DESIGN FOR LASER WELDING

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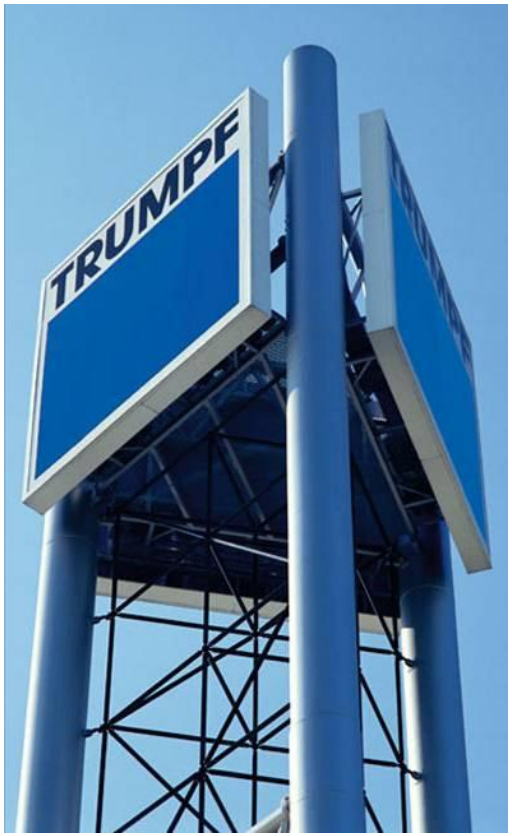

- Introduction
- Why employ laser welding?
- Fit-up & basic joint configuration
- Joint bridging techniques
- Joint design & feature considerations
- Summary

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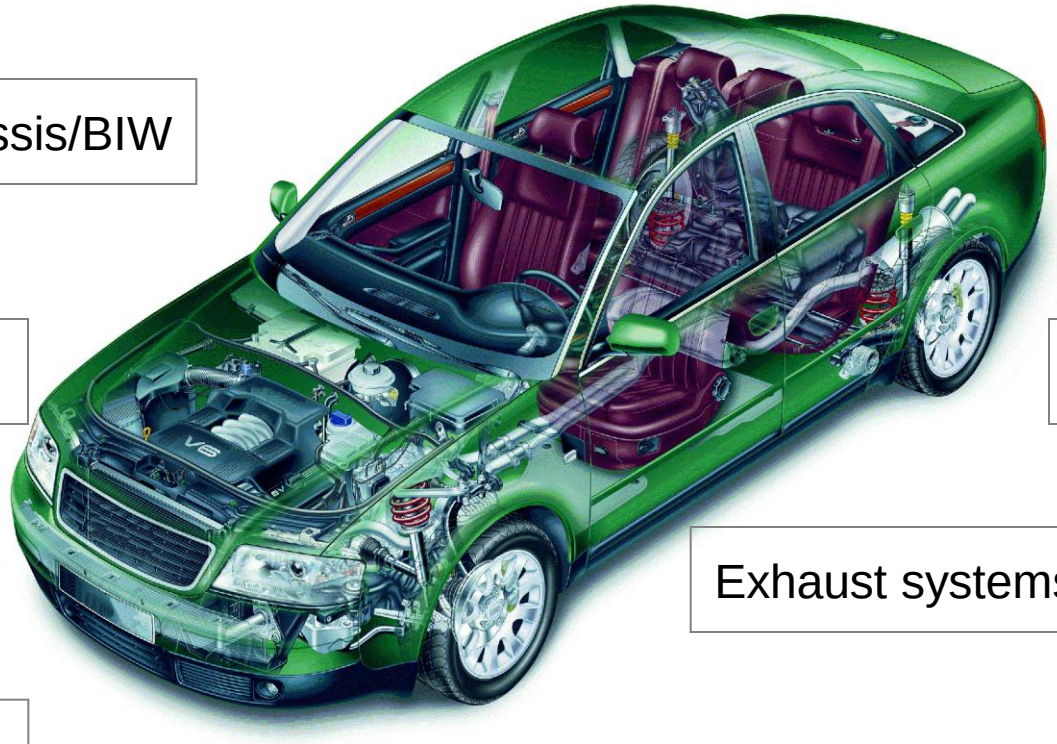
Laser applications - Automotive Industry

Passenger-safety

Interior

Electronic

Chassis/BIW



Engine

Components

Exhaust systems

Powertrain

Suspension

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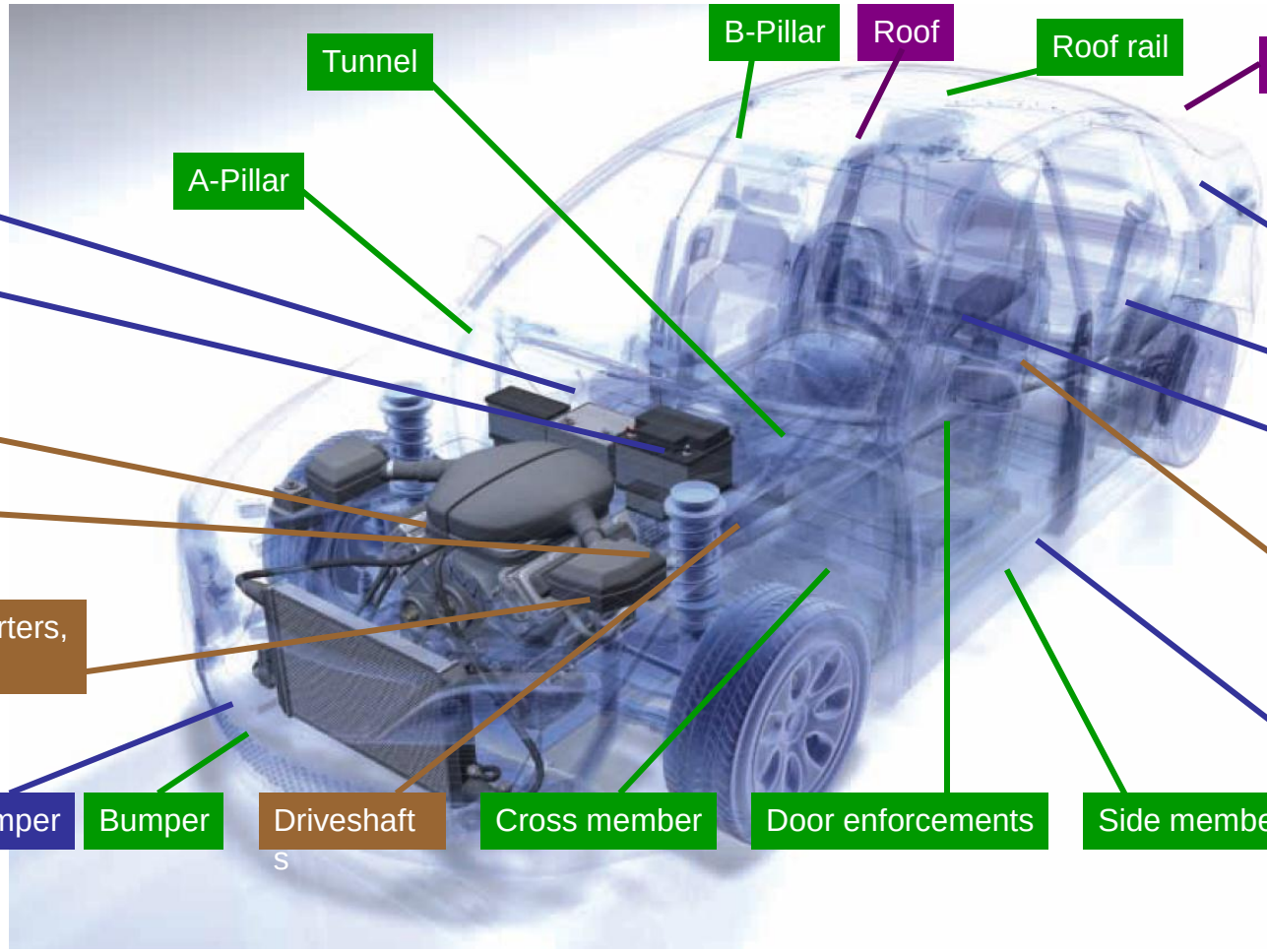
Laser applications - Automotive Industry



Remote | Hotforming | Brazing | Powertrai

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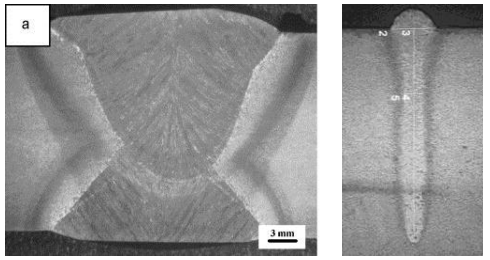
Why employ laser welding?

- **Minimum heat input and high aspect ratio resulting in …**
  - *> minimal shrinkage & distortion of the workpiece*
  - *> small heat affected zone*
  - *> narrow weld bead with good appearance*



- **High strength welds often resulting in …**
  - *> improved component stiffness / fatigue strength*
  - *> reduction of component size / weight* *Design Optimization*
- **Ability to weld in areas difficult to reach with other techniques**
  - *> non-contact, narrow access, single sided process*
- **Flexibility …**
  - *> beam manipulation (beam switching and sharing)*
  - *> variety of part & weld geometries and materials*

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Why employ laser welding?

- **Cost savings ...**

  > high productivity >> faster cycle time = less stations & less floor space

  > reduction of manual labor, scrap & re-work

  > reduction of component material and weight

  > can eliminate secondary processes

Laser Welding vs. Resistance Spot Welding

- **Reduction or elimination of flanges**

  > reduction of component size / weight

  > reduced cost

  > greater visibility / accessibility

- **Increased strength / stiffness**

  > localized increase of component strength / stiffness / fatigue strength

  > weld shape optimization for component loading / stresses

  > elimination of lower electrode access holes

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Drivers - Automotive Industry

Process Stability ↑

Stiffness ↑

Floor space ↓

Cost ↓

Throughput ↑

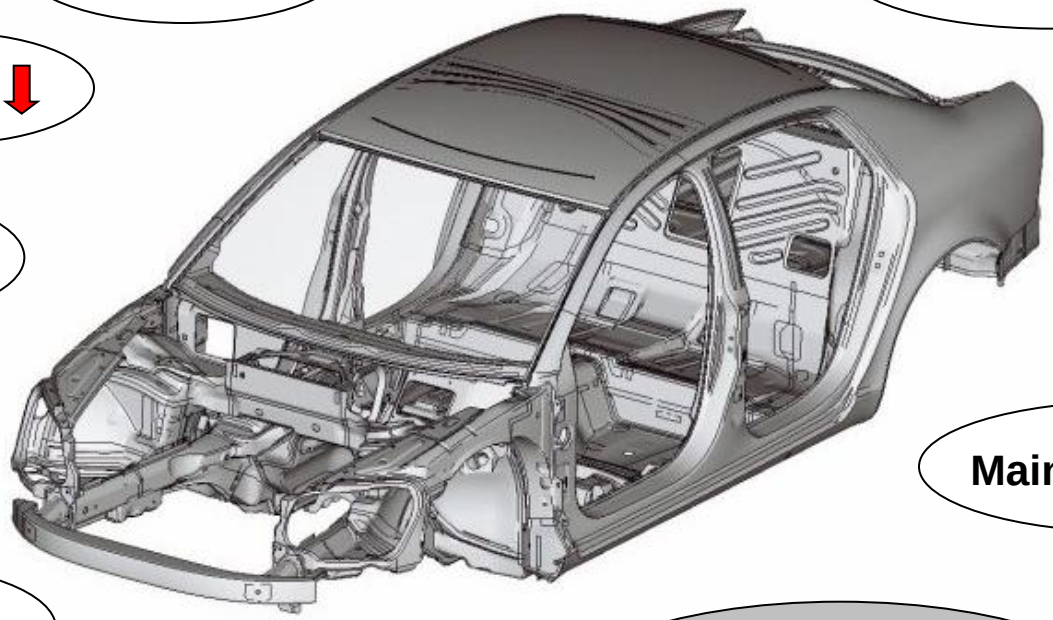
Access ↑

Weight ↓

Quality ↑

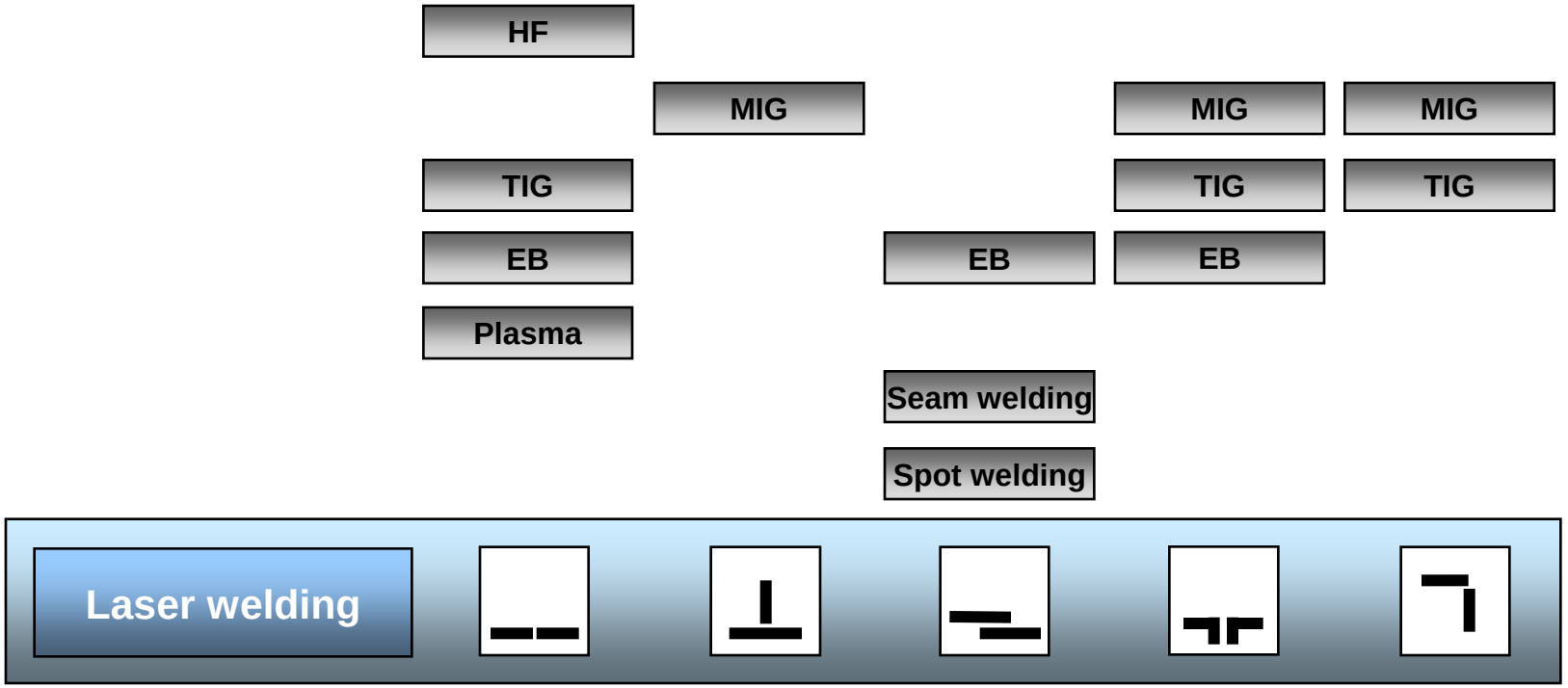
Maintenance ↓

Visibility ↑



Body designed for laser manufacturing

Laser – The Universal Tool for Welding



- Narrow weld seam
- Min. heat affected zone
- Little metallurgic effects on the material

- Little distortion
- No filler material required
- High process speed
- Non-contact
- No wear

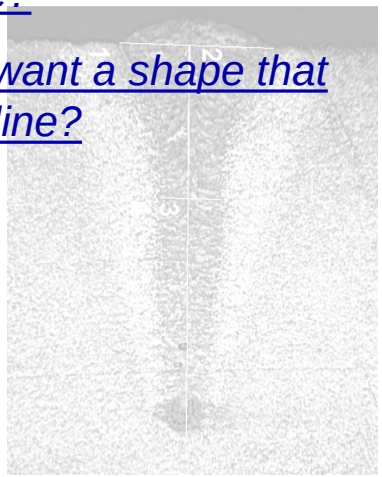
Laser as a tool

- relatively wide / narrow
- continuous / stitch / spot
- through / partial
- line / optimized shape
- conventional / remote
- multiple layers

When would you want wide? When narrow?

What benefits does partial penetration have?

Why would you want a shape that is not a straight line?



