Laser Welding Insights and Applications –

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Topics

- Principle of laser beam generation / beam handling / beam shaping
- Overview of Beam Welding Technologies
- Different types of laser beam sources
- Quality requirements
- Range of materials to be used and welded
- Practical application examples

Beam technologies

Why do we need Beam Technologies?

We need such technologies for the following reasons:

1. They have a very high energy ouput
2. They can focus on a tiny area of material e.g.0.1mm (0,004“). As a consequence, the beam can pinpoint to a precise area giving a high power density to the area to be welded.
3. This allows the operator to weld deeply with precision with the minimum distortion and with the maximum of design compatability

All of the above negates outmoded theories and opinions such as: „

„We have a lot of alternative and established welding procedures…“ / „Difficult to handle…“

„Safety aspects…“ / „Very expensive…“ / „Not reliable…“ / „Pores…“ / „No stable…“

LASER

Light

Amplification

by a **S**timulated

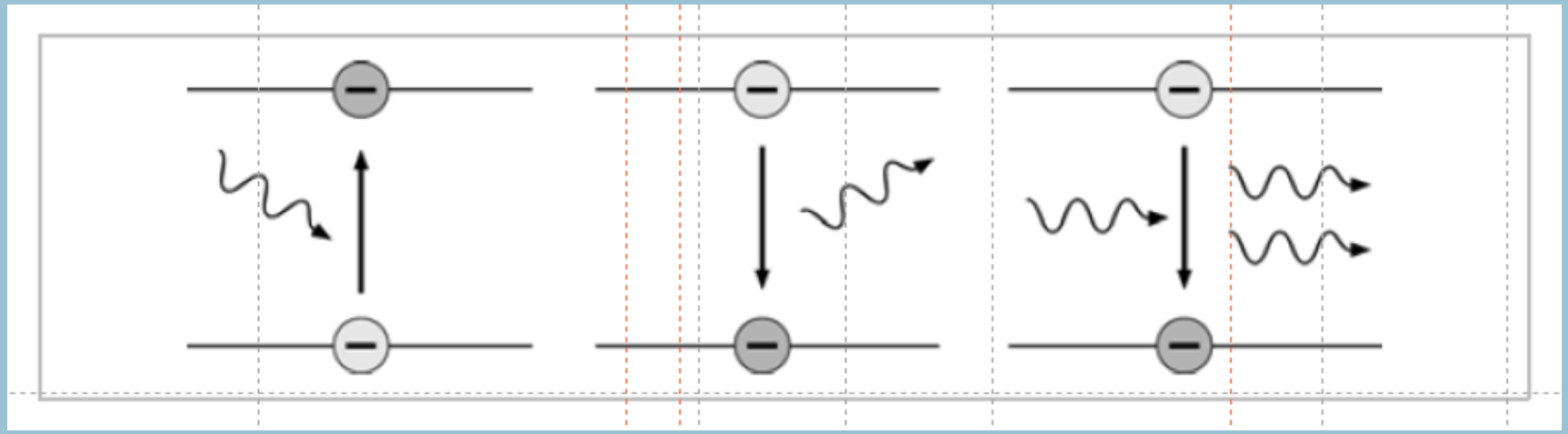
Emission

of **R**adiation

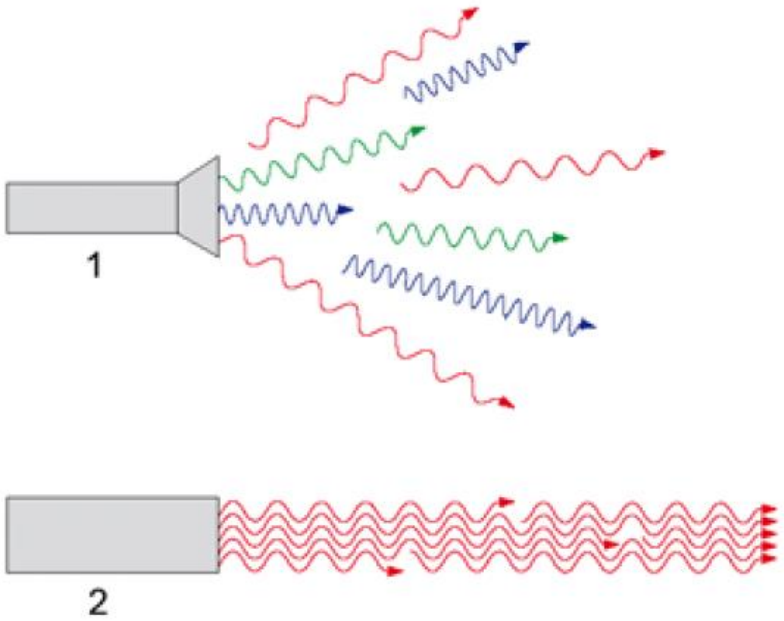
LASER

Principle of laser beam formation

In a laser by which I mean Light Amplification by Stimulated Emision of Radiation, a photon (light wave) strikes an excited atom, tiggering the emmision of yet another photon with the same properties. Both photons continue onwards, in the same direction and with the same wavelength.



