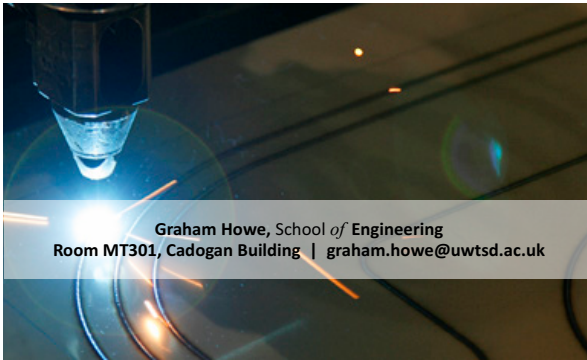


Laser Welding



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What did we look at last time?

- Use of Lasers Cutting.
- Flame Cutting
- Fusion Cutting
- Sublimation Cutting
- Laser Drilling (4 types)
 - Single-shot
 - Percussion Drilling
 - Trepanning
 - Helical Drilling
- Laser Cutting Economics
- Advantages & Dis-advantages

3

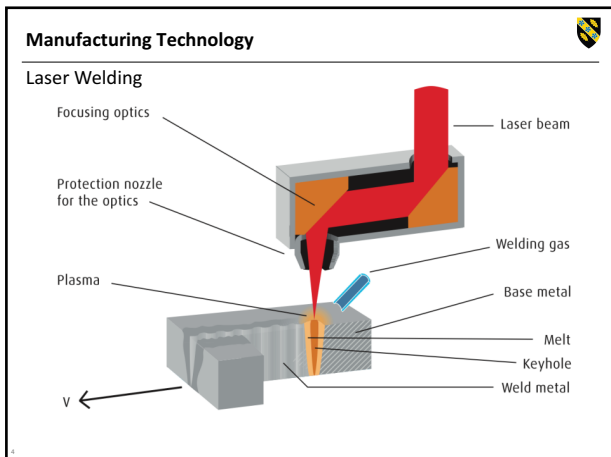
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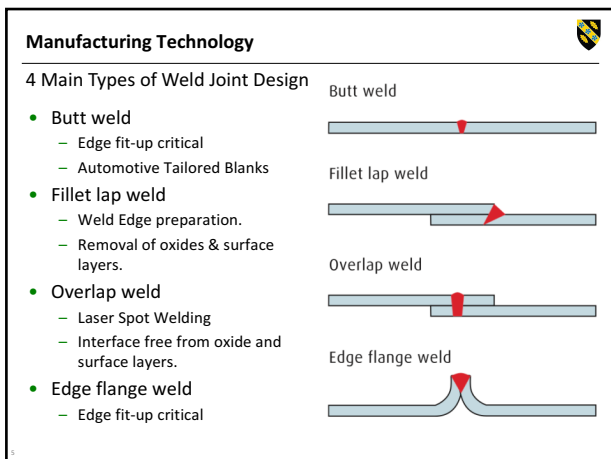


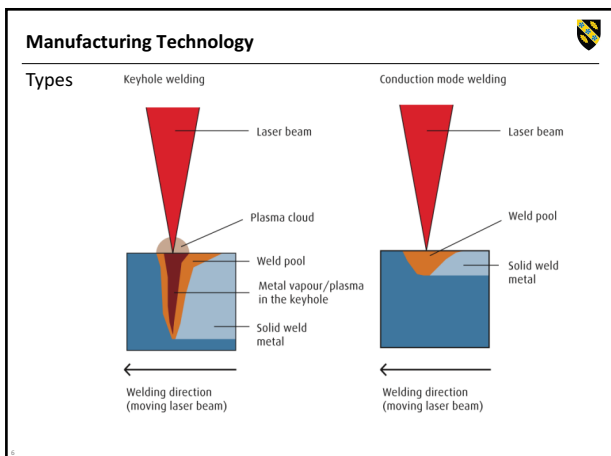
What we will look at today

- Laser Welding
 - Metals
 - Polymers
- Requirements & Processes
- Design Considerations
- Applications and Case Studies

3







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Conduction mode welding

- Typical of low-power lasers (< 500W)
 - Where power density is normally not sufficient to create a keyhole.
 - The resulting weld is characterised by a relatively wide and shallow profile.