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Material selection

1. **Causes of porosity, underfill, undercut:**
   - Volatile constituents (e.g. S, P)
   - Volatile coatings/surface contaminants (e.g. Zn, oil based lubricants)

Notes for welding of Zn coated steels in overlap configuration

a. Increased weld length may compensate for porosity in non-critical components

b. Electro-galvanized & electro-galvaneal are better than hot dipped galvanized

c. Bare to Zn is often okay (especially electro plated)

d. Zn to Zn configurations usually require a gap and/or Zn exhaust path for reasonable results (e.g. dimples, shims, knurling, fixture/tooling, leading pressure finger, part design, joint design)

e. Watch out for patent infringements!

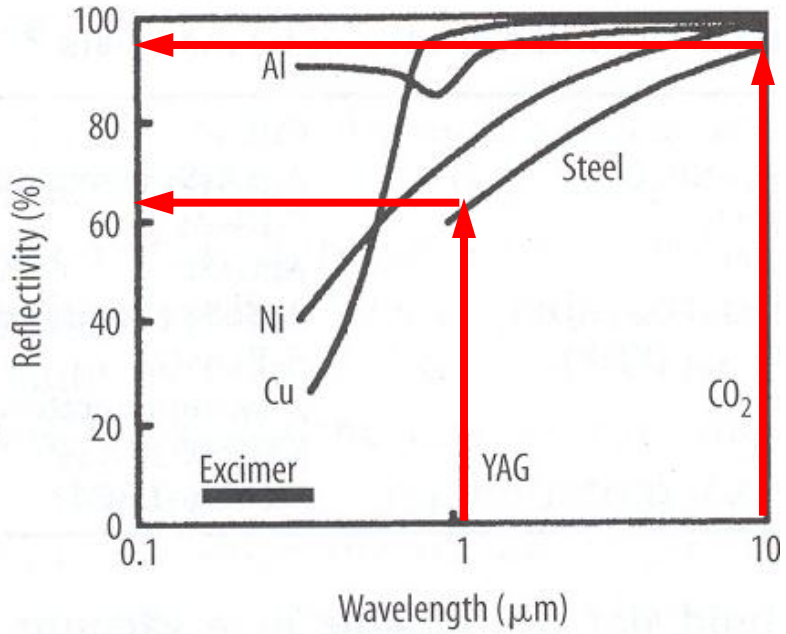
Material selection

2. **Brittleness & cracking:**

   - Can occur in steels when >0.3%C (>0.4%C equivalent)
   - 6000 series aluminum

3. **Reflectivity**

   With high reflective materials (e.g. Al, Cu) – 1 micron wavelength has greater absorption than 10.6 microns



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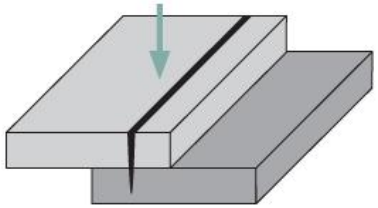
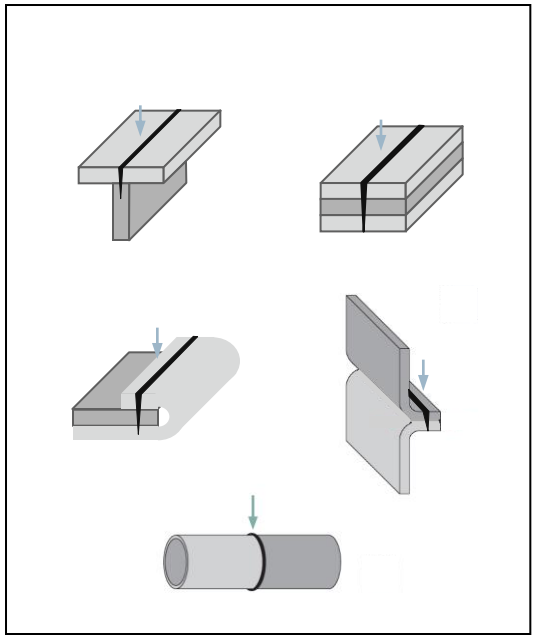
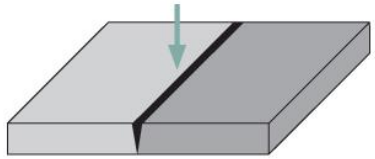
Seam and joint types

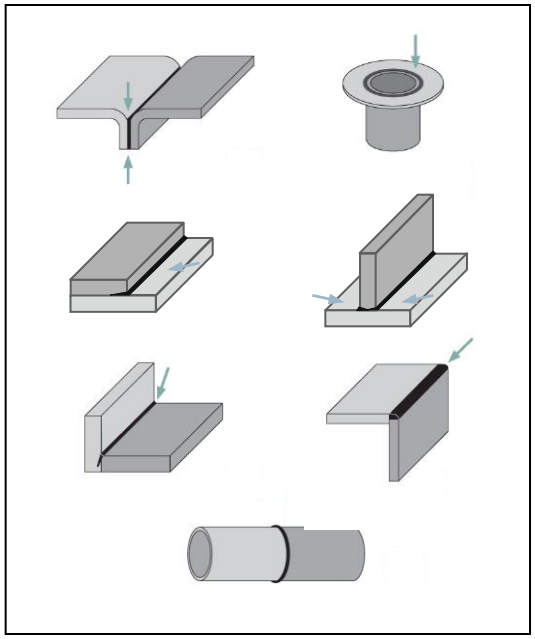
Lap weld on lap joint





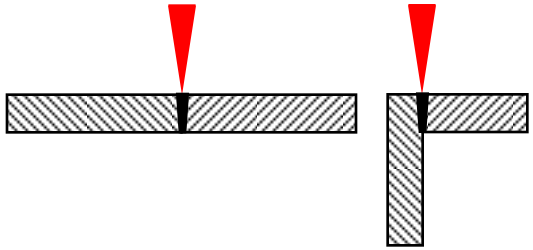
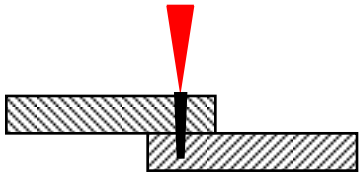
Seam weld on butt joint



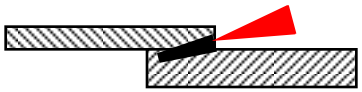
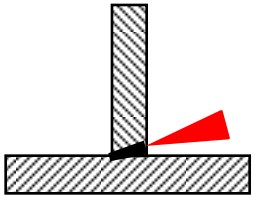


Seam and joint types

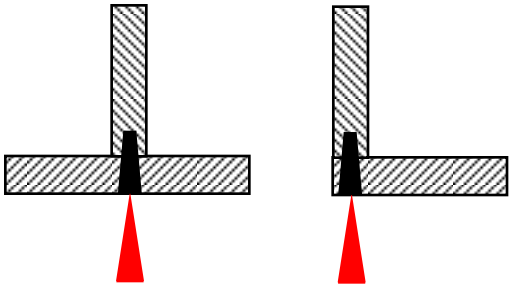
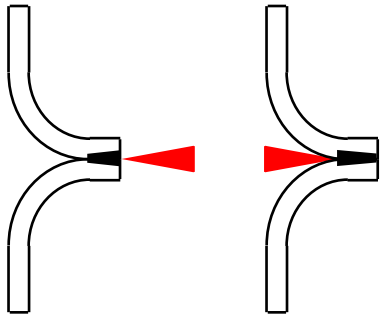
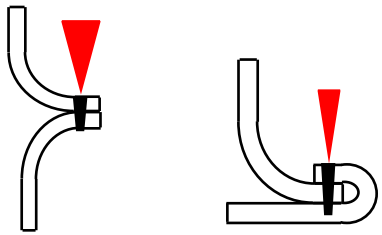
Think about a positive & negative characteristic of both the butt & lap weld configurations.

Name	Example	Characteristics
Seam weld on butt joint		**+ Weld Fusion Area** • less material = weight & cost savings • faster or less power • less HAZ / distortion • no issues w/ Zn • no step **- Positioning Tolerance** • edge requirements • fit up can be more difficult to obtain
Lap weld on lap joint		**+ Positioning Tolerance** • larger process window • can have aesthetic underside **- Weld Fusion Area** • more energy required = slower or higher power & more distortion / HAZ • inefficient process

Seam and joint types

Name	Example	Characteristics
Seam weld on stepped lap joint		+ **weld fusion area** - **positioning tolerance**
Seam weld on T-joint		+ **weld fusion area** - **positioning tolerance**

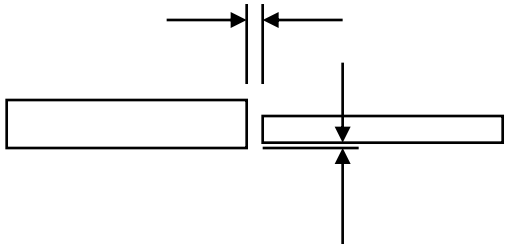
Seam and joint types

Name	Example	Characteristics
Lap weld on T / border joint		+ **positioning tolerance** - **weld fusion area**
Seam weld on flange		+ **weld fusion area** - **positioning tolerance**
Lap weld on formed seam		+ **positioning tolerance** - **weld fusion area**

Fit-up requirements

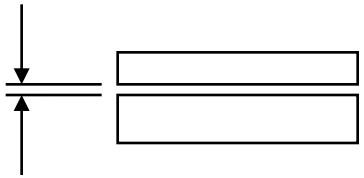
Butt joint configuration:

- Gap: 3-10% thickness of thinnest sheet
- Offset: 5-12% thickness of thinnest sheet



Overlap joint configuration:

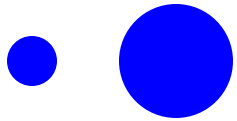
- Gap: 5-10% thickness of top sheet



Why is this general guideline not absolute?

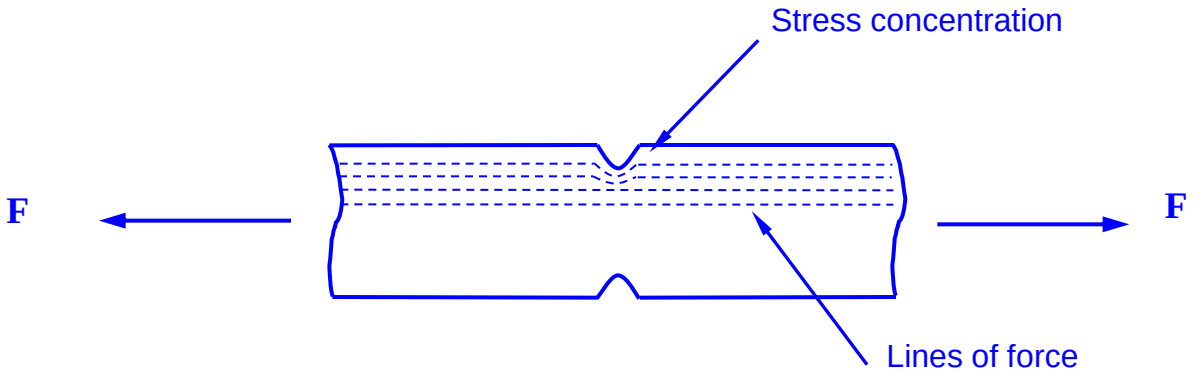
(What influences the amount of gap that can be bridged?)

- *Focus spot size*
- *Edge geometry for butt weld*
- *Strength requirements*



The importance of good fit-up

- For autogenous laser welding, weld strength is a function of weld joint fit-up.
- A gap (or mismatch) reduces weld strength because it can yield an underfill and/or undercut which …
  a. Reduces weld area (S = F/A)
  b. Creates a stress riser



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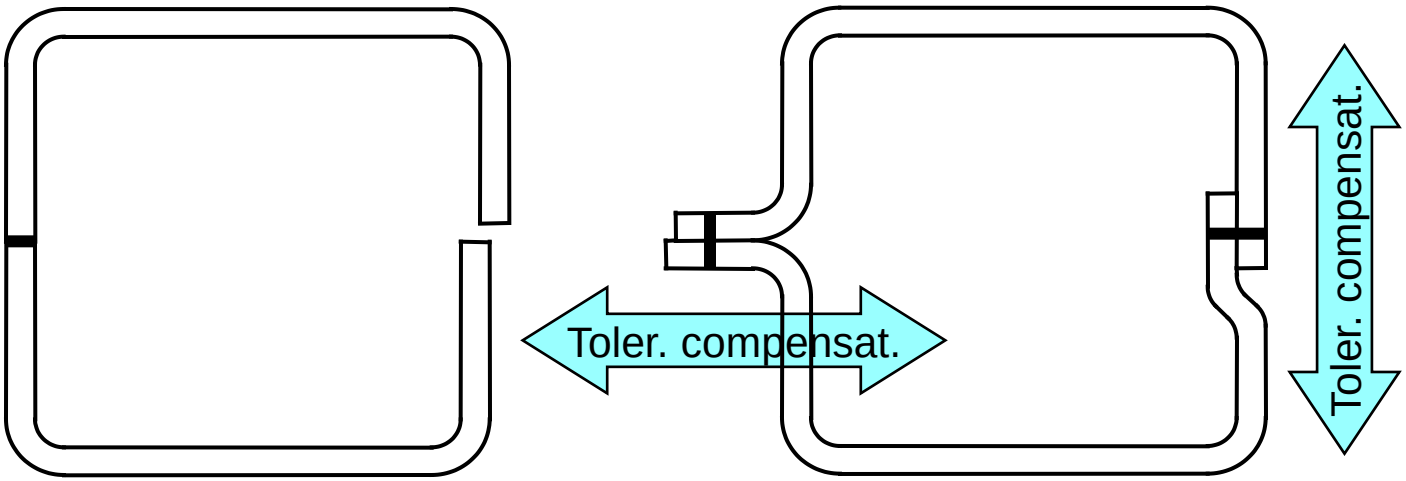
Tolerance compensation



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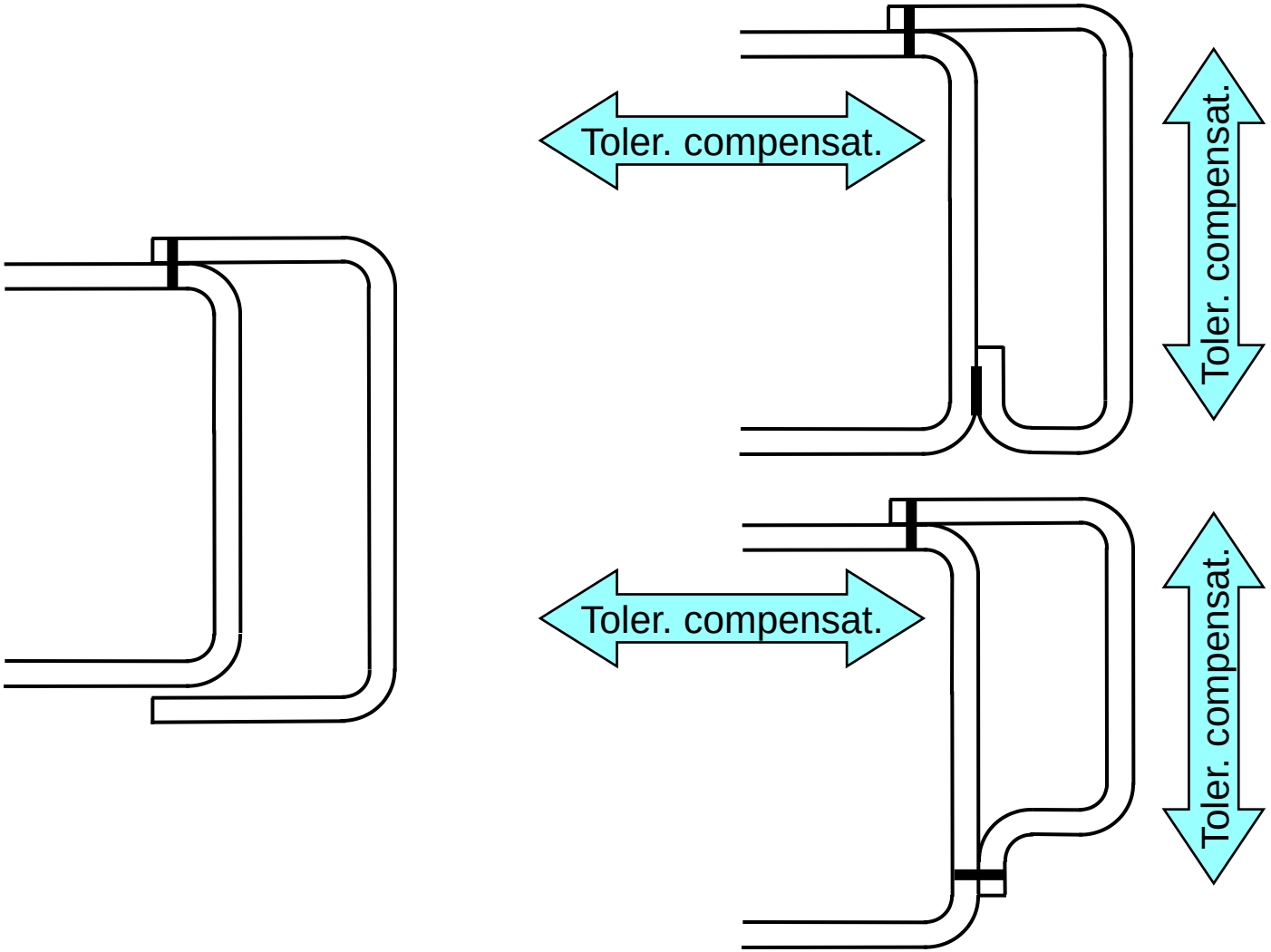
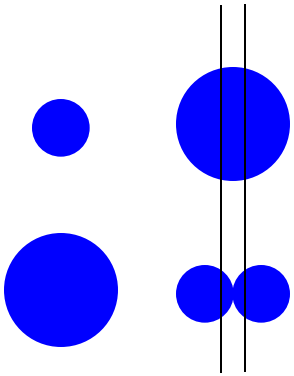
Tolerance compensation