Why a laser can do more than a light bulb



1 Flashlight with incandescent bulb

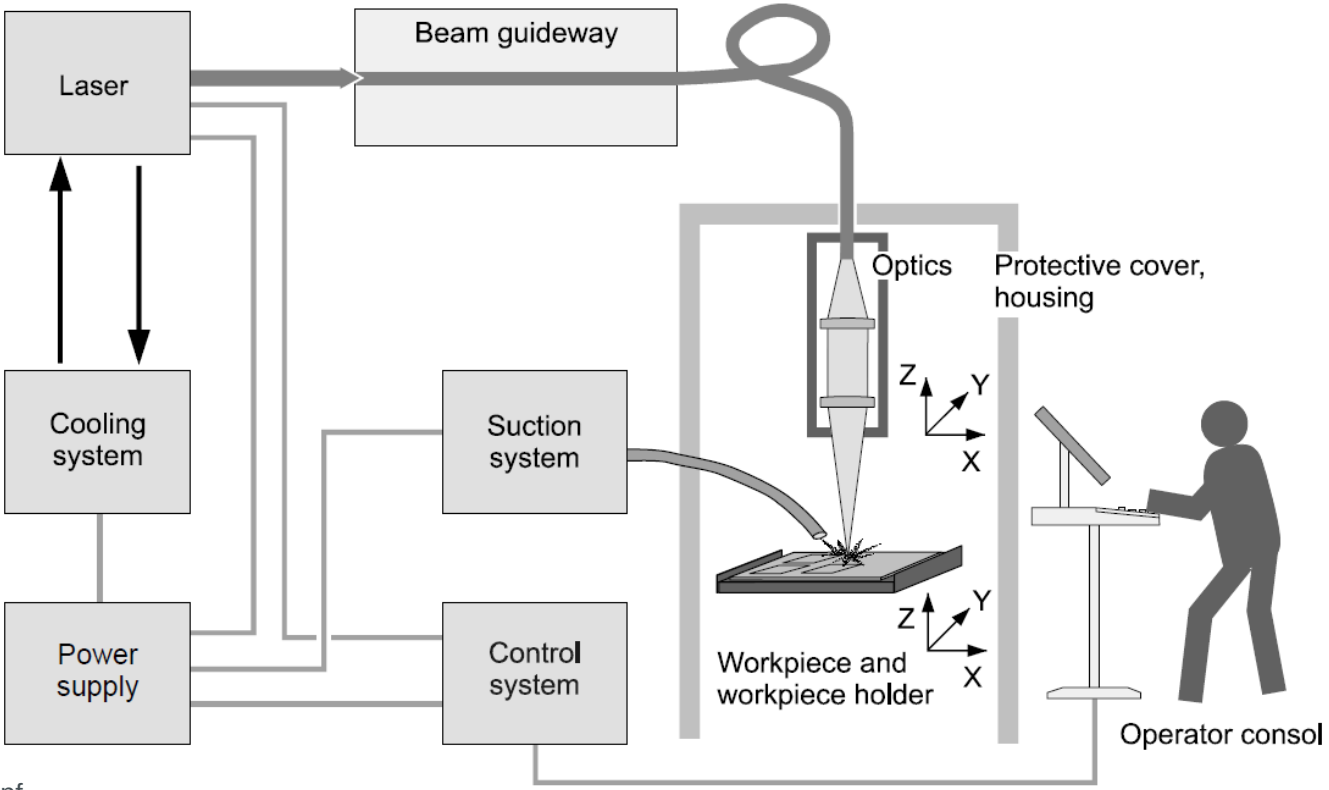
2 Laser

Properties of laser light

- Monochromatic: all light waves have the same wave length
- Coherent: all light waves are „in phase“, or in step with each other, producing a continues laser beam
- Directional: all light waves have almost the same direction

For materials processing especially the last property is important. Laser light forms a compact beam with tremendous power. It can be guided over long distances and highly focused. At the focus, the entire power of the laser beam is concentrated on the workpiece. At the focus, the power density is ten million times higher than that of an incandescent bulb.

Components of a laser system



Source: Trumpf

Laser Beam Welding

Workstation for laser welding of parts used in the food and beverage industry

Types of lasers

Laser type	Gain medium	Typical examples and wavelength	Typical areas of application
Gas lasers	Gases or gas mixtures	CO_2 (carbon dioxide) 10.6 µm	Primarily cutting and welding of metals. Also: hardening, marking.
Solid-state lasers	Crystal or glass doped with optically active ions.	Nd:YAG (neodymium:yttrium aluminum garnet) 1.064 µm Yb:YAG (ytterbium:yttrium aluminum garnet) 1.03 µm Yb:glass (ytterbium:glass) 1.05-1.1 µm Nd:YLF (neodymium:yttrium lithium fluoride) 1.047 µm	Primarily welding of metals, cutting, soldering, marking. Also: drilling, structuring, ablation.
Diode lasers	Semiconductors	GaInP (gallium indium phosphide) 0.67-0.68 µm GaAs (gallium arsenide) 0.78-0.98 µm	Direct application: soldering, hardening, heat conduction welding. Indirect application as optical pump source for solid-state lasers.

