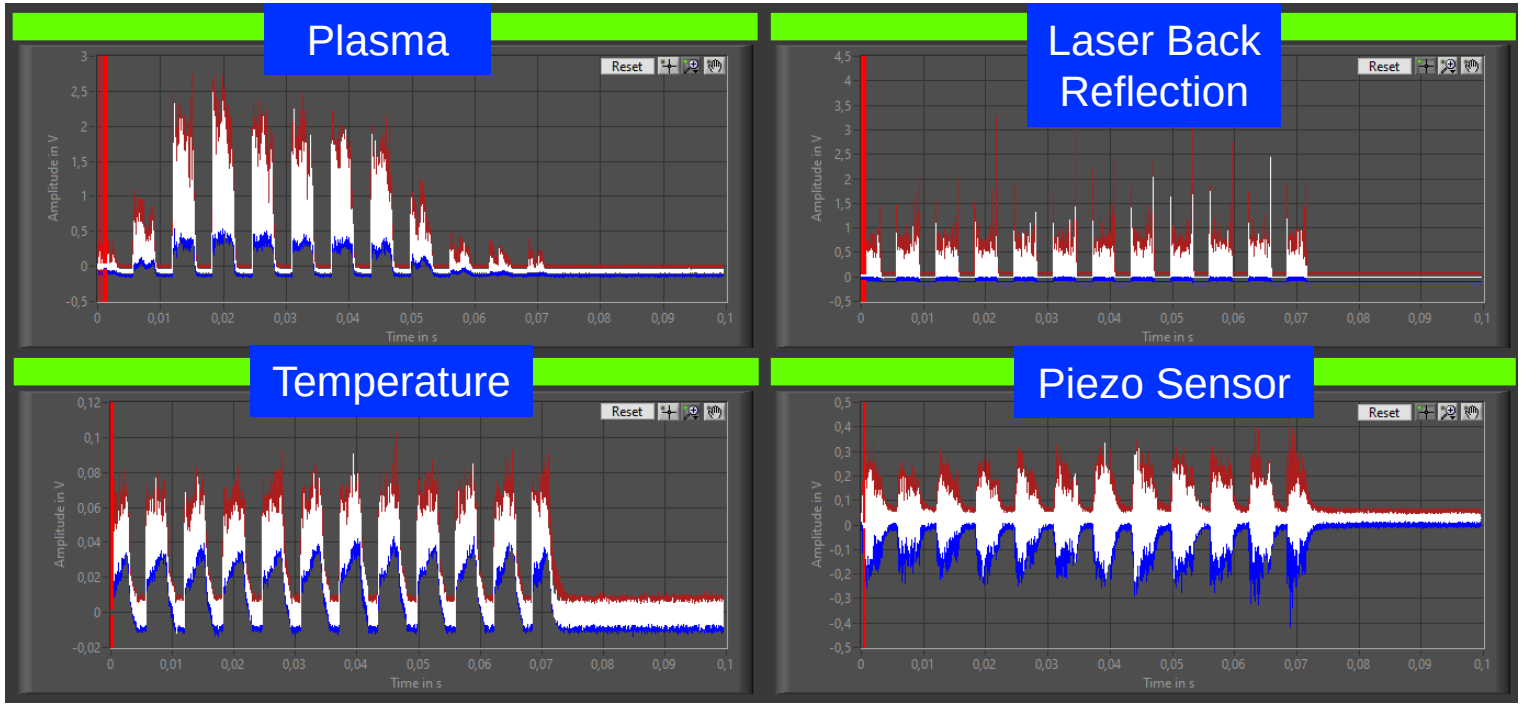
CHALLENGE: SPOT WELDING WITH NARROW LASER POWER PROCESSING WINDOW

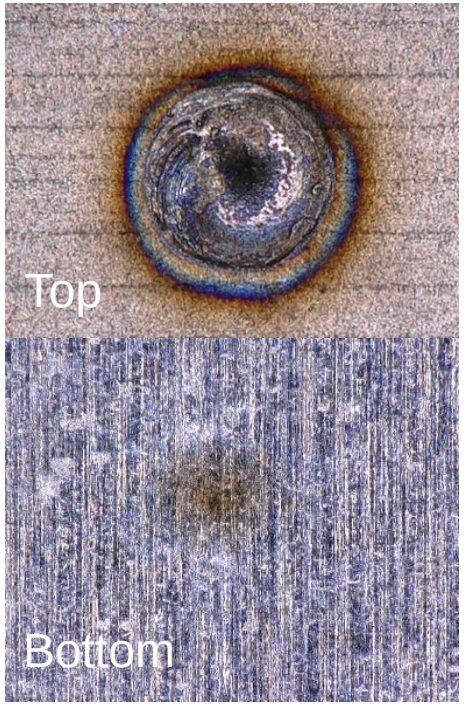
- **Spot welding of razor blades, galvo processing setup**
  - Plasma signal strongly dependent on deflection angle!
  - > Process Monitoring evaluation based on all 12 weld spots