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Key-hole Welding

- High-power laser welding is characterised by keyhole welding.
- Laser power density in excess of 105 W/mm² melts and partly vaporises the metal.
- Pressure of the vapour displaces the molten metal so that a cavity is formed. The 'Keyhole'
- Inside the keyhole, the absorption rate of laser radiation increases due to multiple reflections in the keyhole.
- Whenever the beam hits the wall of the keyhole, a part of the beam energy is absorbed by the material.

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Local atmosphere

- The local atmosphere at the weld pool has a decisive effect on the welding result.
- This atmosphere can be used to tune seam properties.
- The atmosphere depends on the species of gas supplied and also on the design and position of the gas nozzle.
- The welding gas is directed to the workpiece through a nozzle system in order to protect molten and heated metal from the atmosphere.
- The welding gas can be made to play an active role in the welding process, such as increasing the welding speed and improving the mechanical properties of the joint.
- Setting up the nozzle and gas flow is critical for the weld quality.

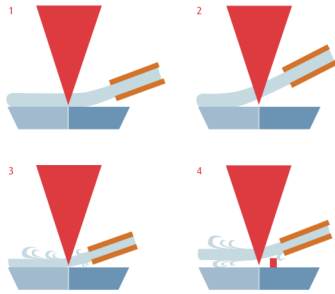
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Nozzle Set-up & Gas Flow

1. Correct nozzle positioning. Result: even shielding of complete seam
2. Wrong nozzle positioning. Result: improper shielding of seam and detrimental air injection
3. Nozzle too small, gas flow too large. Result: improper shielding of seam and detrimental air injection
4. Barrier between nozzle and seam (spatter etc.). Result: improper shielding of seam and detrimental air injection



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Applications

- We've already mentioned that the atmosphere in which the weld is being made is critical for applications such as tailored blanks.
- Therefore the gas used can considerably impact this.
- The formability of laser-welded butt joints is frequently tested with a stretch-draw test.
- In this test, a punch stretches the seam area until it cracks.
- The distance the punch travels is then compared to that of the base material.
- The next slide shows results for different pure welding gases and one special mixture on butt-welded 0.8mm steel sheets.

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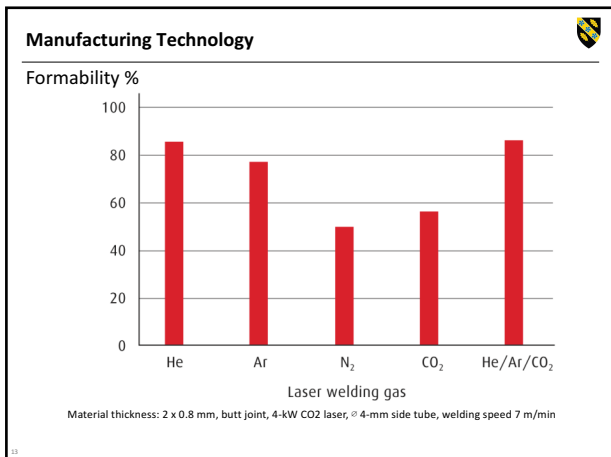
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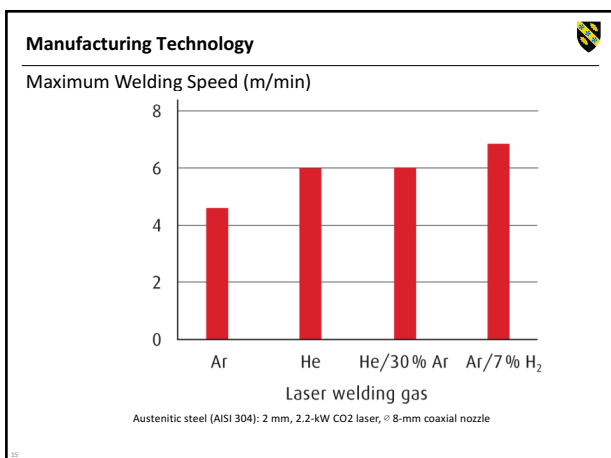
Tailored Blanks