Joint bridging techniques

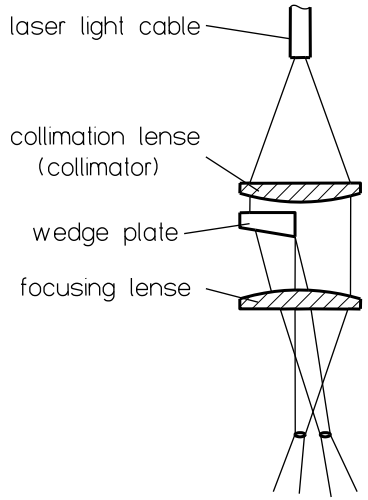
Autogenous

- *Larger focus spot*
- *Twin spot*



- slower, more heat input

+ 2x higher power density
+ Less wasted energy
= *faster !!*
- Directionality

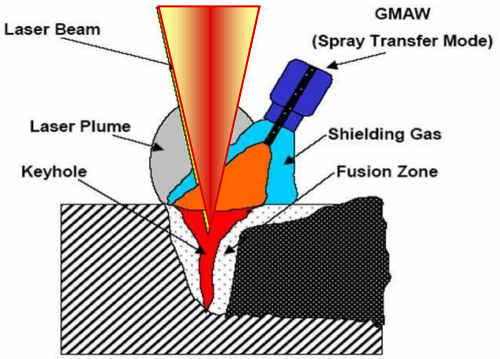


Non-autogenous

- *Hybrid (laser + MIG + wire feed)*
- *Wire feed*

- cost, complexity, may require vision system

+ gap & metallurgical bridging



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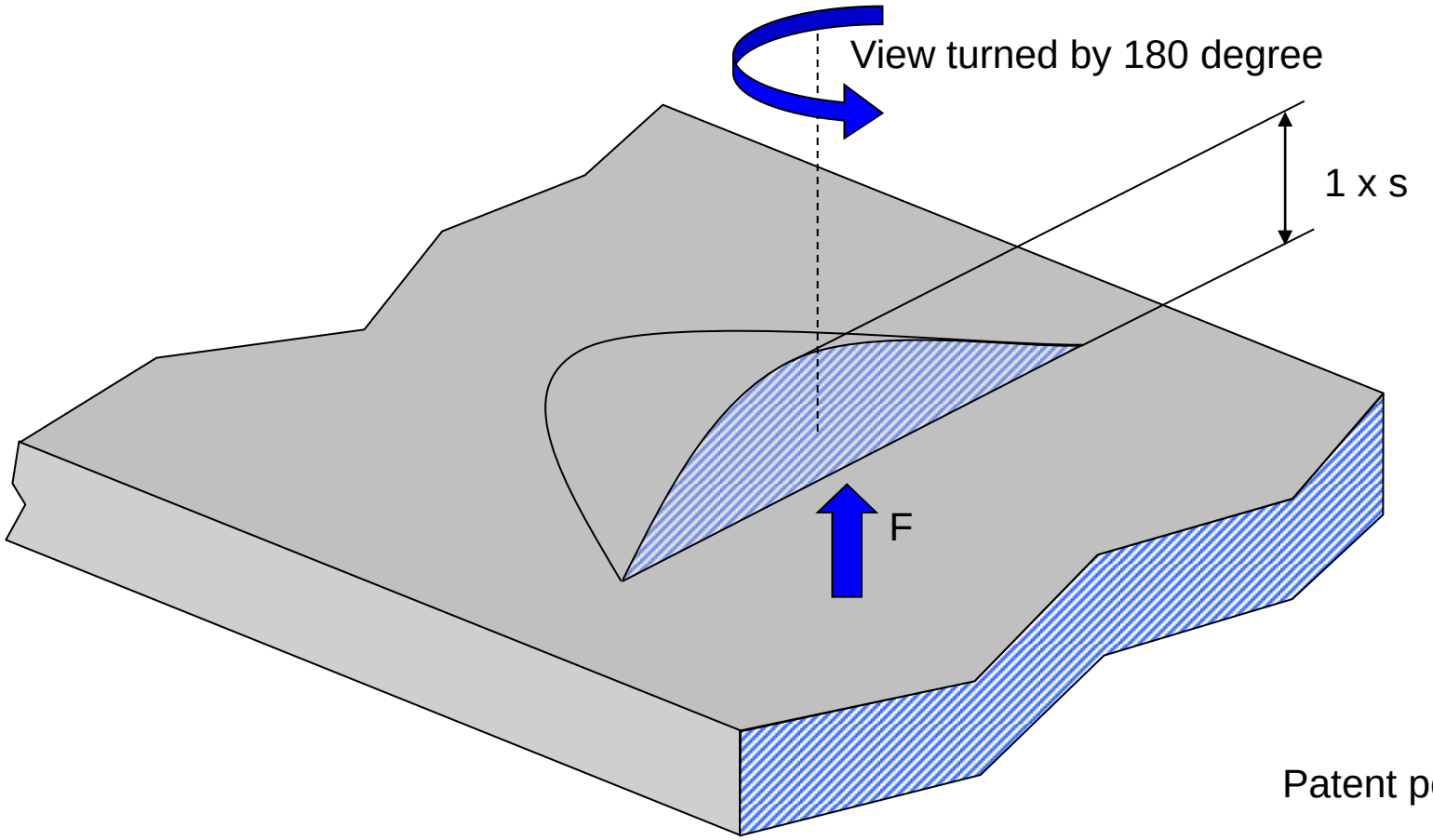
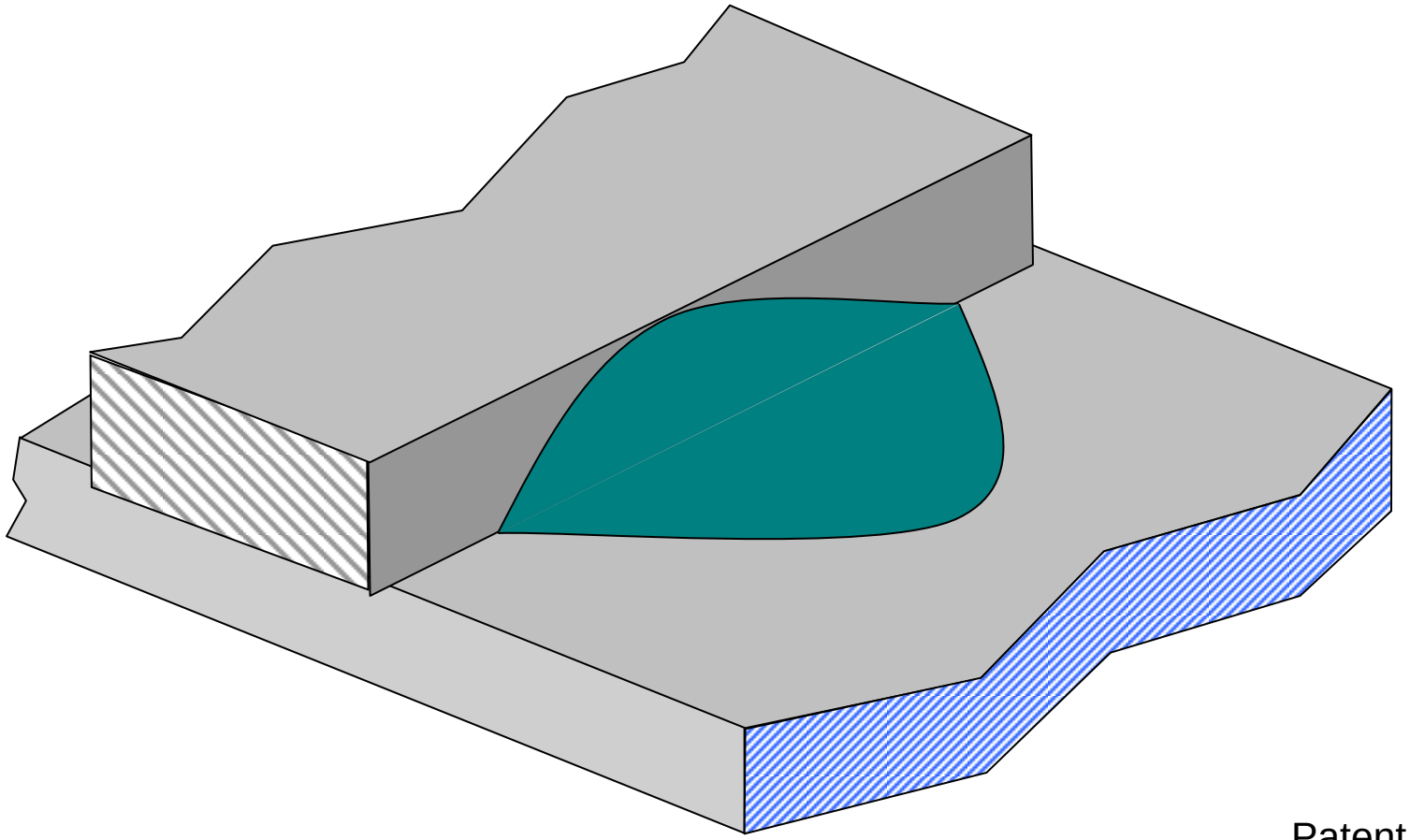
Design features