OK

80W





CHALLENGE: SPOT WELDING WITH NARROW LASER POWER PROCESSING WINDOW

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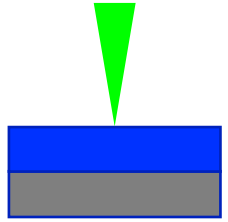
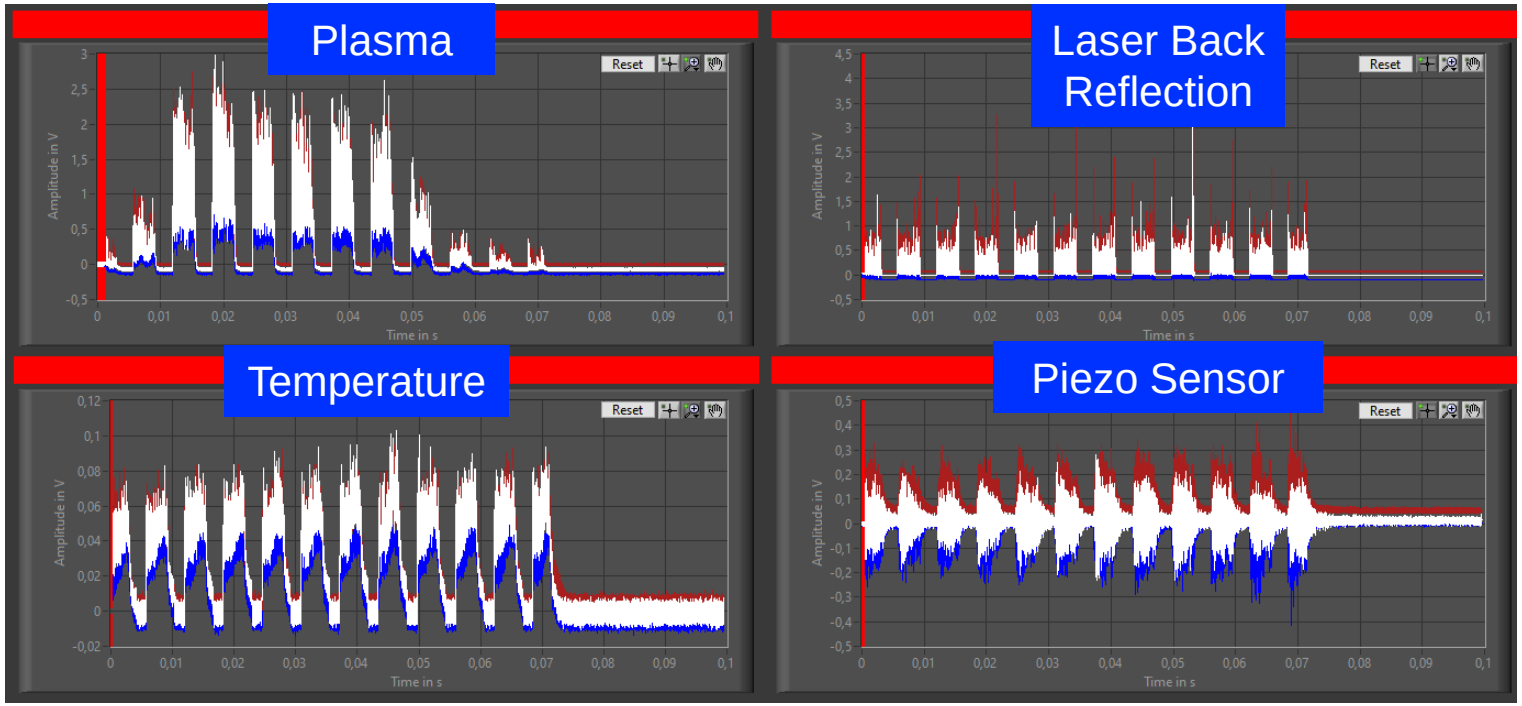
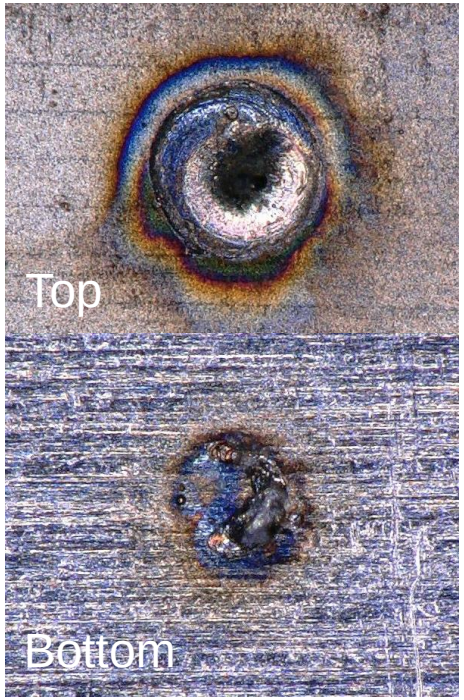