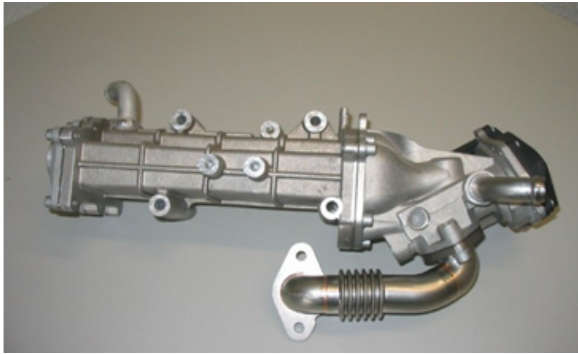
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- Manufacturing Technology**
- Formability
- The formability achieved with nitrogen or carbon dioxide is evidently inferior to that achieved with helium or argon, due to the presence of pores in the joint.
 - If air is applied as a welding gas, the result is just as bad: the nitrogen content is absorbed in the molten pool and then trapped in pores.
 - Helium is characterised by a very large tolerance window for variations in the positioning of side tubes.
 - Helium is well suited for tailored blank welding.
 - Helium is a finite natural source, and its availability is limited.
 - Alternatives for pure helium are increasingly being demanded.
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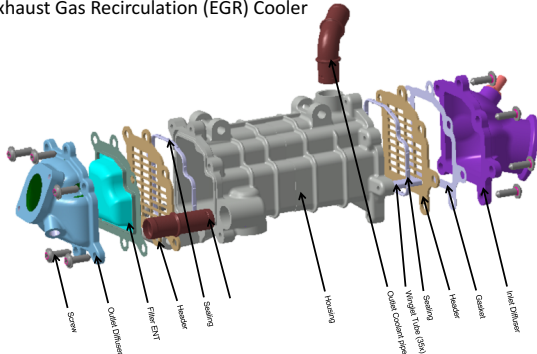
Case Study – EGR Cooler



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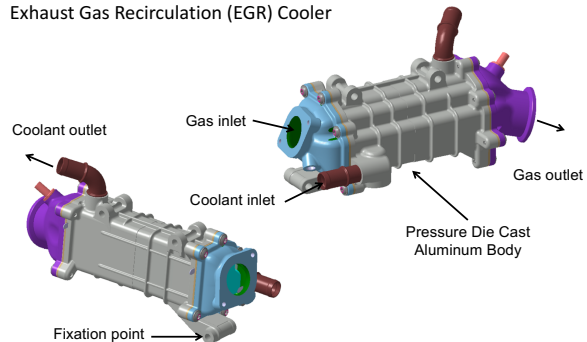
Exhaust Gas Recirculation (EGR) Cooler



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Exhaust Gas Recirculation (EGR) Cooler



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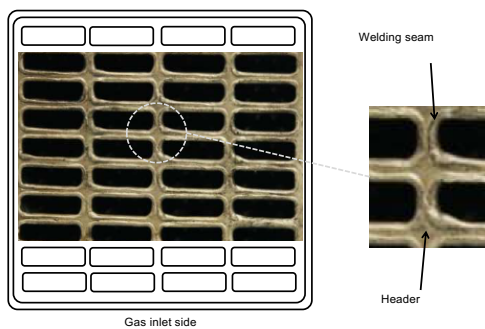


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Laser Welding Header Joint



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Welding of Stainless Steel

- The same considerations applying to mild steels, such as plasma formation and nozzle arrangement, also apply to welding gases for stainless steels.
- The metallurgical impact of welding gases on the weld metal, however, differs from that on mild steels.
- This is due to the fact that stainless steels contain considerably larger amounts of alloying elements.
- Where stainless steel is used in highly corrosive environments or at elevated temperatures likely to cause oxidation, then the choice of brazing alloy and technique is important.