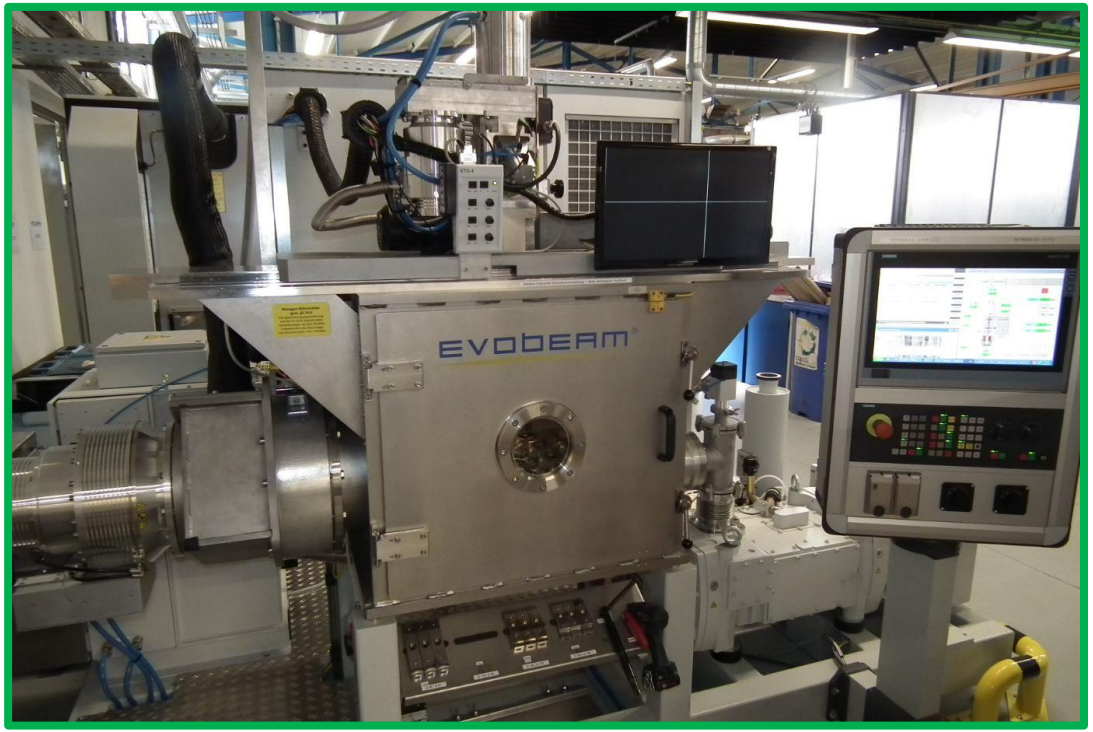
Source: Trumpf

Development of the Laser beam efficiency of solid state lasers

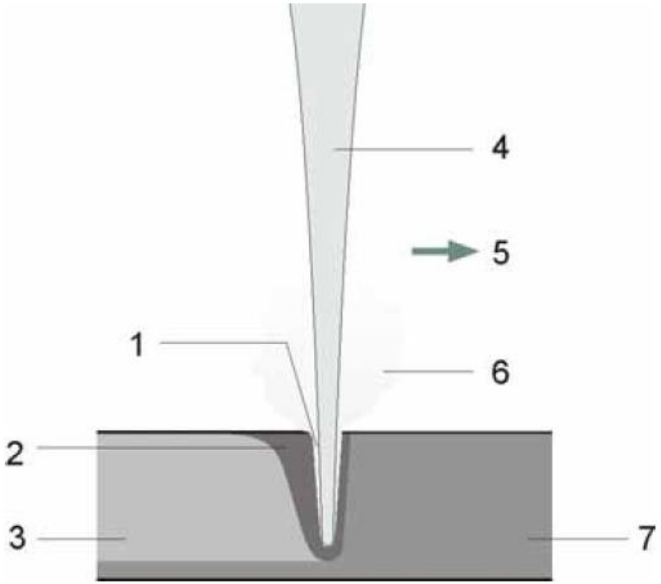
- Nd:YAG-Laser (stimulated by lamp): 3 -4%
- Nd: YAG-Laser (stimulated by diode): 10 – 20%
- Disc-Laser: 25%
- Fiber-Laser: > 30%

Electron Welding Welding

Workstation for the electron beam welding of parts for the beverage industry



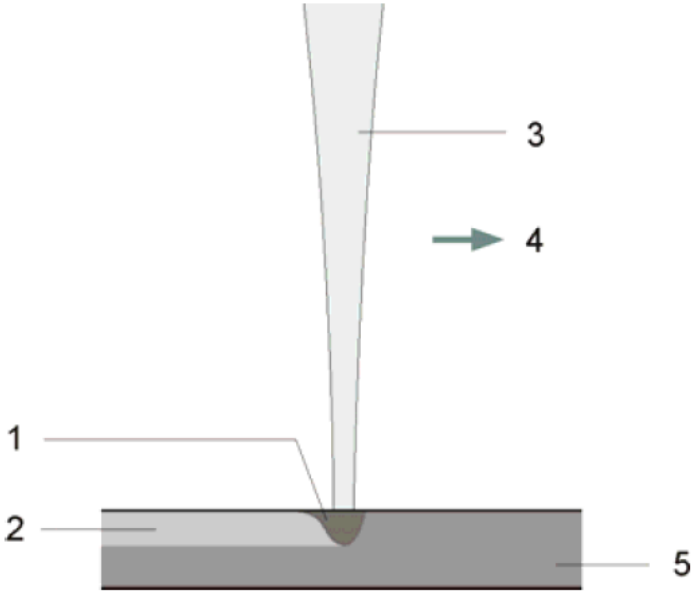
Areas of beam welding: Deep penetration welding



1: Keyhole
2: Molten material
3: Weld seam
4: Laser beam
5: Direction of machining
6: Dissipating metal vapor
7: Workpice

- high power densities > 10kW/mm²
- Metal is not only melted, it is also vapored
- Dissipating vapor exerts pressure on molten metal and partially displaces it
- Material, meanwhile, continues to melt
- Result: deep, narrow, vapor-filled hole: called keyhole
- Keyhole is surrounded by molten metal and moves with the laser beam through the metal
- Molten metal solidifies behind the keyhole

Areas of beam welding: Heat conduction welding



1: Molten material
2: Weld seam
3: Laser beam
4: Direction of machining
5: Workpiece

- Material is melted by the beam along the joint
- Molten material flow together and solidifies by forming the weld
- Weld depth ranges from a few tenth of a millimeter to 1 millimeter
- Used for thinwall parts or from cosmetic welds

Quality requirements needed when liquids are in contact with welding

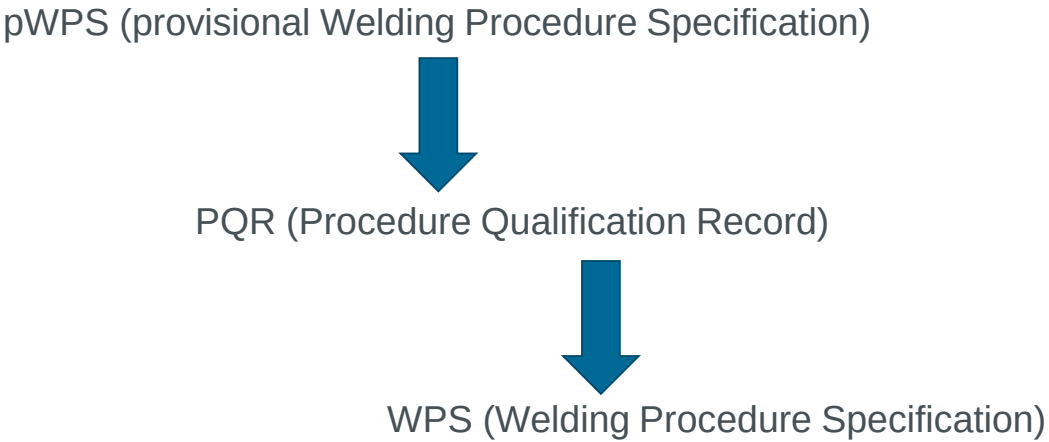
In this regard **none** of the following should be present: -

- Porosities
- Cracks
- Misalignments *
- Undercuts *
- Discolorations *
- Metalurgical segregations

* All the allowed ranges of requirements given by 3-A, ASME, EHEDG or specific customer needs must be fullfilled.

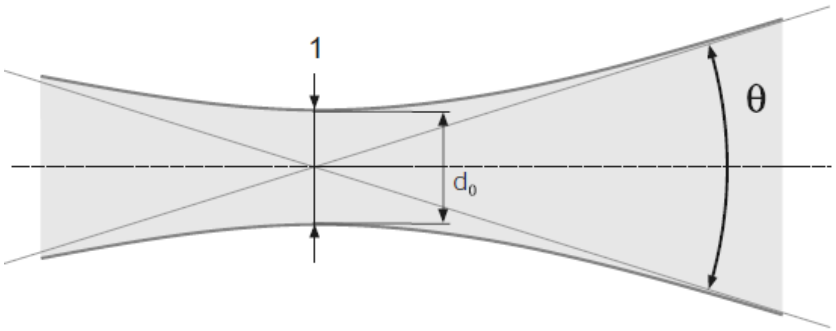
How to qualify the beam welding process?