SmartSense+ labels an increase in laser power of 10W as NOK (leading to too much weld penetration within lower sheet)

NOK

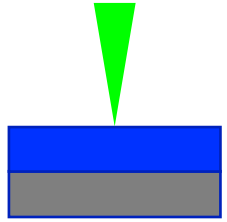
90W



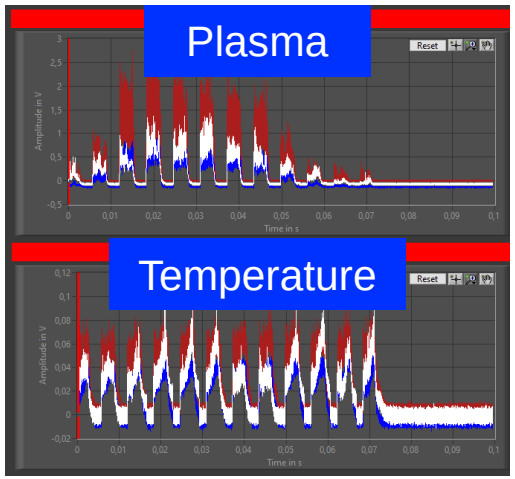


ISSUES: OUT OF FOCUS / INSUFFICIENT CLAMPING / BLADE MISSING

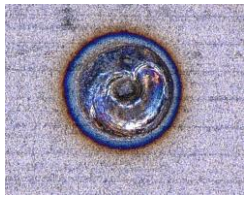
- **Spot welding of razor blades, galvo processing setup**
  - > Process Monitoring evaluation based on all 12 weld spots