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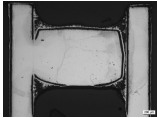


Laser Welding

- Laser welded stainless steel EGR coolers show high corrosion resistance.
- Brazed (Standard Nickel Filler Metals) stainless steel EGR coolers show reduced corrosion resistance or brittle phase risk

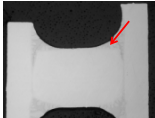
Brazed (Standard Nickel Filler Metals) AISI 304 Cooler

(Boron alloyed standard filler)
Significant selective corrosion



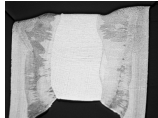
(Boron free standard filler)

No corrosion, but crack
due to brittle phases



Laser welded AISI 304 Cooler

No corrosion



Cross sections of tube /header-joints after 1000h „dip and dry“ – test (pH 1.9; chloride: 200 mg/l)

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Plastic Laser Welding



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Plastic Laser Welding

- Laser plastic welding is a method of bonding two or more thermoplastic components together.
- Many methods for joining thermoplastics, laser plastic welding has a few clear advantages;
 - Higher joining quality
 - Minimal resulting flash
 - Higher quality controls
 - Less stress to the component
 - Weld complex and intricate shapes

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Plastic Laser Welding

- Energy is applied to the materials, softening them (lowering their viscoelasticity) at the joint interface and promoting this diffusion.
- Although, "laser plastic welding" is the term most often used to describe this technology
- "Transmission welding" is a much more descriptive term and more accurately portrays the process.
- The process relies on passing laser energy through an upper transmissive layer down to the surface of the lower layer where the energy is absorbed. The resulting heat melts the plastics and creates a weld seam.
- First used in production environments in the mid-1980's for welding automotive components.

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Plastic Laser Welding



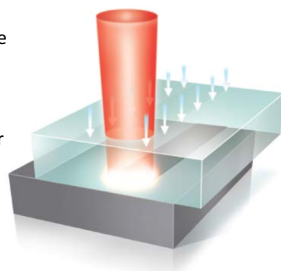
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Plastic Laser Welding

- The process relies on passing laser energy through an upper transmissive layer down to the surface of the lower layer where the energy is absorbed. The resulting heat melts the plastics and creates a weld seam.
- Need to use an absorbent lower part
- Posing a limitation for applications where colour and appearance are important.



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Requirements for laser welding

- There are four important requirements for the laser welding process to occur;
 - Laser Transparent Top Layer
 - Laser Absorbing Bottom Layer
 - Material compatibility
 - Contact
- Most thermoplastic resins are laser transparent in their natural state; without the use of additives.
- Note that “laser transparent” should not be mistaken for “optically transparent”

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Influences to laser transmission

- What do we know from polymer processing that could help in understanding what could influence laser transmission?
- There are several influences on the laser transmission including but not limited to;
 - Additives (UV stabilizers, colorants, heat stabilizers)
 - Fillers (glass fiber, carbon fiber, blowing agents)
 - Thickness
- Only a percentage of the laser energy needs to transmit through the top layer for the welding process to occur, the rest of the energy will be absorbed, reflected, and scattered before it reaches the weld joint.

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Influences to laser transmission

- The laser absorbent layer is responsible for turning the remaining laser energy, once it has passed through the transparent top layer, into heat at the surface of the absorbing layer.
- To make a plastic absorbent, the typical additive used is carbon black at an amount usually between 0.2 and 0.4% by volume.
- Ideally, the transmission rate of the absorbing partner should read absolute zero. In this way all of the energy would stay at the surface of the absorptive layer where it is required to create a weld.
- It is possible to weld two pieces of clear plastic to one another with the use of additives.

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Combination of Polymers

- It is safe to note that it is possible to weld the most common thermoplastics, such as: PA 6, PA 66, POM, PBT, PC, ABS, PP and PE in their pure form.
- Chemically compatible and have similar melting temperatures.