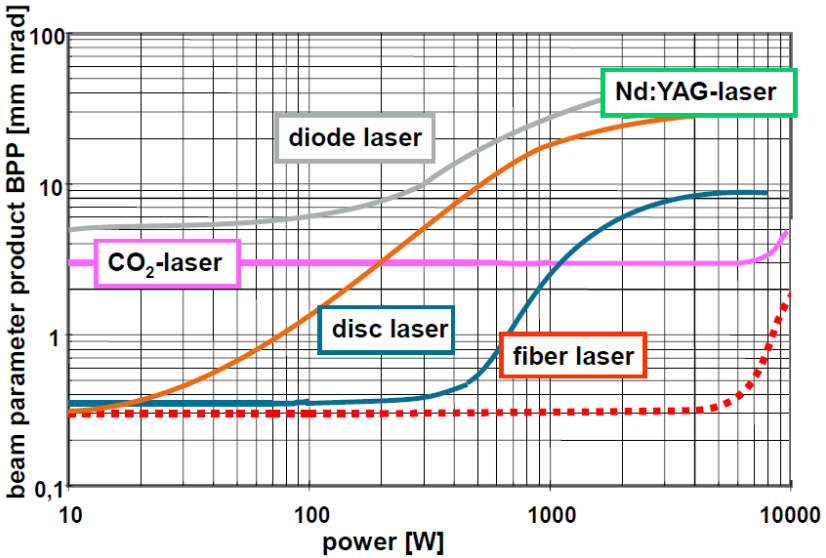
- Procedures have to be qualified according international standards: ASME Sect. IX
  ISO 15608



Beam quality and output power of high-powered lasers

The beam parameter product BPP is the diameter of the beam waist (1) multiplied by the angle of spread





Source: Tünnermann et al. / Fraunhofer IOF

The focused laser beam

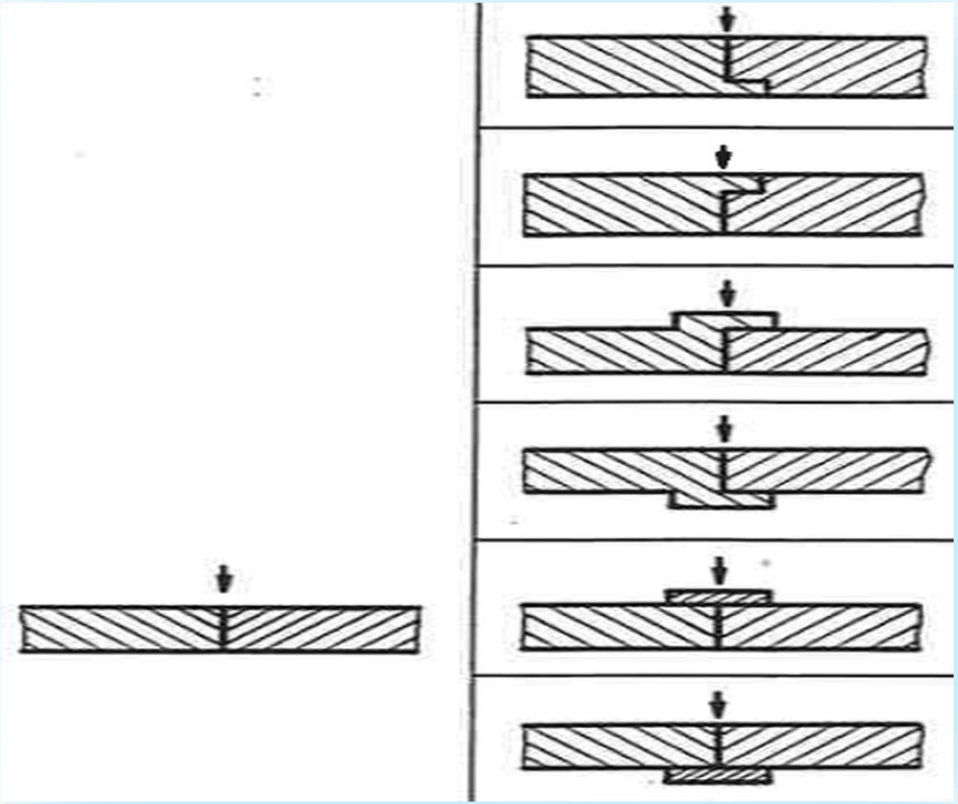
Source: Trumpf

Range of materials used in the food application

- Product contacted materials: higher alloyed standard stainless steels e.g. 316L / 1.4404
  duplex stainless steel like 1.4462
  superaustenitic stainless steel e.g. AL6XN / 1.4529
  (nickel based alloys)

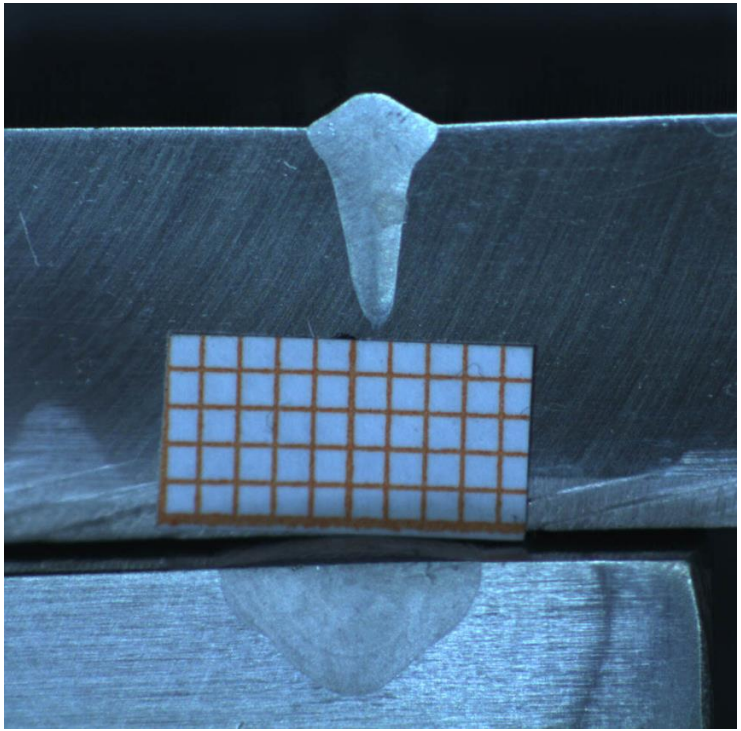
- Non-product contacted material: standard stainless steel like 304/1.4301 or 304L/1.4307
  lean duplex steel