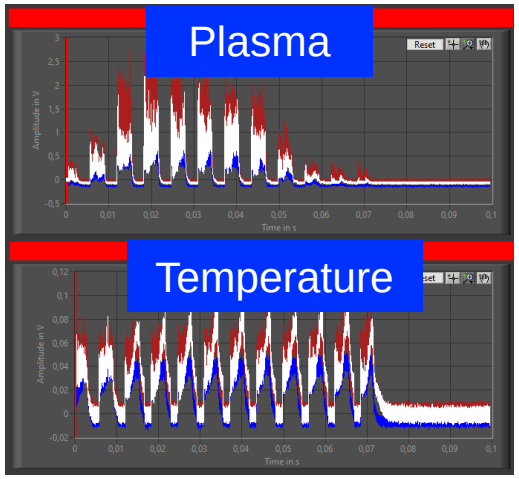
De-focussing -1.0 mm



NOK



Poor clamping



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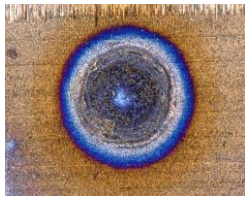
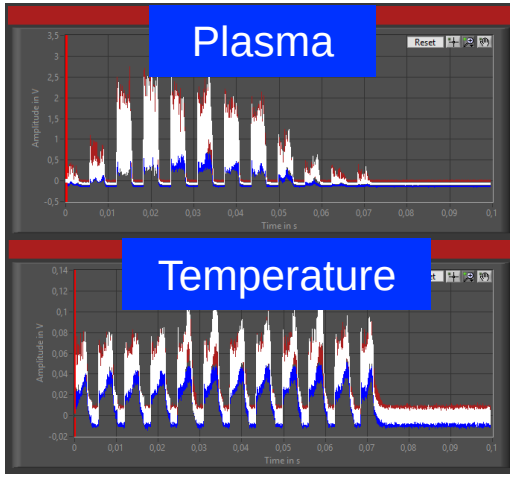
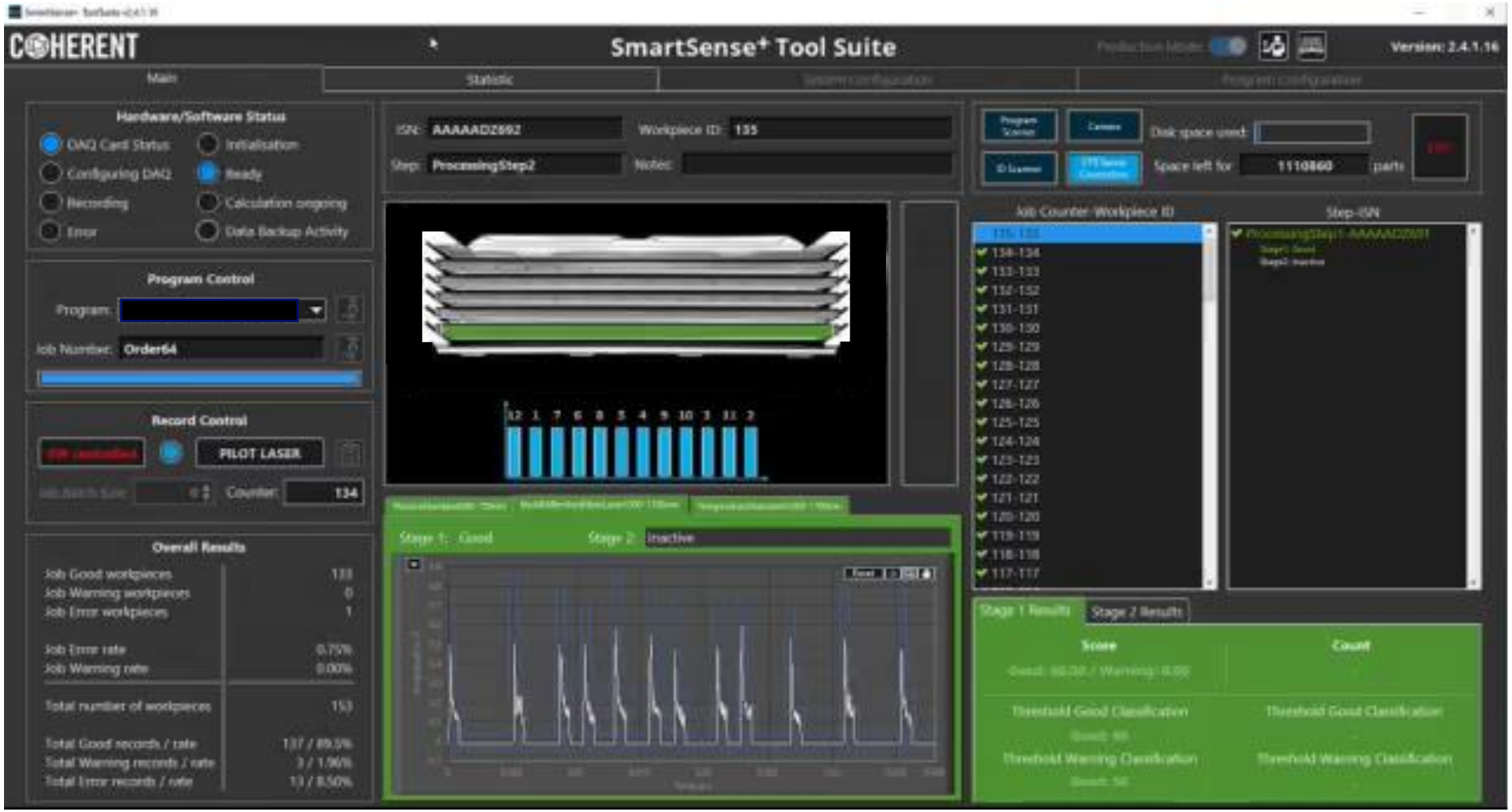


No blade



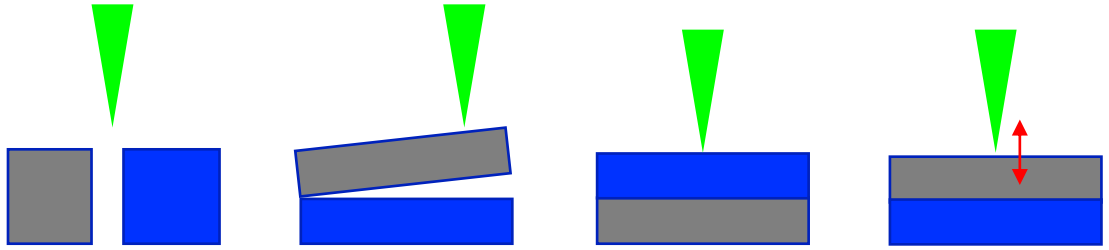
NOK

CUSTOMER APPLICATION: WELDING OF RAZOR BLADES



SMARTSENSE+ DETECTION GOALS FOR WELDING

- Gap between joint line
- Laser power
- Out of focus
- No shielding gas
- Surface contamination
- Dirty cover glass of the processing optics
- Wrong welding materials



Q & A