Patent pending

Design features

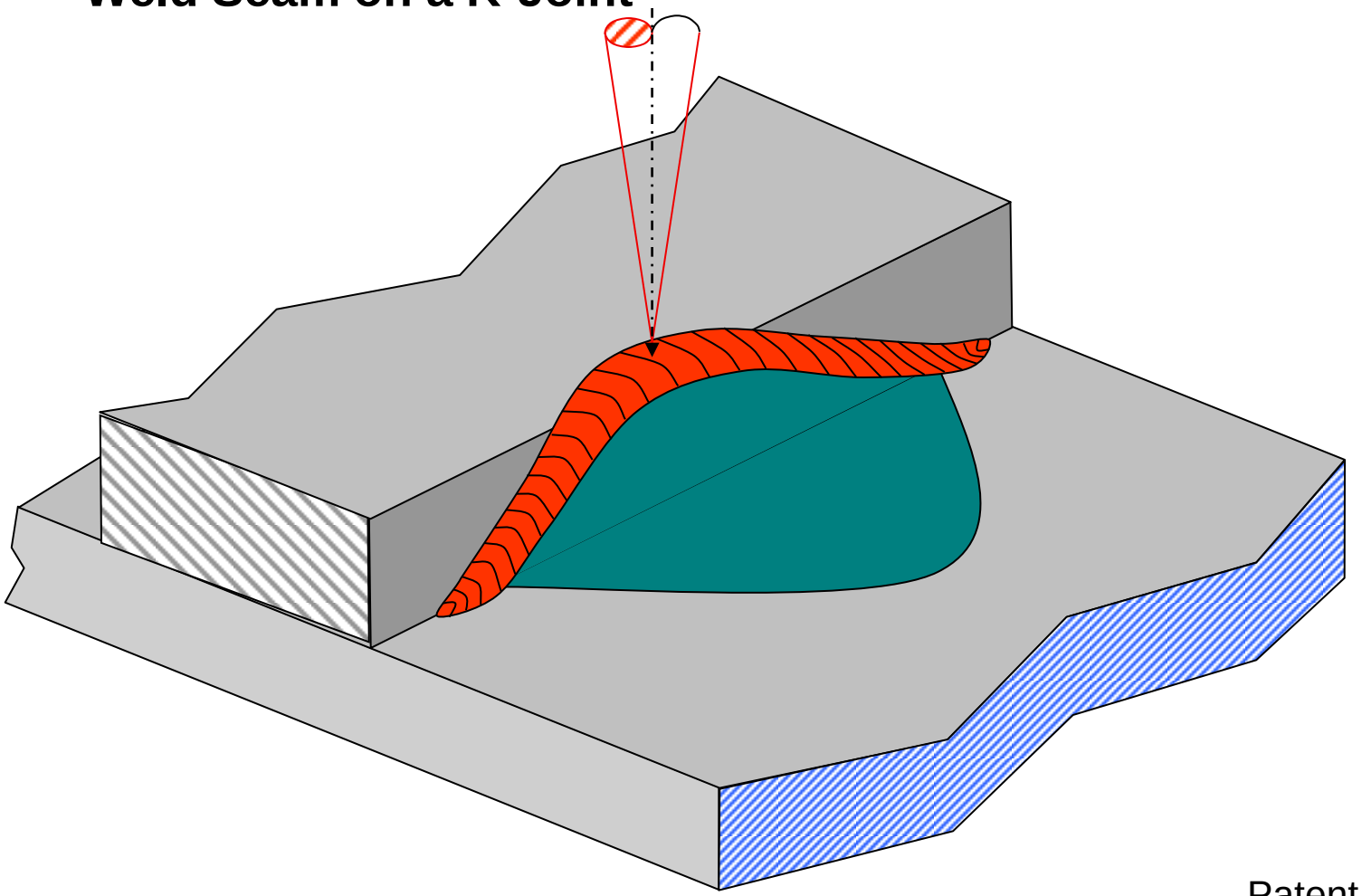
Material fit of a K-Joint



Patent pending

Design features

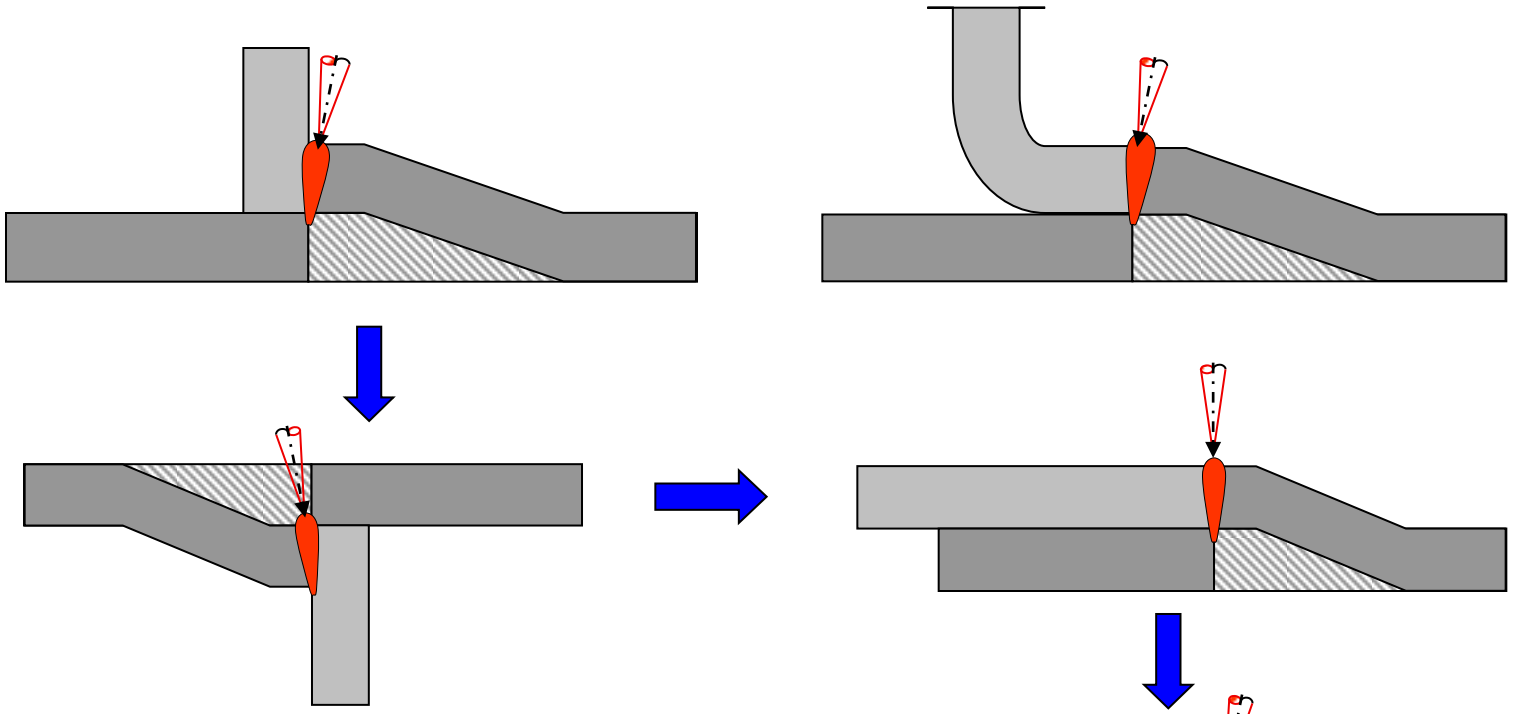
Weld Seam on a K-Joint



Patent pending

Design features

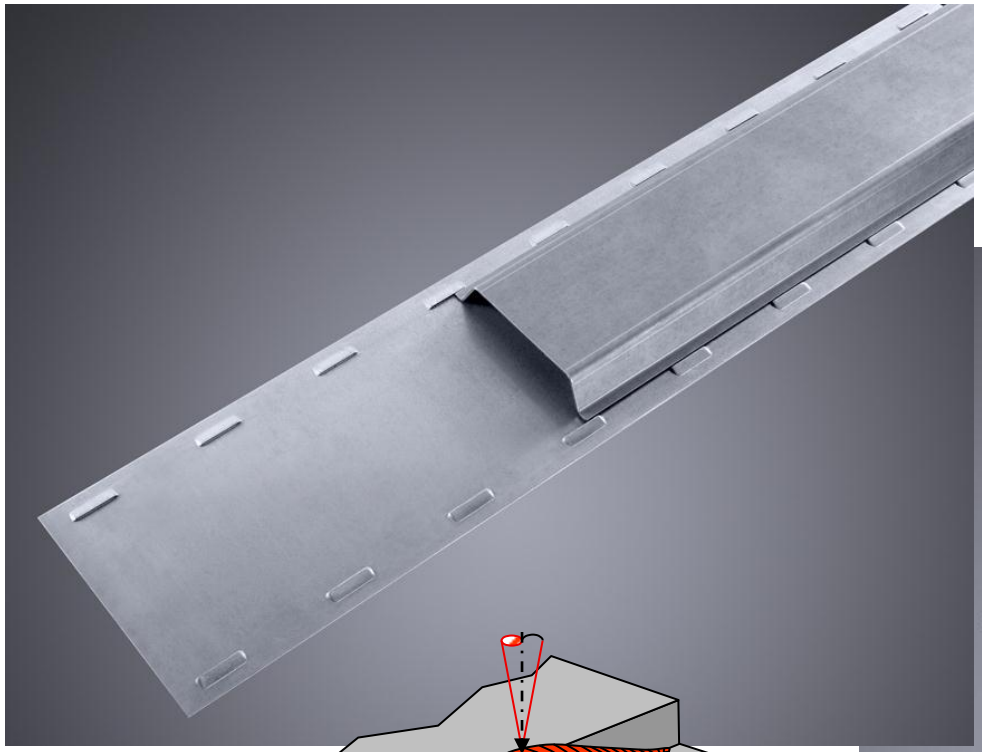
Different Applications of a K-Joint

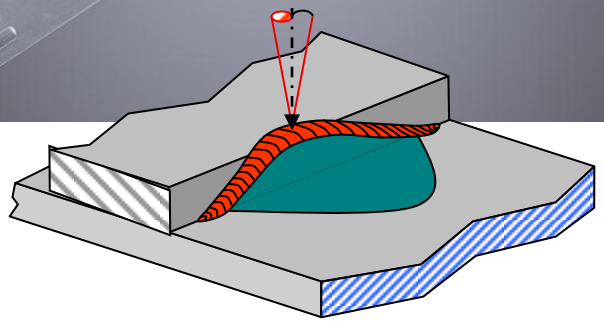


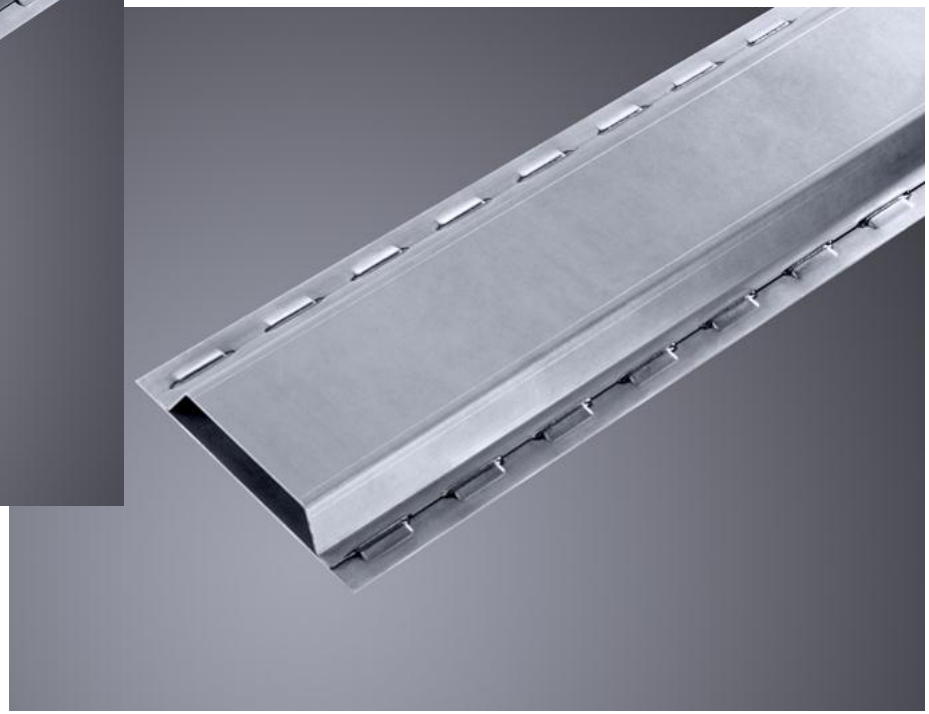
Patent pending

Design features

K- Joint in Application / Flange-reduced Design







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Design features

Specialized cutting & bending of tubes

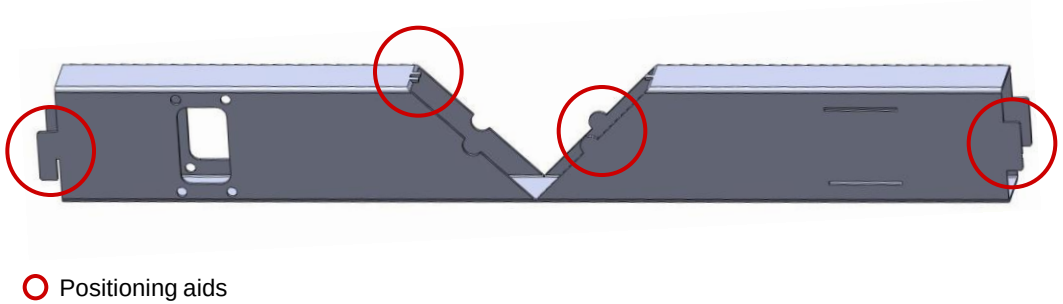
Multiple bend tubes:
Allows 3 dimensional structures.

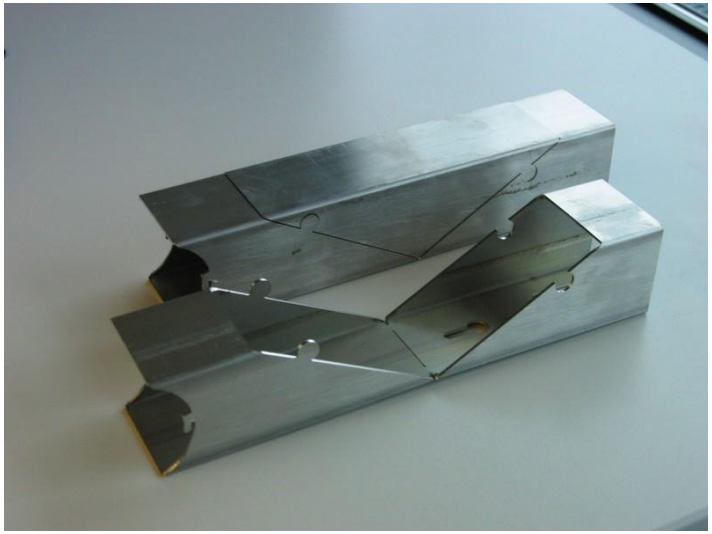
Bend tubes:
Allows high quality on corners.

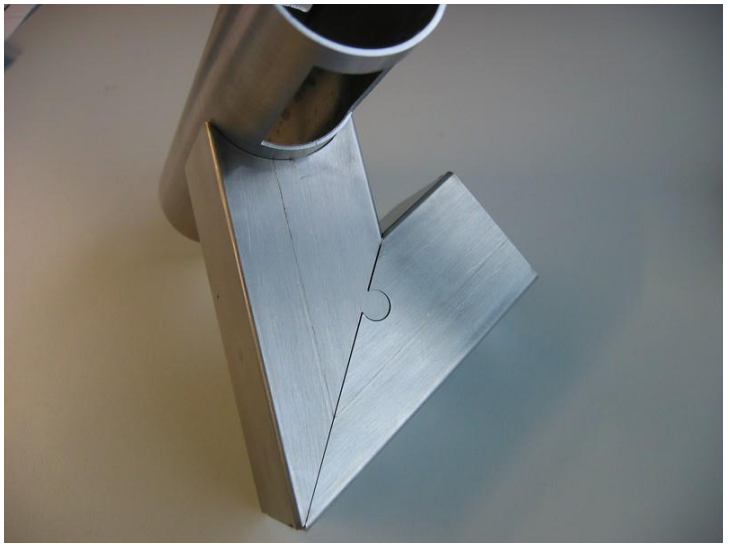
Design features

Specialized cutting & bending of tubes w/ positioning aids

Special bent tubes techniques create connections with the need of only a few welds.

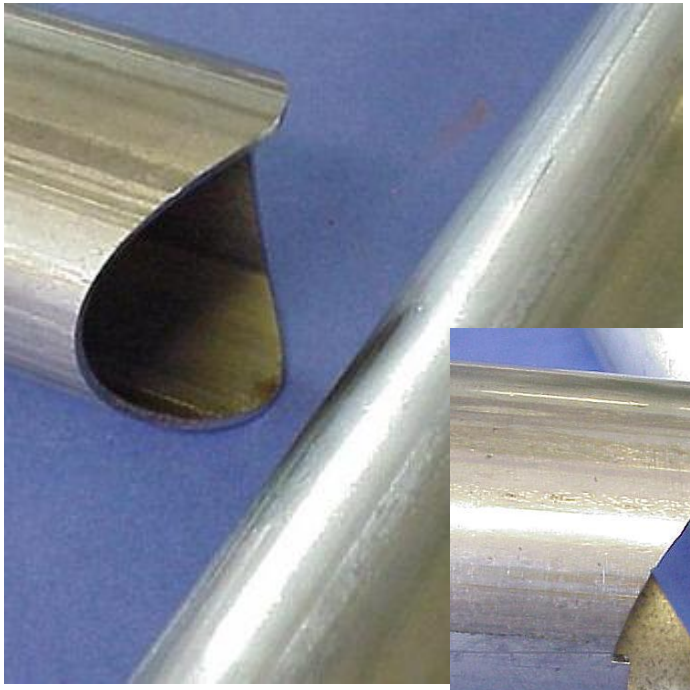


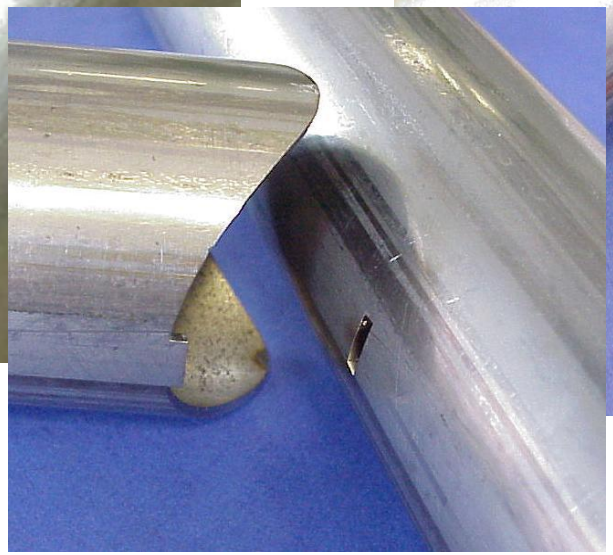


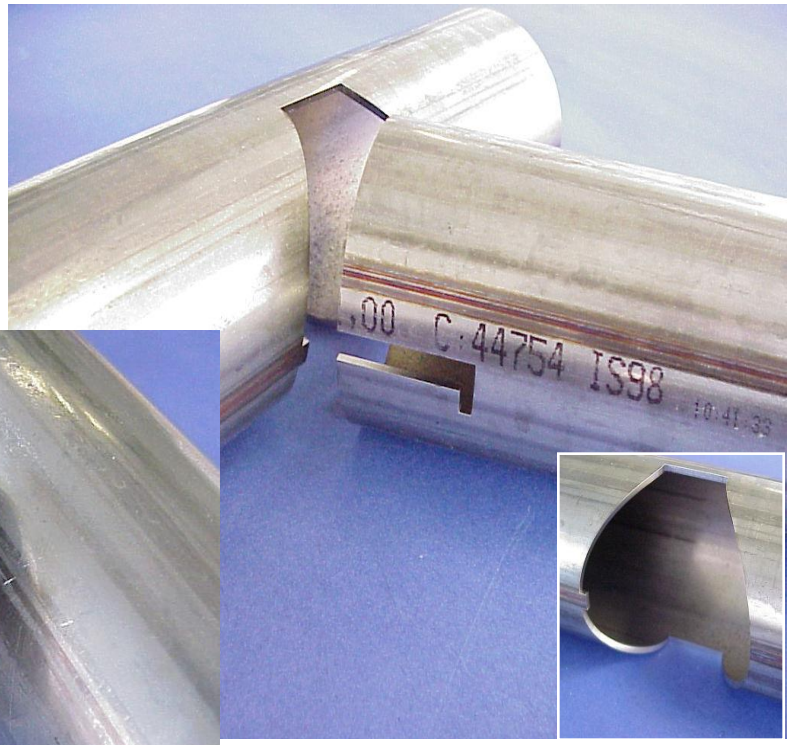


Design features

Positioning tabs & bayonets for tubes







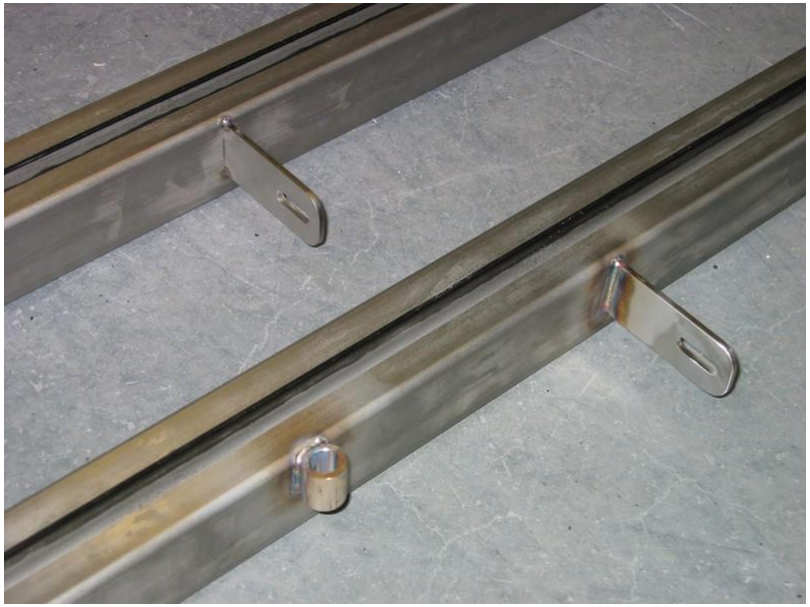
Perfect interface for welding operations

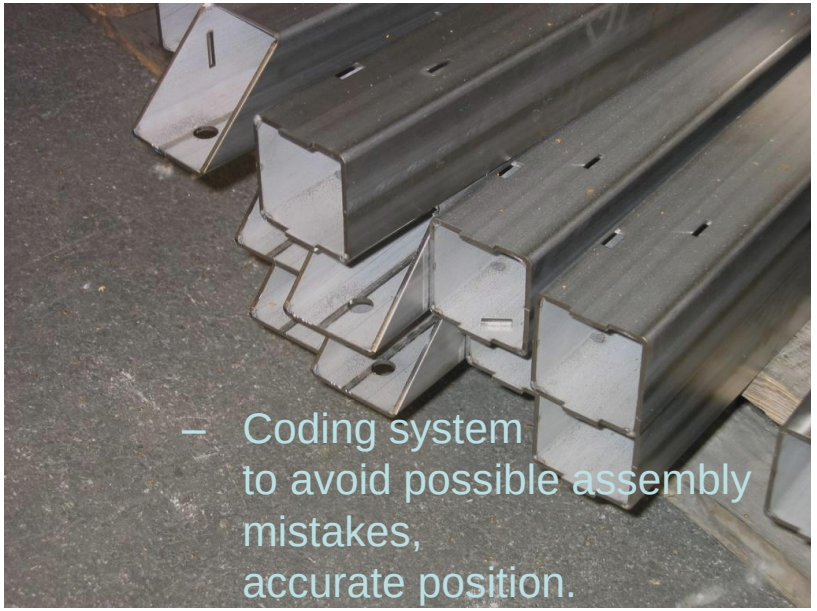
Precision location

Bayonet coupling ensures orientation and reduces need for precision fixturing.