Examples for the preparation of the parts before welding

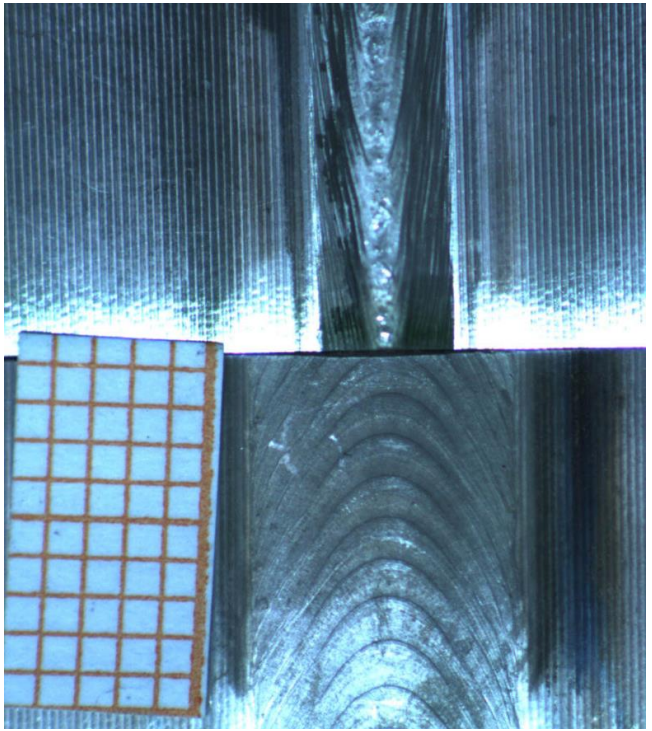


Comparison of the weld bead profils fabricated by TIG and Beam welding

Macroscopic of the vertical cuts



Outside surface

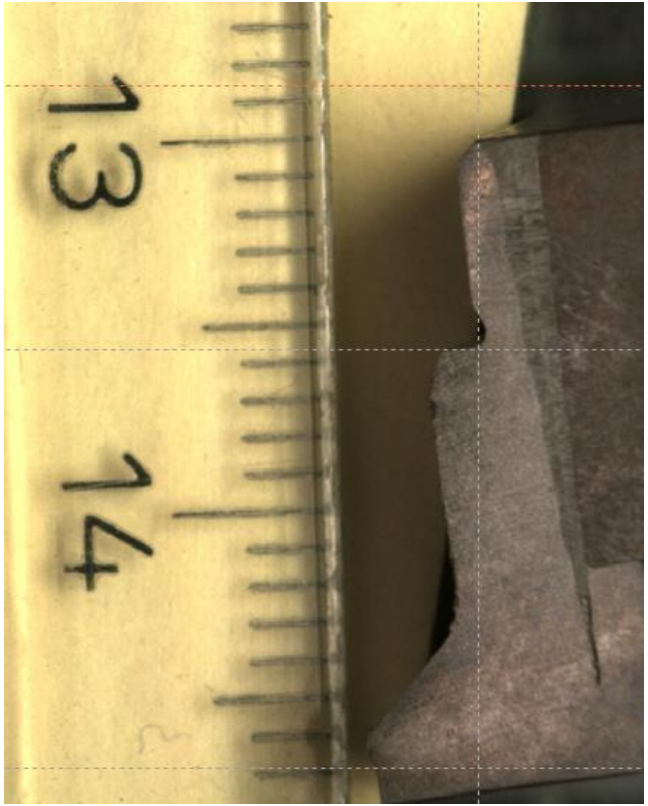


Preparation before welding

1. Cleaned without cleaning agent, residues of grease on the surface
2. Gap among the parts to be connected: 0,015“ (0,4mm)

1. Carefully degreased
2. Gap before welding < 0,002“ (0,05mm)
3. Sharp edges to be fused

Fusion welding of a two different material components by EBW

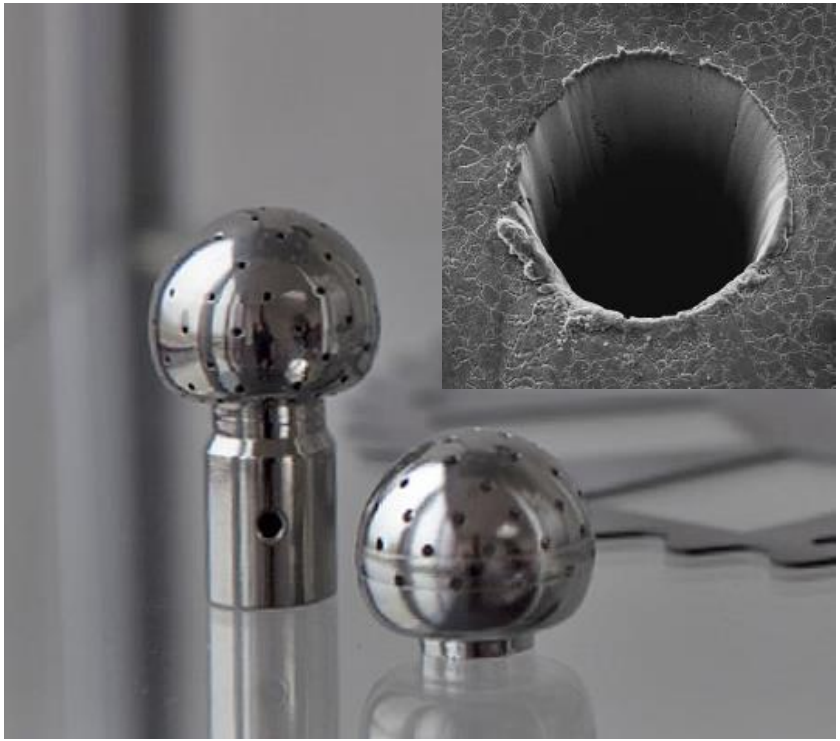


- Inside: duplex stainless steel (1.4462)
- Outside: standard stainless steel (316L)
- Penetration depth: 0,55“ (14mm)
- Width of the weld: < 0,079“ (2mm)

Laser Beam welding of a bellow

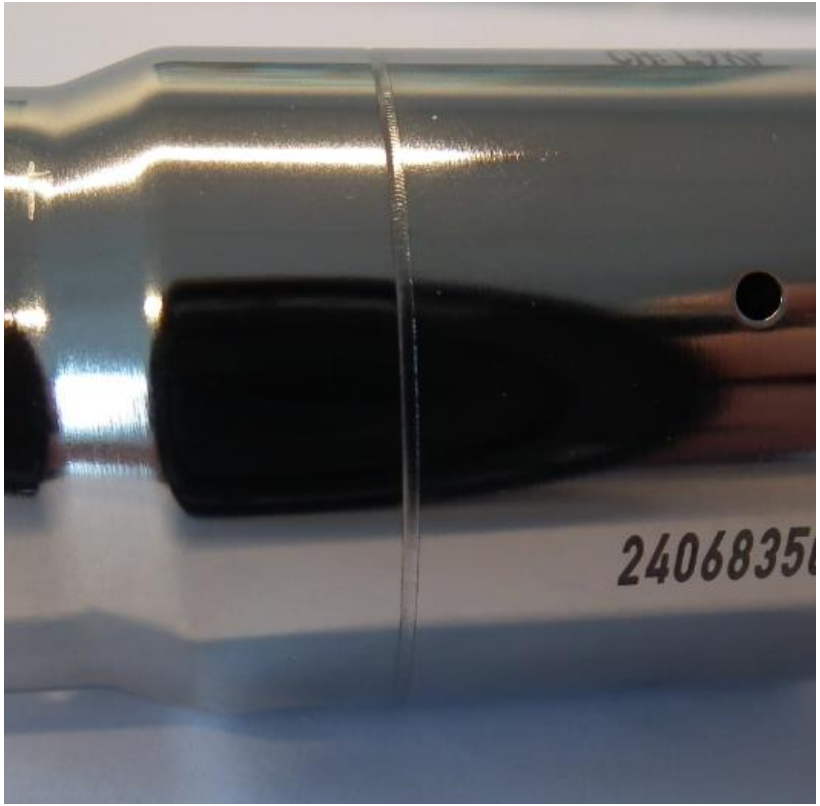
- Material: 316L/1.4404
- Wall thickness of the bellow: 0,006“ (0,15mm)
- Both side cleaned by ultrasonic cleaning
- Exact positioning in a fixture while welding
- Each part approved by leakage test

Laser drilling of sprayballs



- Diameter of the drill holes: 0,004“ – 0,04“ (0,1mm – 1mm)
- Wall thickness 0,04“ (1mm)
- Stainless steel type316L,

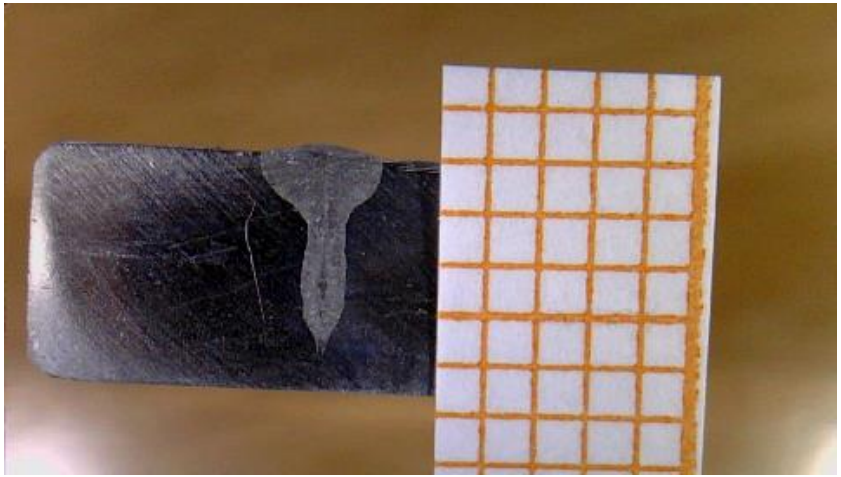
Laser beam weld on a cleaning device



- Penetration depth: 0,2mm
- Function of weld: distorsion lock of a thread
- Material: 316L
- Very low heat input: no tempering colors to be removed from the surface

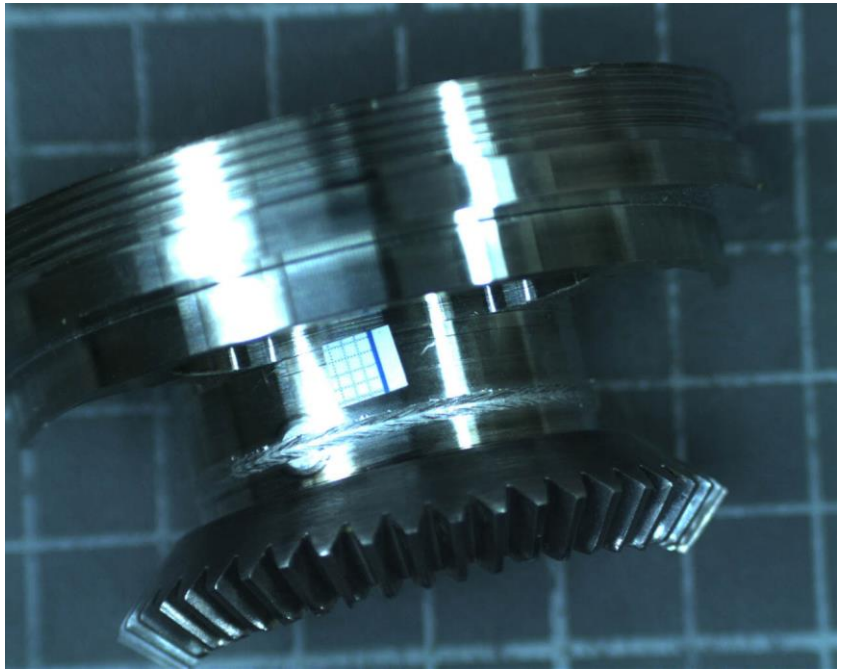
Valve actuator

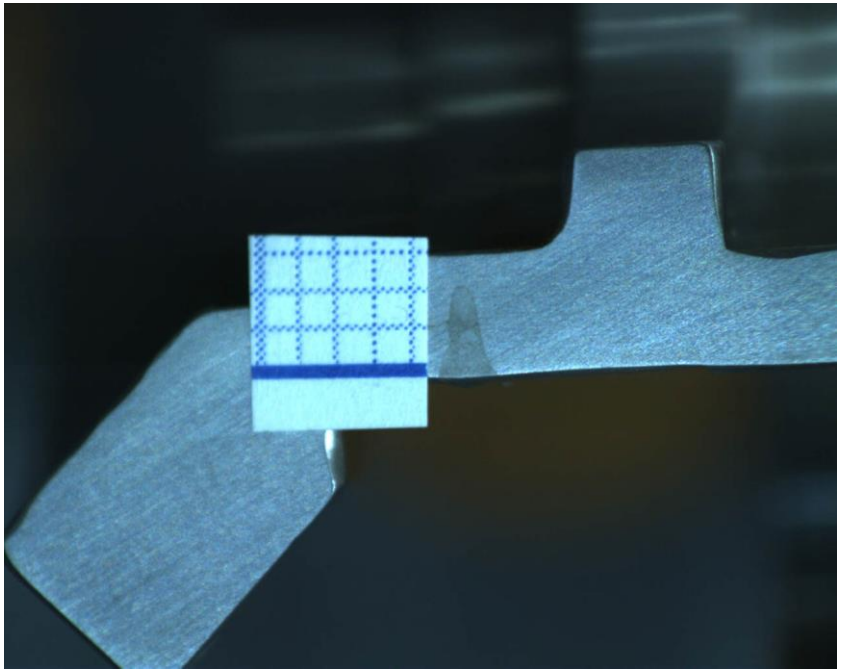
- Material 316L
- Penetration depth: 0,08“ – 0,16“ (2mm – 4mm)