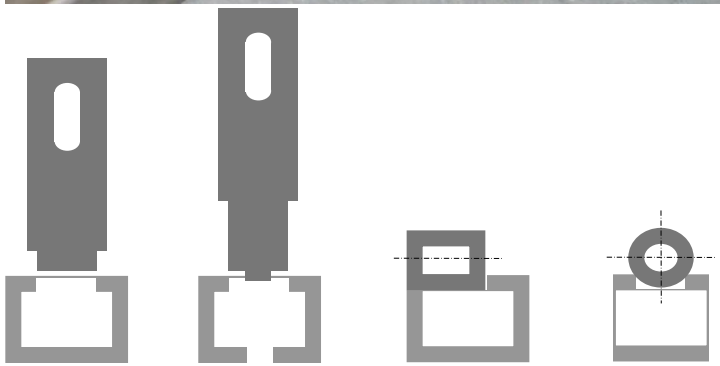
Design features

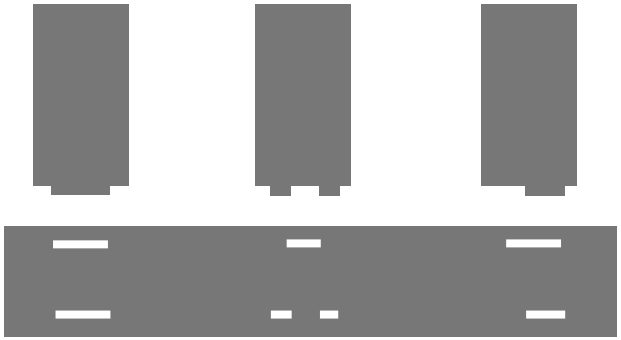
More Tube Interfaces





– Coding system
to avoid possible assembly mistakes,
accurate position.





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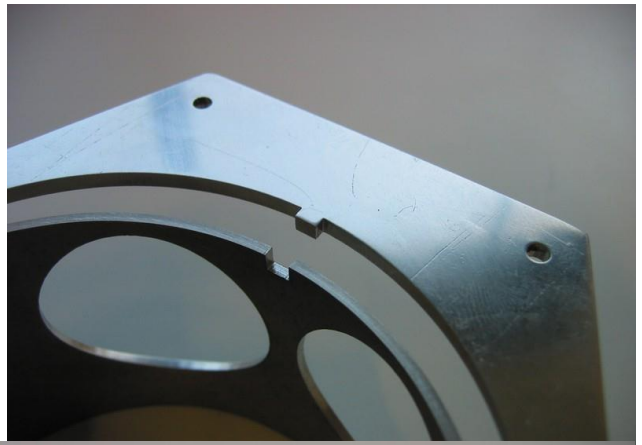
Design features

Positioning tabs for tubes & plates

Mounting plate to tube:
Well suited for welding
High positioning accuracy



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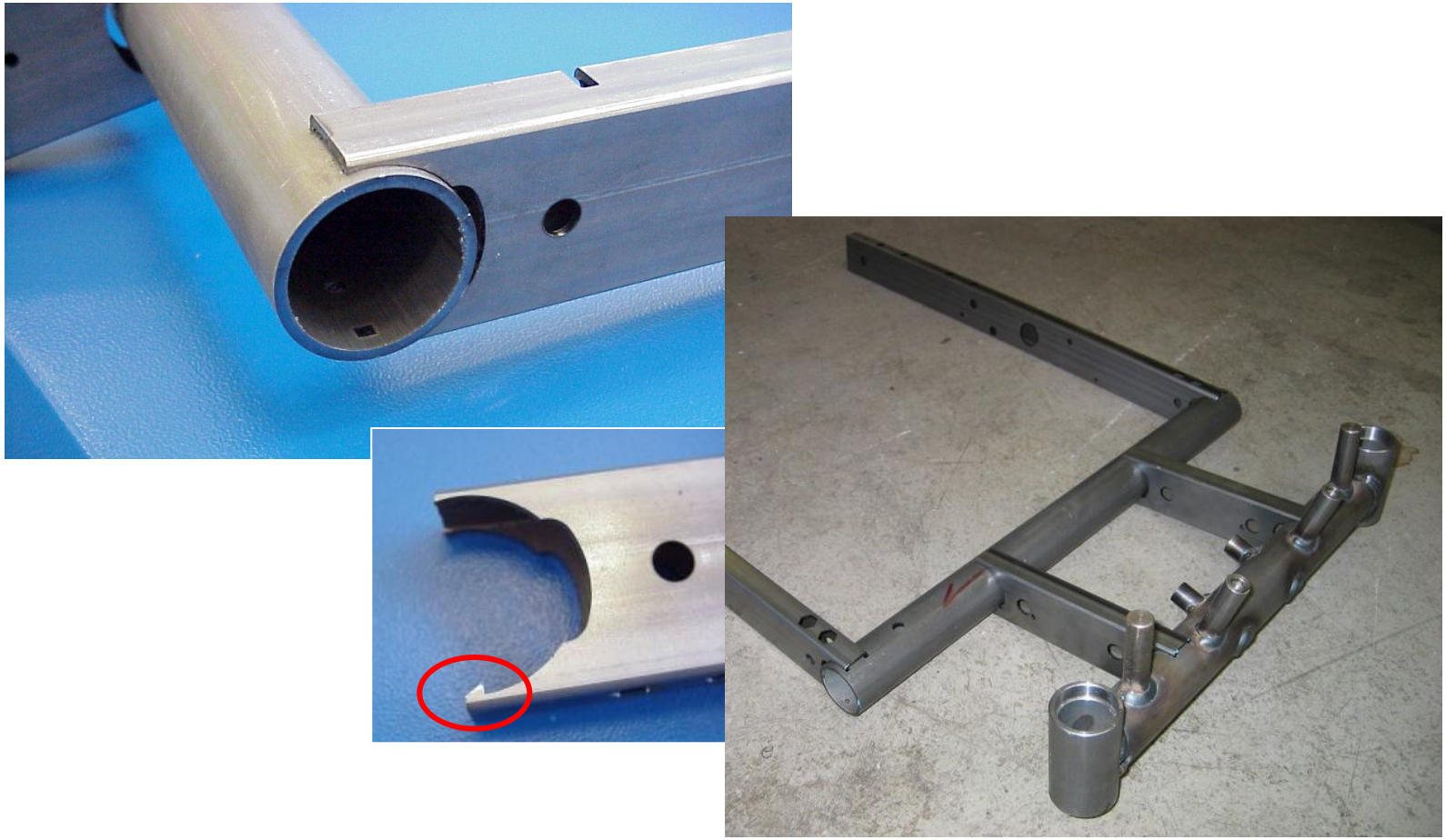
Design features

Interlocking tabs for tubes



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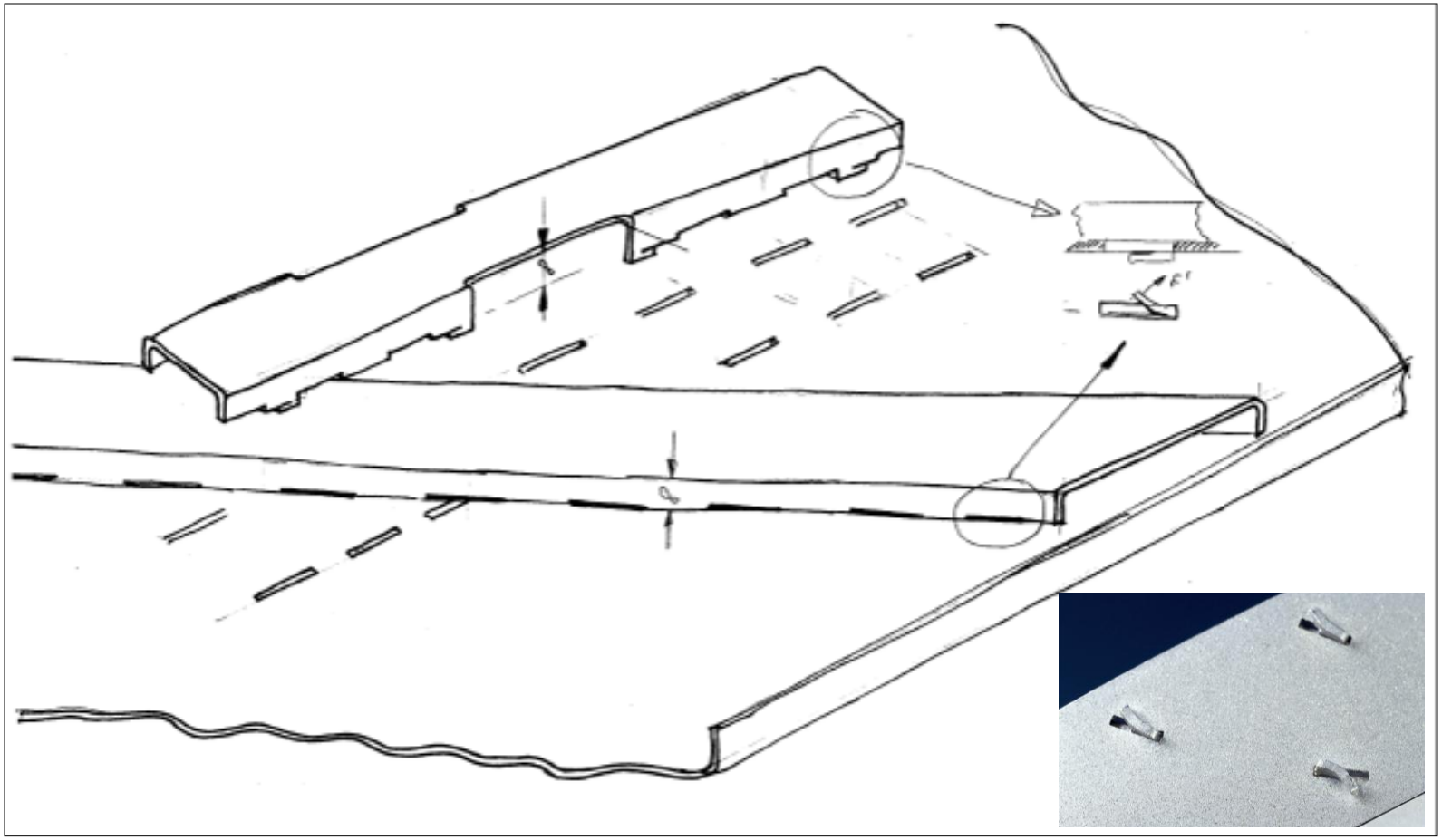
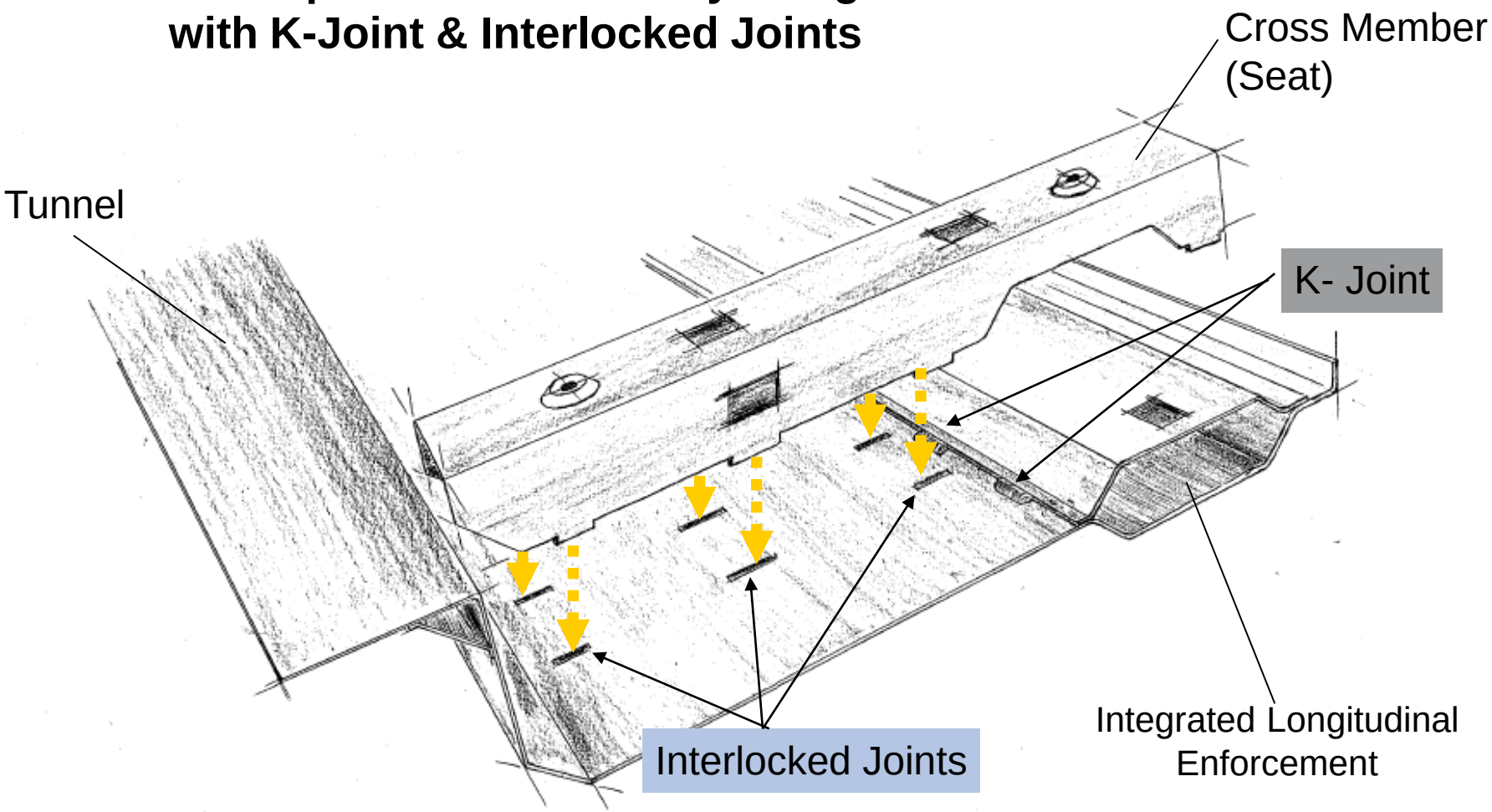
Design features