Laser Beam Welding of gear components

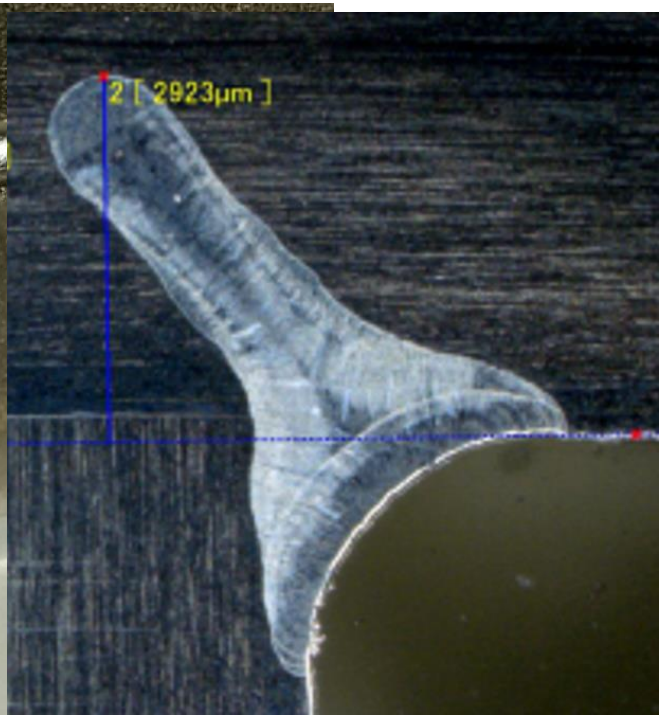
- Material 316L; Penetration depth: 2,5mm





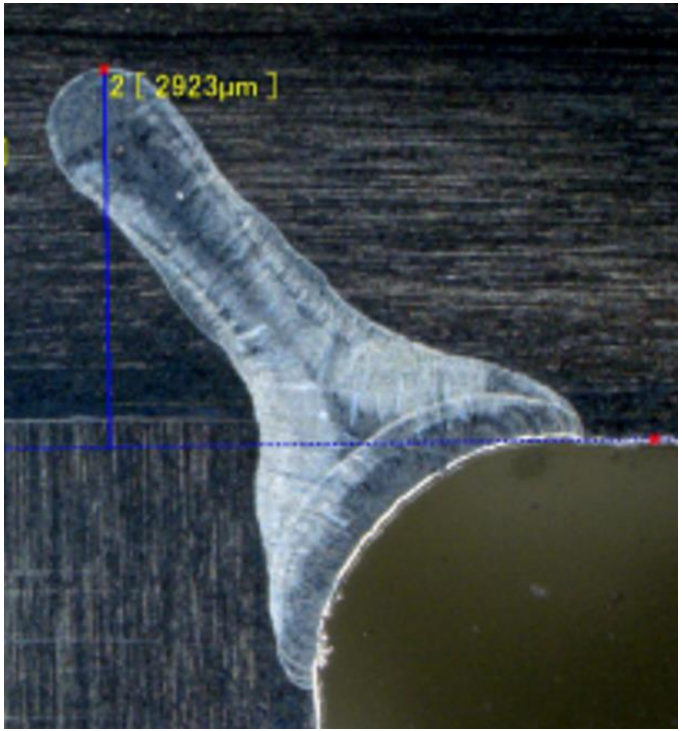
Laser Beam Weld of a double T-joint

- Material: 316L

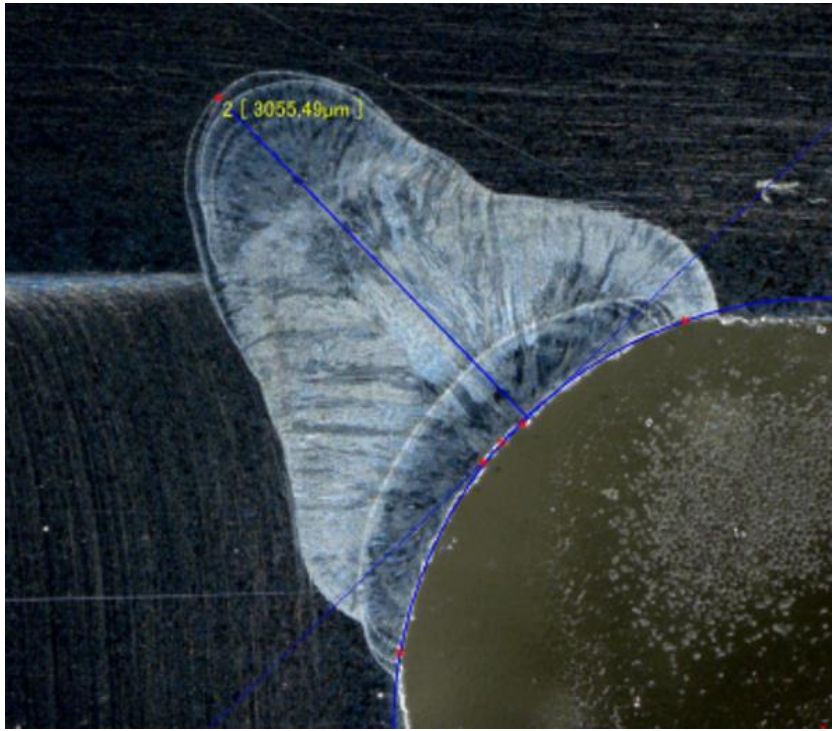


Comparison of two different T-joint connections by variation of the focus position