Integrating locating & interlocking features



Design features

Concept for an Underbody design with K-Joint & Interlocked Joints



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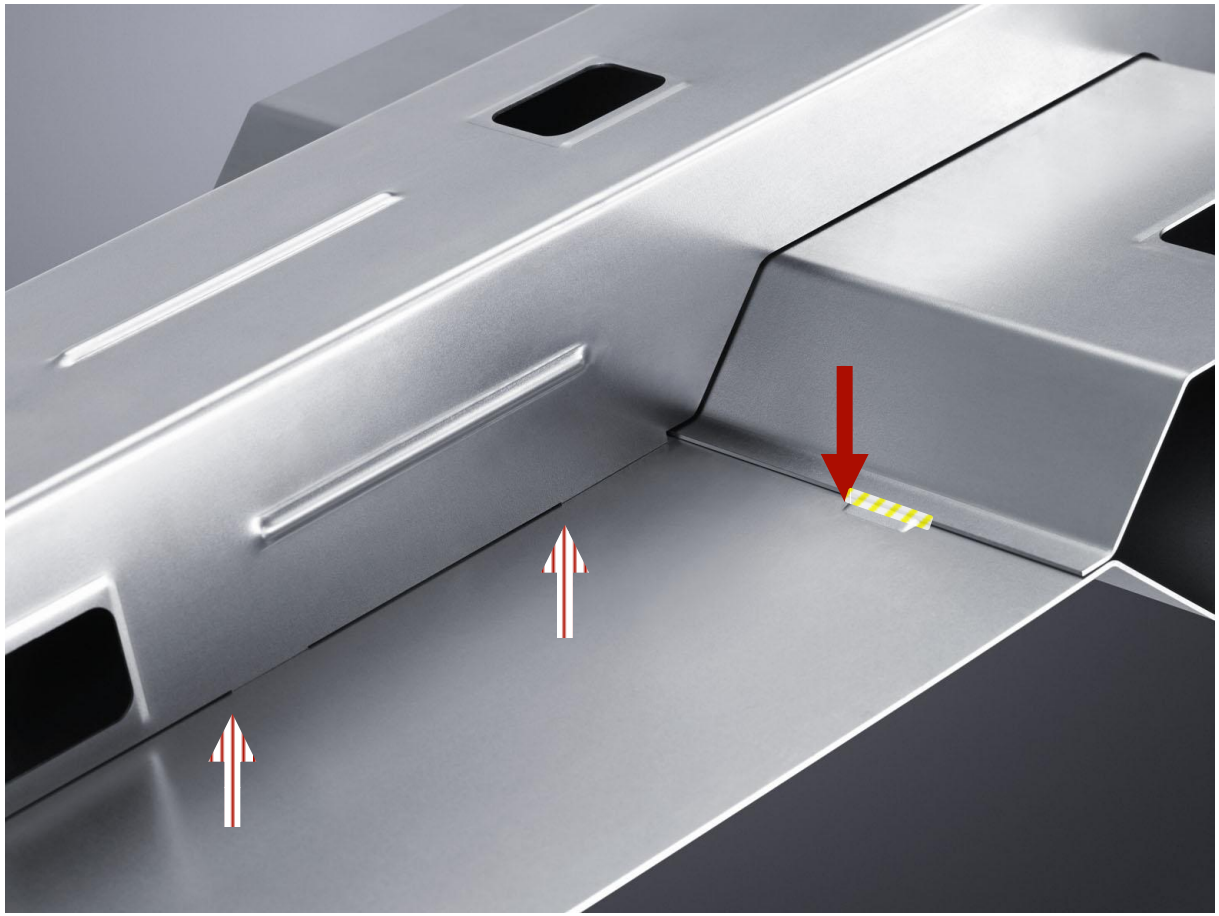
Tolerance Compensation

K-Joint & Interlocked Design for Underbody



Design for laser welding summary (pt. 1)

- Design & re-design components for laser welding
  - Reduce component weight & cost by reducing or eliminating flange widths *(enabled by single sided, narrow beam access)*
  - Increase vehicle accessibility & driver visibility by reducing or eliminating flange widths *(enabled by single sided, narrow beam access)*
  - Reduce component weight and cost by reducing gage thickness *(enabled by increasing strength through optimized weld shapes and/or continuous weld seams in high stress locations)*
  - Reduce component weight and cost, and increase strength *(enabled by elimination of RSW lower electrode access holes in structural reinforcements)*

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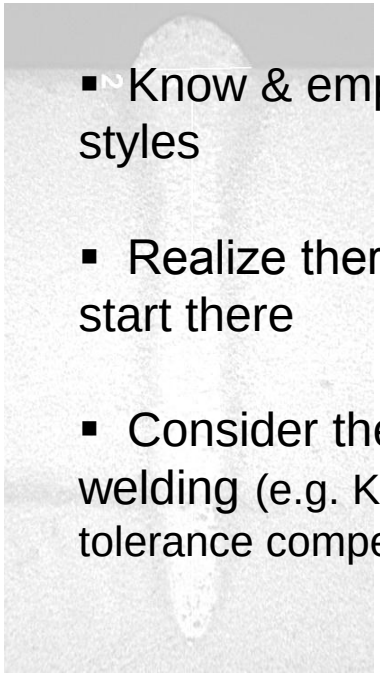
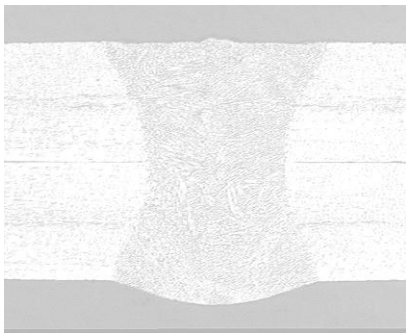
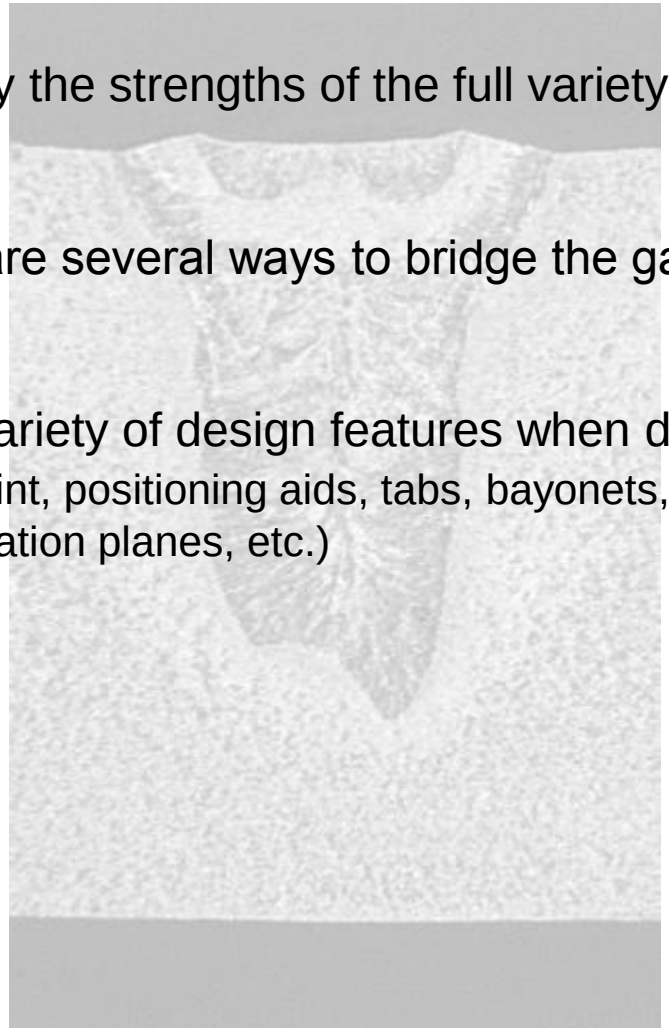
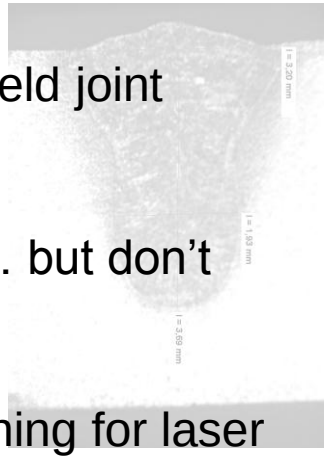
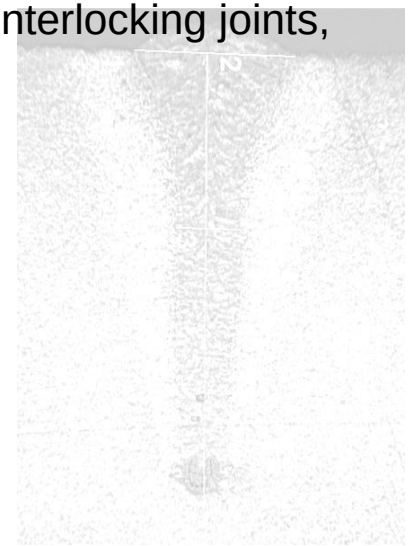
Design for laser welding summary (pt. 2)

- Know & employ the strengths of the full variety of weld joint styles
- Realize there are several ways to bridge the gap, … but don't start there
- Consider the variety of design features when designing for laser welding (e.g. K-Joint, positioning aids, tabs, bayonets, interlocking joints, tolerance compensation planes, etc.)

Continuous Education / Improvement

Laser Welding
Christopher Dawes
Abington Publishing (1992)

Laser Welding
Walter W. Duley
John Wiley & Sons (1999)

Laser Material Processing – Fourth Edition
William M. Steen / Jyoti Mazumder
Springer (2010)

AWS Welding Handbook
Welding Processes, Part 2
Ninth Edition, Volume 3
American Welding Society (2007)

LIA Handbook of Laser Material Processing
John F. Ready – Editor in Chief
Laser Institute of America (2001)

TRUMPF Open House – Tomorrow Evening

Please Join Us!

Thursday, May 17th

5:30 – 9:00 PM

5:30-6:00 Registration

6:00-6:20 Keynote address by Gary Vasilash

6:30-9:00 Machine Demonstrations

Open House

Held in conjunction with the Advanced Laser Applications Workshop (ALAW)

Please join TRUMPF for
Advanced Laser Applications Workshop (ALAW) and Open House

Open House Schedule

5:30 pm – 6:00 pm **Registration**

6:00 pm – 6:20 pm **Keynote Address Followed by Q&A**

The Power of Choice
There is no "one size fits all" in industrial lasers. Optimization of diverse applications requires different laser technologies. TRUMPF offers the largest application and service network in the world as well as the broadest industrial laser portfolio of any manufacturer including CO_2, Nd:YAG, disk, fiber, direct diode and more.

6:30 pm – 9:00 pm **Machine Demonstrations**

Machine demonstrations will include:

- High speed 3D cutting (CO_2 laser)
- Robotic remote welding and cutting (disk laser)
- High precision cutting (fiber laser)
- Automated pulsed welding (pulsed laser)
- Precision laser marking (marking laser)

RSVP

Please RSVP with your NAME, COMPANY, and CONTACT INFORMATION by May 10, 2012 to felix.brinkmann@us.trumpf.com

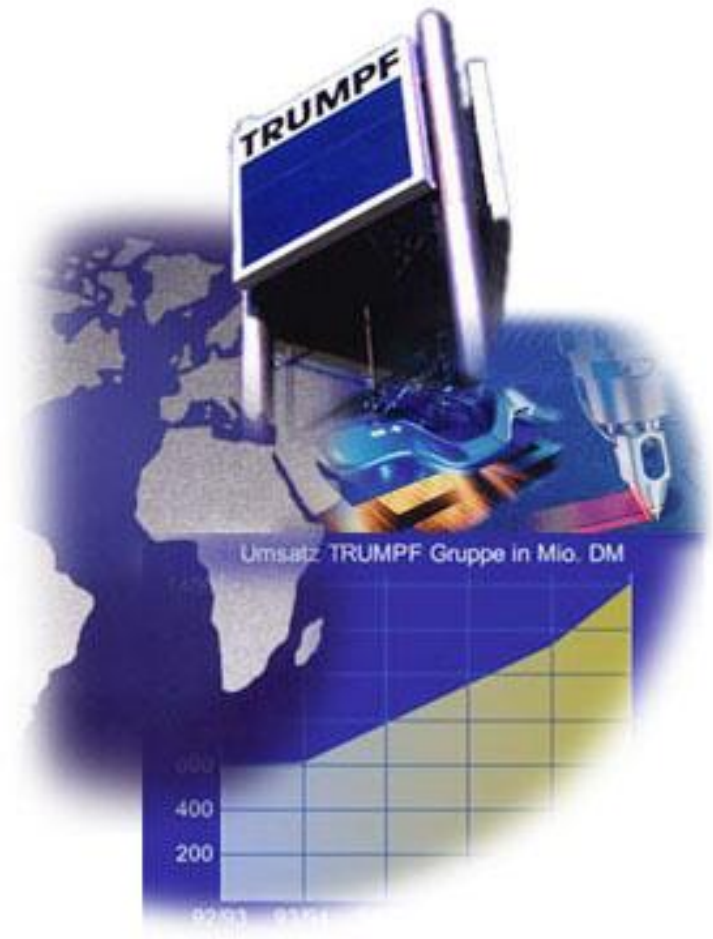
Please feel free to extend this invitation to your colleagues.

May 17, 2012 – 5:30 p.m.

TRUMPF Laser Technology Center
47711 Clipper Street
Plymouth Township, MI 48170

Keynote Address featuring
Gary S. Vasilash, Editor-in-Chief,
Automotive Design & Production

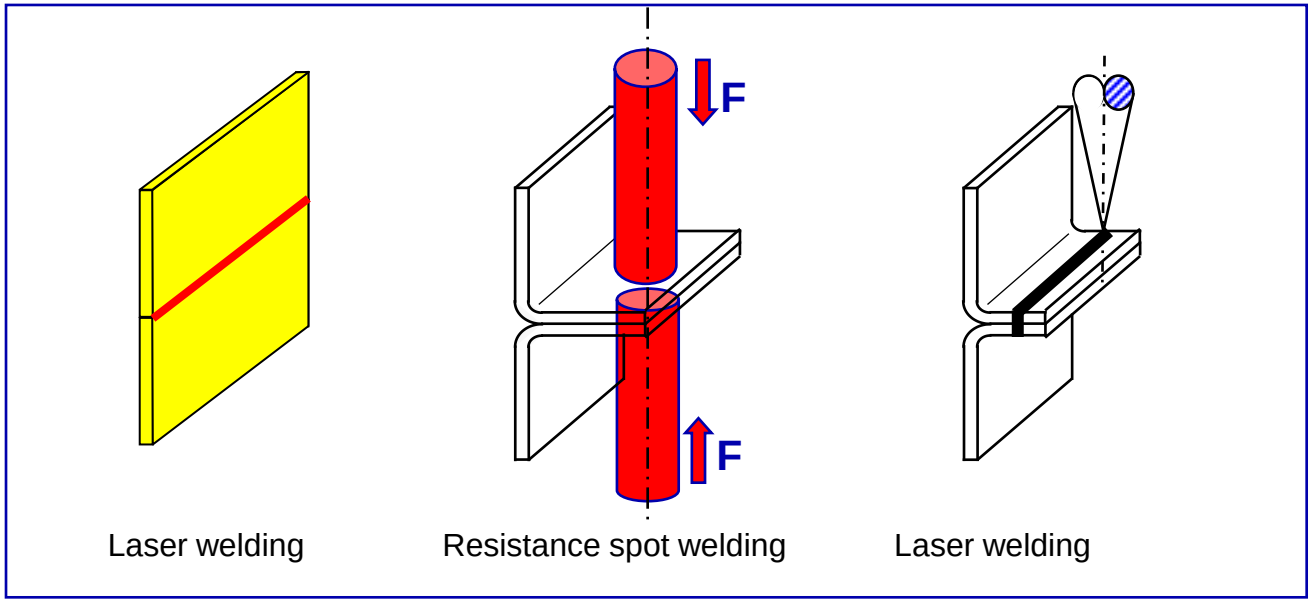
With more than 20 years of experience writing about the automotive industry, best practices and new technologies Gary Vasilash's work has appeared in a variety of publications, ranging from *The Wall Street Journal* to *Lightworks*, a journal of contemporary art. He has made numerous presentations at a variety of venues ranging from the annual meeting of the Association for Manufacturing Technology (AMT) to the Center for Constructive alternatives at Hillsdale College.