Focusposition: 0



Focusposition: +3mm



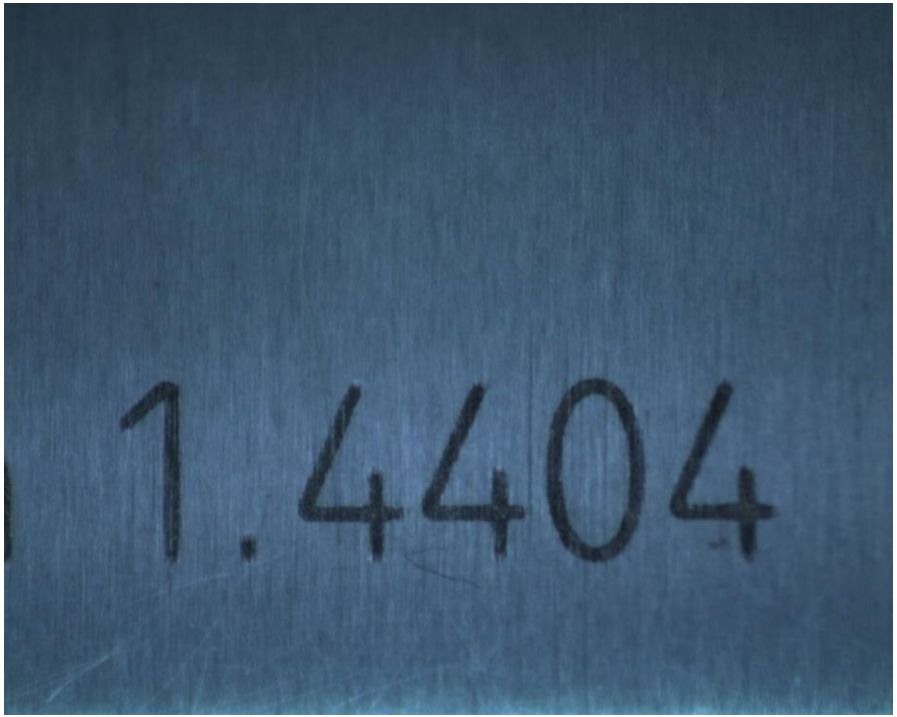
Laser marking

Laser engraving on atmosphere

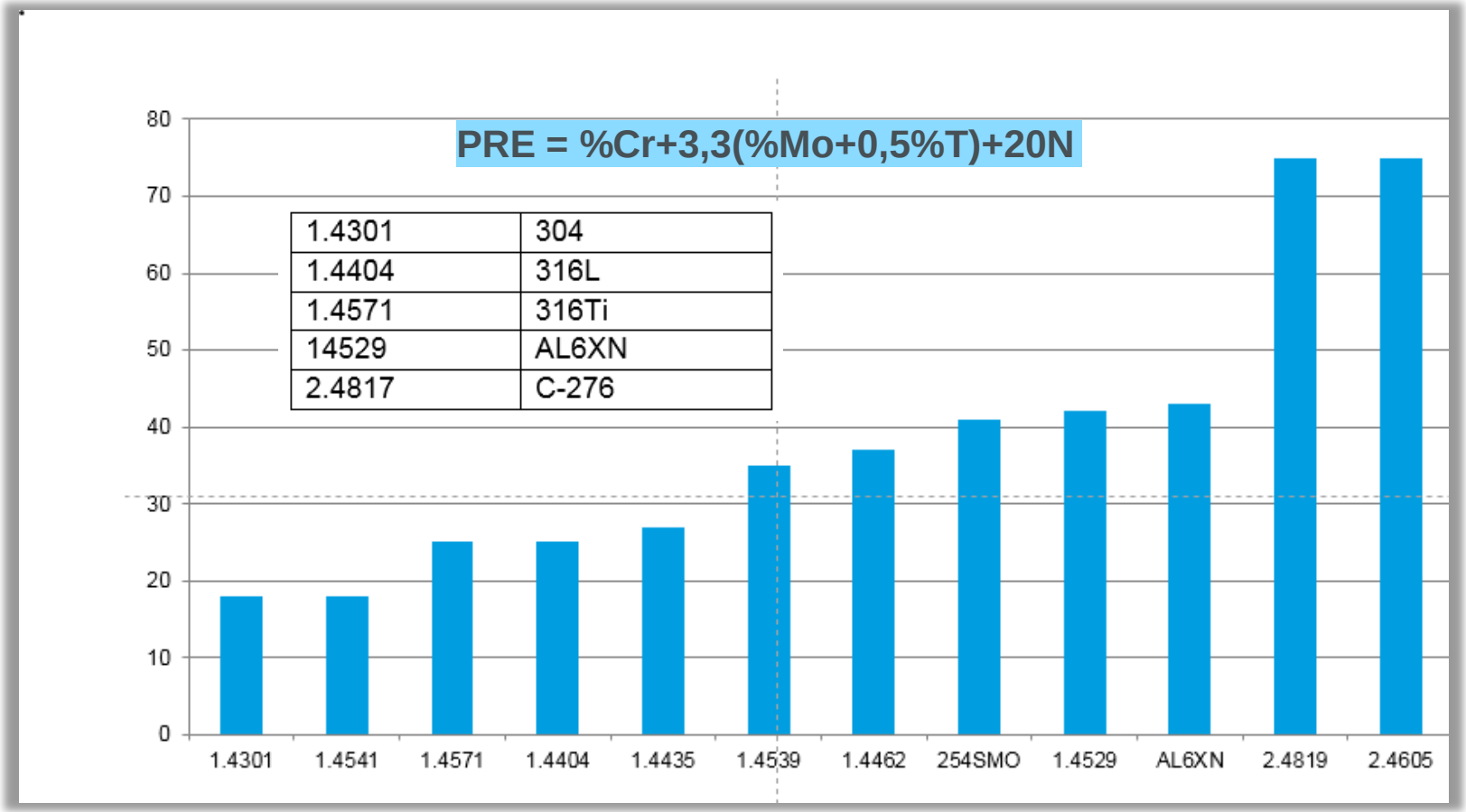
Laser engraving with gas protection (nitrogen)

Laser marking

- Laser labeling by tempering



Overview of different materials with PRE-indices



Potential research activities

- Beam Welding on higher (than 316L) alloyed stainless steel (segregation) – Is there the addition of higher alloyed filler wire required?
- Activities started: Research project between GEA Tuchenhagen and Helmholtz-Zentrum Geesthacht / Germany to evaluate the influence of high energy density welding (LBW and EBW) on the corrosion resistancy.

Perspective

- In addition to the Electron Beam Welding, the Laser Beam Welding has been well established in manufacturing of stainless steel components in the food and beverage industry.
- The energy efficiency and the beam quality were increased tremendously the last 15 years.
- Deep and small welds can be realised in high speed and with a minimum of distorsion.
- Including the potential of beam welding in the process of product development will offer new design possibilities. Especially in the case, that research activities in the field of welding superaustenic stainless steels without filler wire succeed.

Thank you very much for your attention.

Peter Merhof