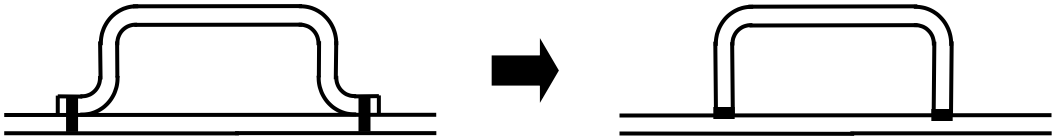


Thank you

TRUMPF Laser Technology Center
Plymouth, MI
(734) 454-7200

Design optimization





- Flange Reduction or Elimination (flangeless design)
- Better Accessibility
- Less Interference

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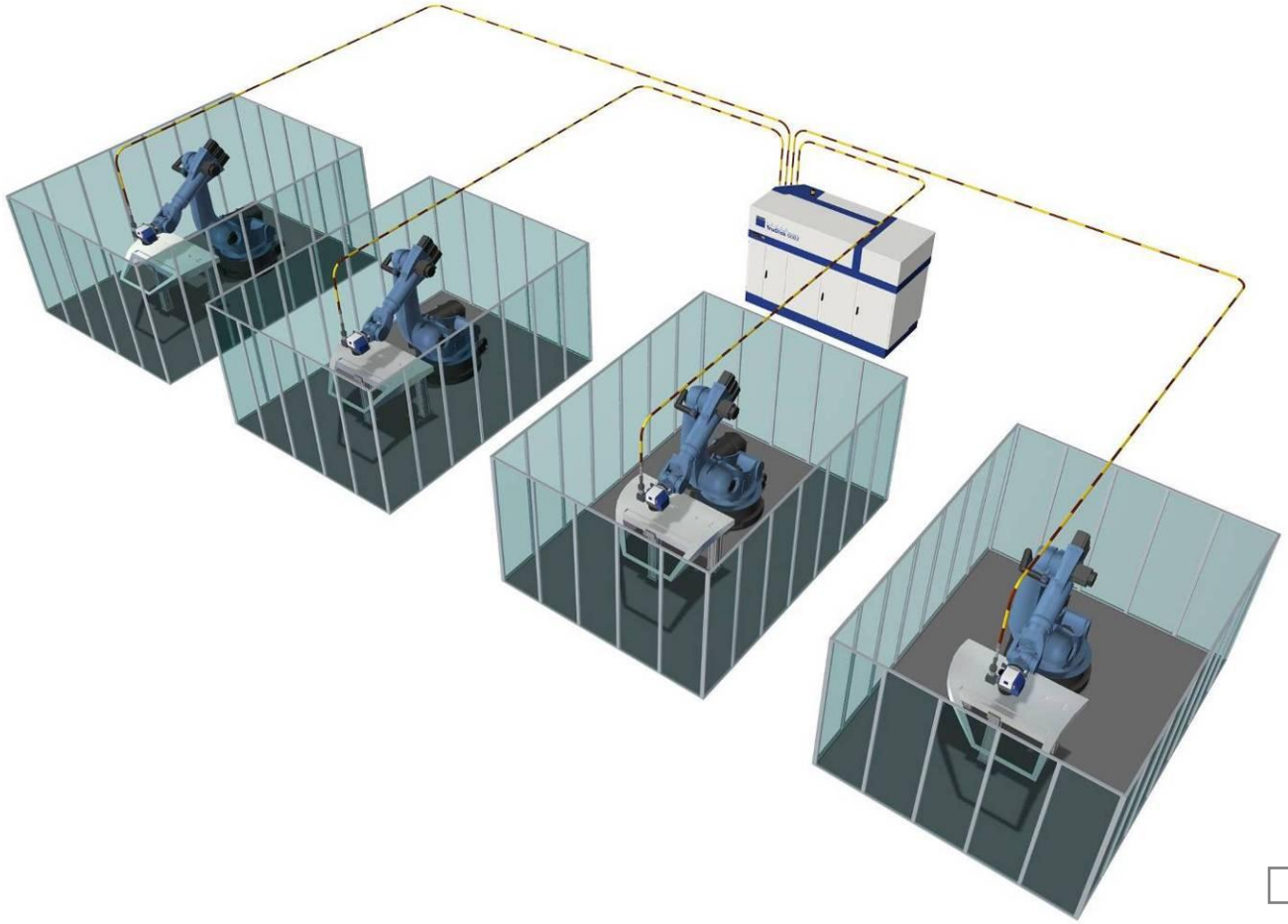
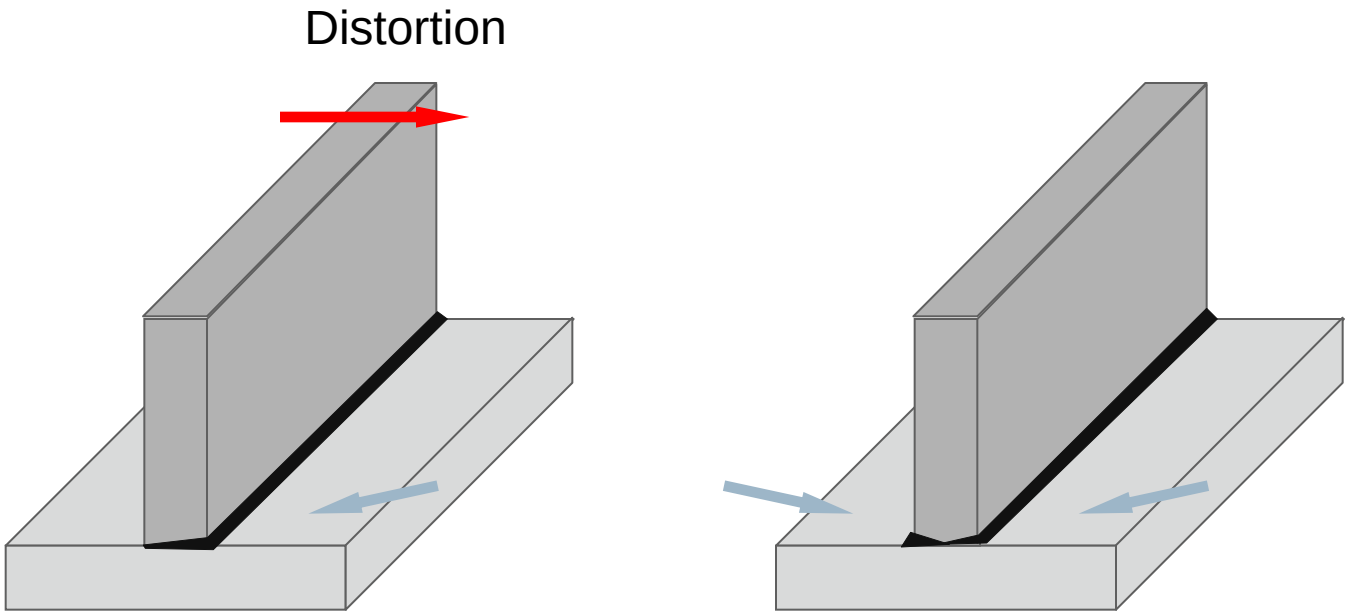
Principle of time sharing

➔ Throughput maximization & manufacturing flexibility



Principle of energy sharing

➔ Reduced distortion



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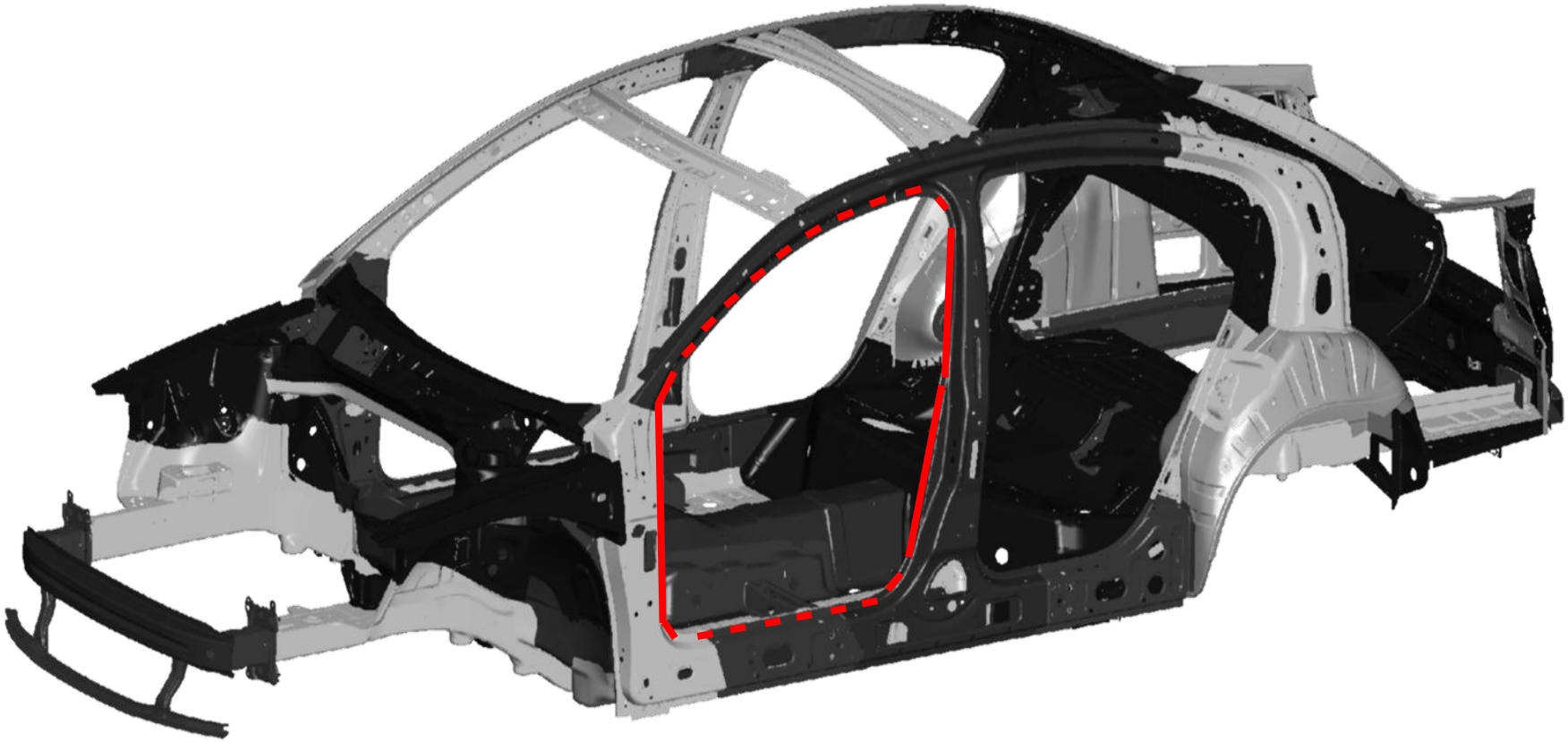
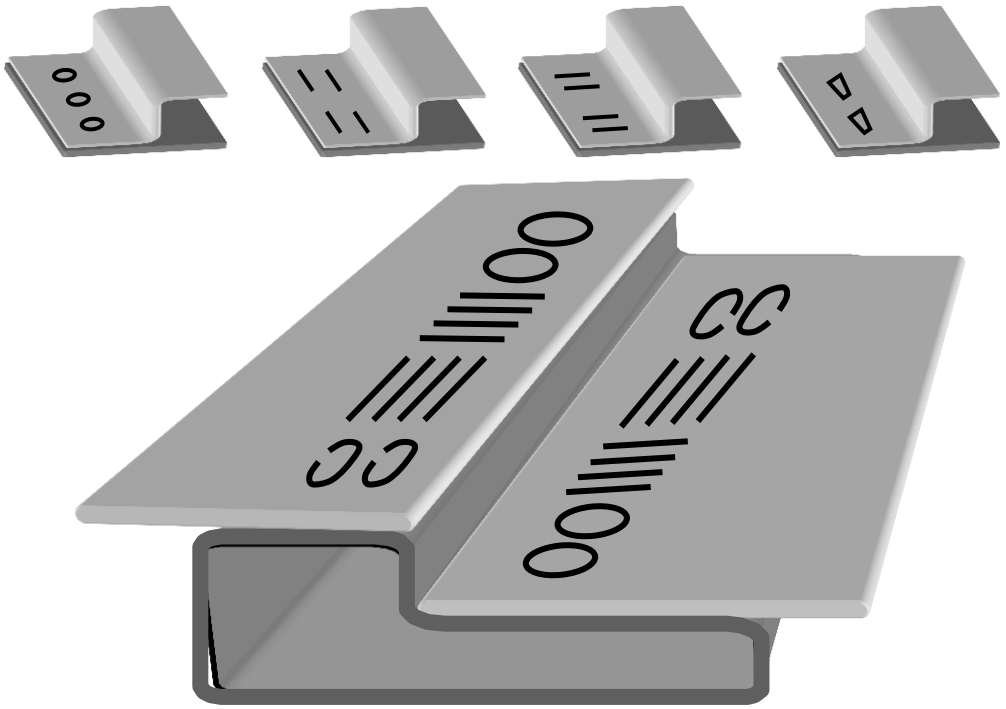
Continuous weld & strength optimization



Advantage: Programmable Weld Shapes

Customized weld patterns for optimal joint strength:

- Distribution
- Orientation
- Shape



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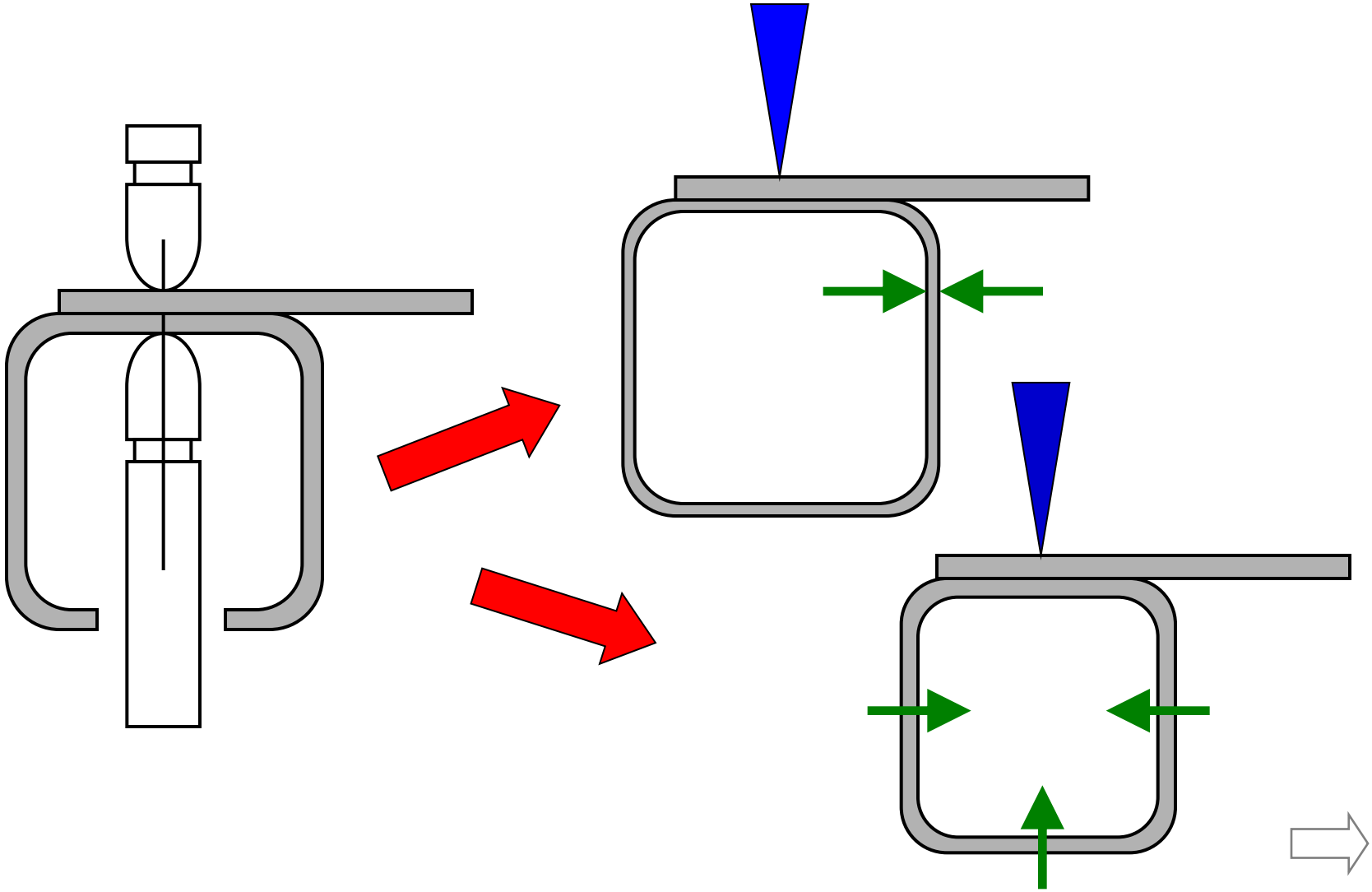
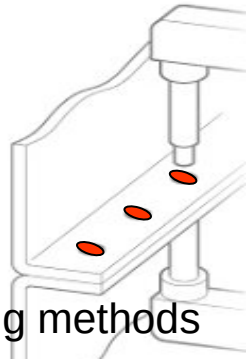
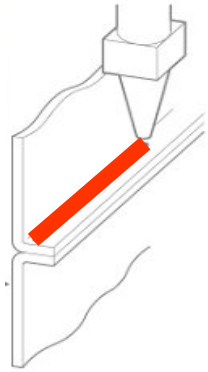
Elimination of lower electrode



Summary: Golf IV / Golf V





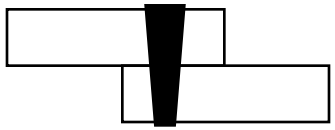
Goals reached:

- Increased process speed (joining)
- Increased productivity
- Increased strength compared to alternative joining methods
- Reduced heat distortion
- Narrow or no flange => Weight reduction
- High flexibility via sharing & back-up of lasers into different work cells
- Reduced floor space

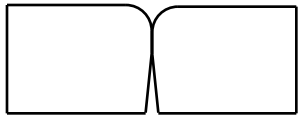
	Golf IV	Golf V	
Floor space Side panel	**2816 m^2**	**1472 m^2**	***(-50%)***
Floor space Underbody	**480 m^2**	**320 m^2**	***(-33%)***
# of Weld spots	**4608**	**1400**	
Length of laser weld	**1.4 m**	**70 m**	

Wide vs. narrow

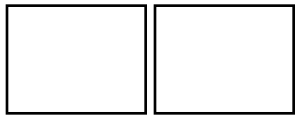
Wide



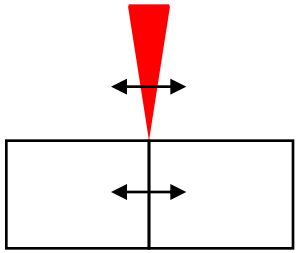
Overlap welding



Poor edges

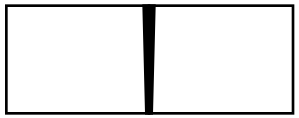


Poor fit-up



Poor beam to seam location tolerance

Narrow

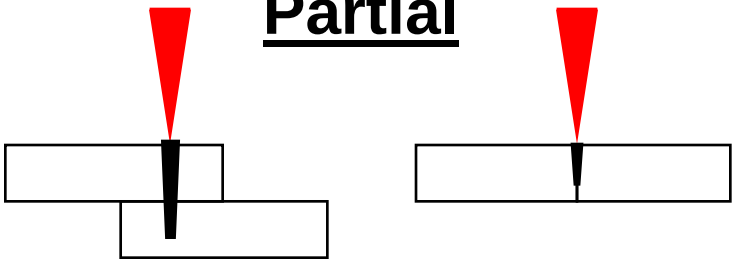


Low distortion, high speed welding w/ minimum power for butt welding configurations

… but, good edges, excellent fit-up, & good beam to seam location tolerance required

Partial penetration vs. full penetration

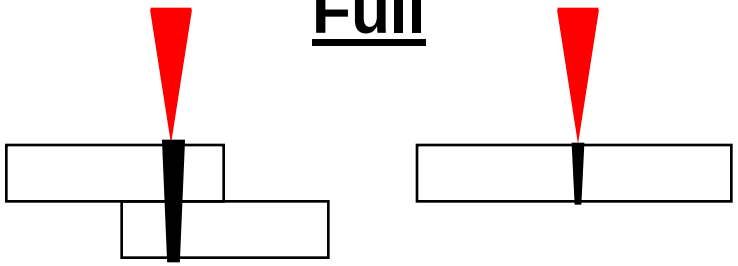
Partial



Compared to through penetration weld …

- Aesthetics on back side of component
- Mating part considerations (fit-up & friction)
- Thickness of lower part (through penetration may be impractical or impossible)
- Protection of heat or spatter sensitive components
- Higher speeds (or lower laser power) w/ less HAZ & distortion

Full



Compared to partial penetration weld …

- Visual weld verification possible
- Larger fusion area for butt weld configuration

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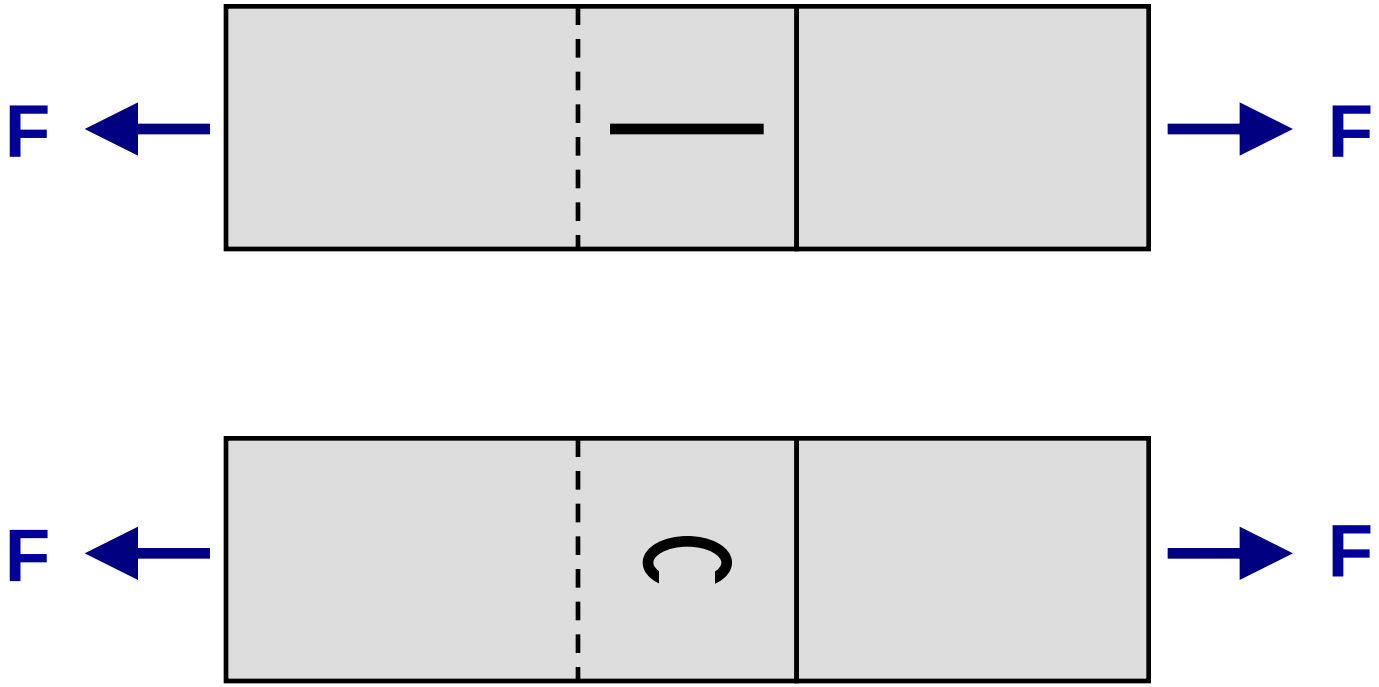
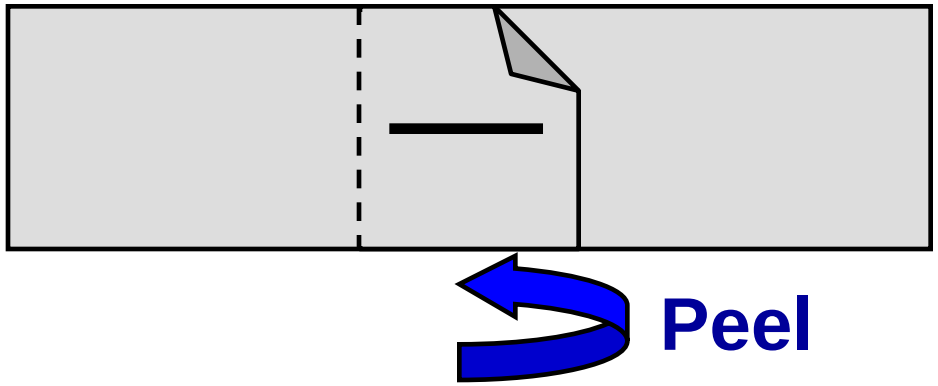
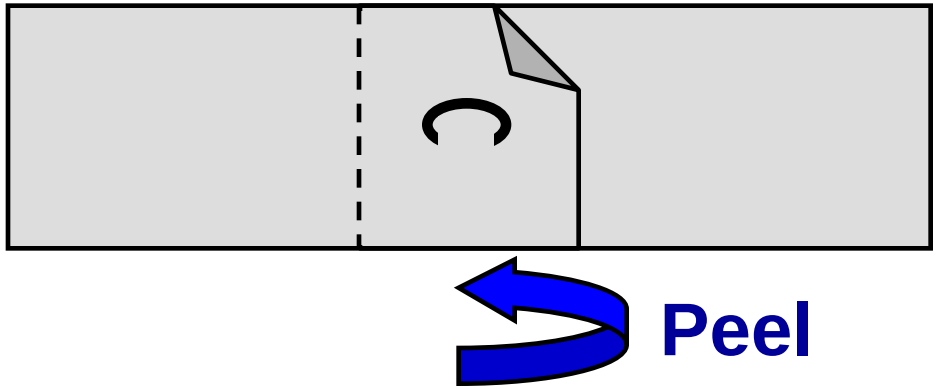
Advantage: Programmable Weld Shapes



Stress = F / A

Advantage: Programmable Weld Shapes





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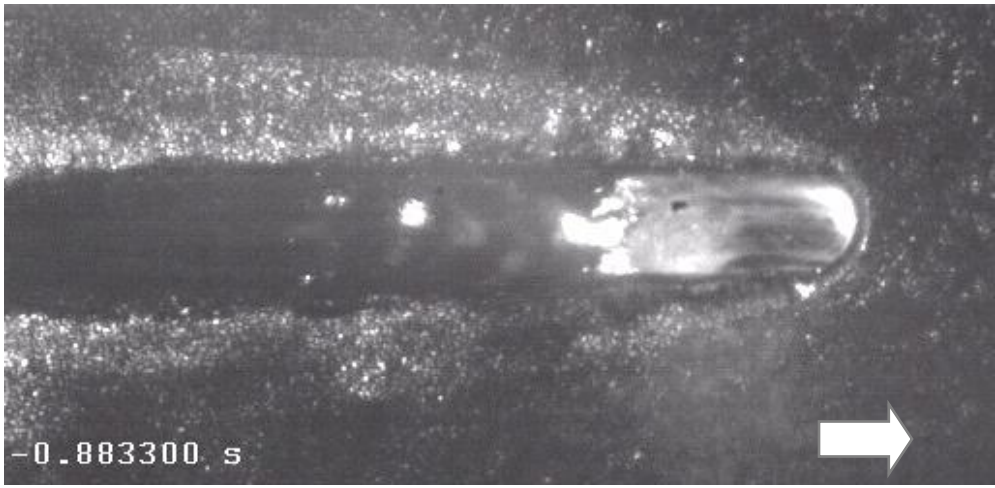
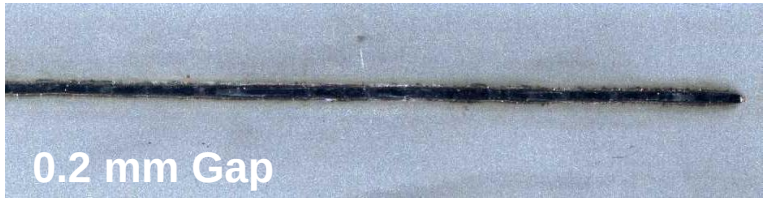
Zn coated material: Gap for out gassing

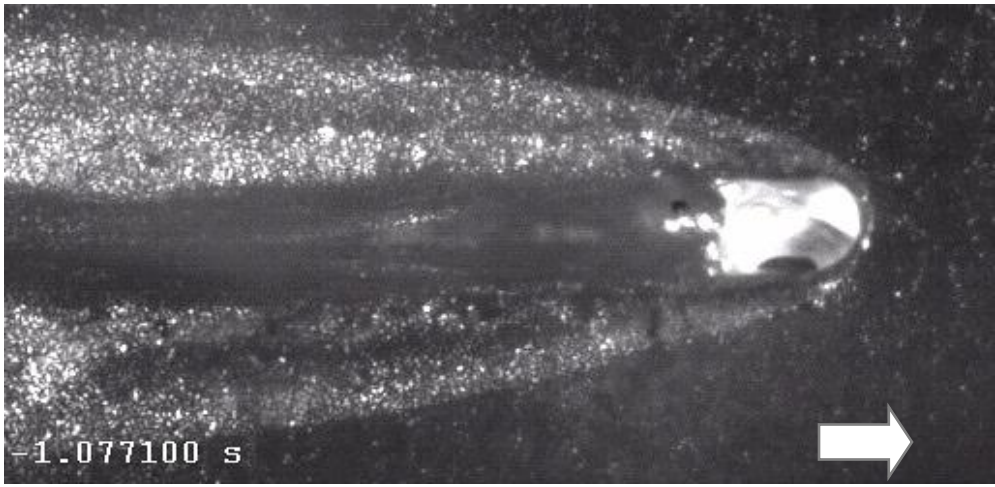
- Evaporating temperature of zinc < melting temperature of steel
- Vapor pressure causes expulsion of molten steel in upper sheet
- Result: Welding seam becomes highly porous and weak



Gap for out gassing: Laser dimpling

- Pre-treatment of one sheet to generate 0.1-0.2mm standoff between sheets
- Use of same laser equipment and optics





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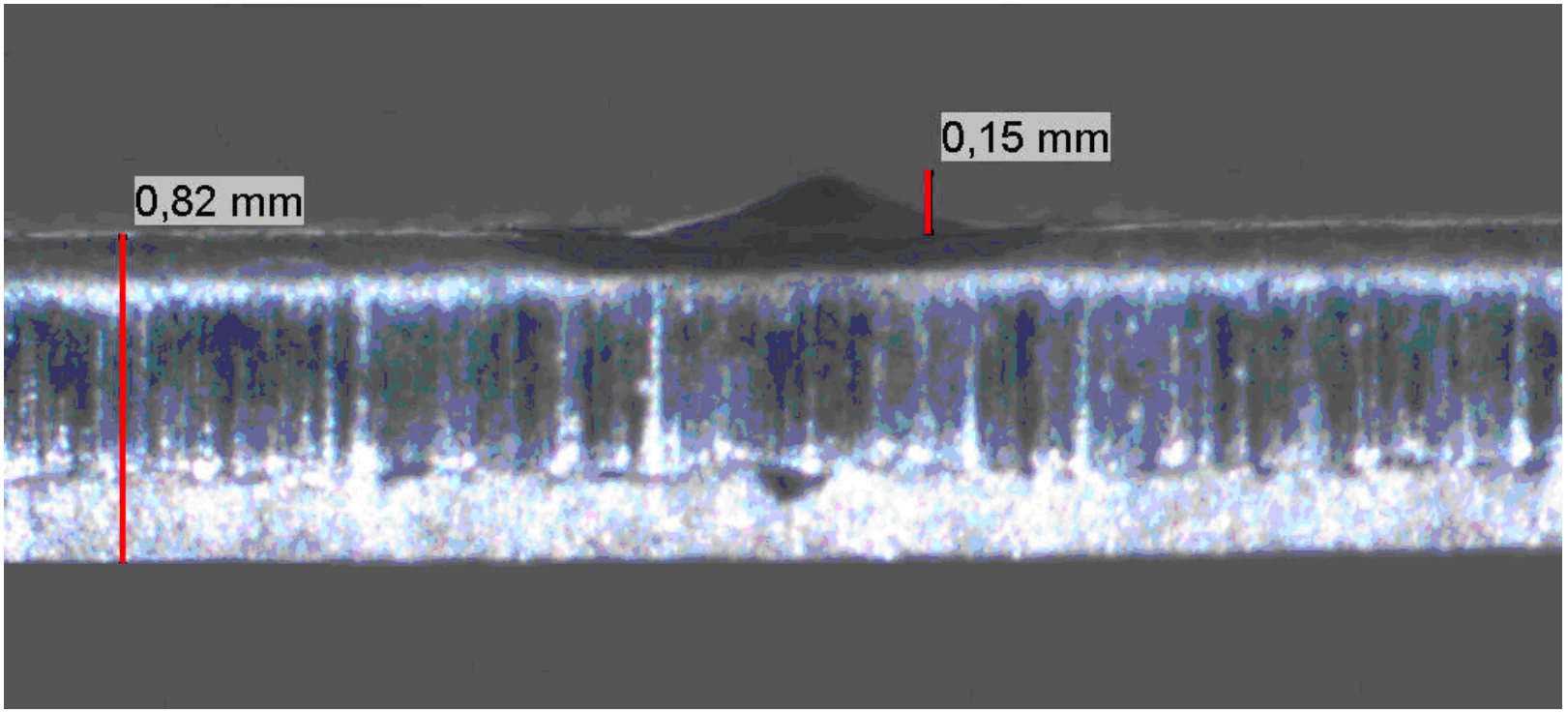
Gap for out gassing: Laser dimpling

- Constant dimple height (depending on zinc layer approximately 0.15 mm)
- Dimple height adjustable via laser parameter



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Gap for out gassing: Laser dimpling

- **Step 1:**

  Laser Dimpling

- **Step 2:**

  Placement of upper sheet

- **Step 3:**

  Scanner Welding