	PS	PS imp. res.	SAN	ABS	PA	PC	PMMA	POM	PVC	PP	PE-LD	PE-HD	PBT	PET
PS														
PS impact resistant														
SAN														
ABS														
PA														
PC														
PMMA														
POM														
PVC														
PP														
PE-LD														
PE-HD														
PBT														
PET														

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5 Processes of Laser Plastic Welding

- There are four main process types of laser plastic welding;
 - Contour
 - Simultaneous
 - Staking (The laser staking method is actually a form of simultaneous welding, but warrants separate mention.)
 - Quasi-simultaneous
 - Hybrid

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5 Processes of Laser Plastic Welding

Contour Welding

- In this process the laser beam, focused into a point, moves relative to the component making a single pass over the joint.
- The width of the joint line can vary from a few tenths of a millimeter to several millimeters.
- Contour welding is especially suited for large parts or three dimensional parts and radial welding.
- Pros: very flexible, excellent process quality monitoring
- Cons: slower cycle times compared to other laser process methods

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5 Processes of Laser Plastic Welding

Simultaneous Welding

- Simultaneous welding is where the entire weld seam is heated at the same time.
- Using specially designed fiber-optics, the laser energy is formed into the pattern of the weld seam and projected onto the entire seam simultaneously.
- There is no relative movement of the laser or the device. This method is ideal for high volume runs that require ultra-low cycle times.
- Pros: fast cycle times
- Cons: expensive as multiple laser sources are typically required, small working area (50mm x 50mm)

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5 Processes of Laser Plastic Welding

Quasi-simultaneous Welding

- Quasi-simultaneous welding is a combination of contour and simultaneous welding.
- A single, focused laser beam is guided by a mirror, tracing the weld path multiple times at very high speeds.
- In this way the entire joint line is effectively heated simultaneously.
- Pros: fast cycle times, excellent process monitoring, flexible
- Cons: For mainly two dimensional parts

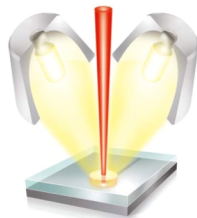
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Hybrid Welding

- Hybrid welding uses high-powered halogen lamp energy to assist the laser in the welding process.
- The halogen lamps pre-heat the plastic around the joint line, in effect requiring less laser energy to melt the plastic.
- The benefits of pre-heating are faster cycle times as well as reduced part stress from temperature shock.
- The halogen light is polychromatic so it will be absorbed by, and heat, both the upper and lower layers.



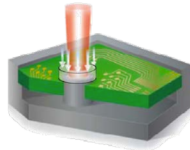
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Text

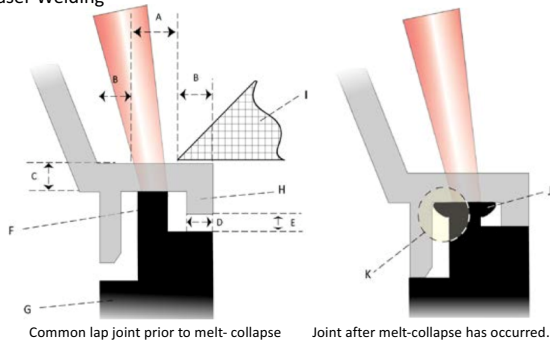
- Laser staking is a form of simultaneous welding. Laser staking is essentially riveting using laser plastic welding technology.
- Commonly used for fastening circuit boards to plastic housings, small plastic discs are positioned over a prong which projects through a mounting hole in the printed circuit board.
- Laser energy is applied to the interface between the disc and the injection molded prong.
- As pressure is applied the prong and disc fuse together to hold the circuit board in place.



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Laser Welding



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Melt Collapse

- Mechanical limiting stops are molded into one or both of the joining parts.
 - These will ensure a consistent melt-collapse as well.
 - These are not commonly recommended as they may lead to internal stress after the parts cool.
- Weld flash (or melt blow-out) results from expanded, un-fused material that leaks from the weld seam.
- Melt covers can keep flash from escaping or entering the component where it is not wanted.
- A melt blow-out reservoir is essentially a small gap designed along the weld seam with adequate room to collect the weld flash.

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Clamping Pressure

- Clamping pressure is necessary to ensure contact of the joining partners so conduction of energy from the absorptive partner to the transmissive partner can take place.
- As the polymers are excited by the laser energy, they will expand.
- If left un-clamped there will be no containment of the expanding polymers and fusion will not occur.
- Each application will have customized clamp tooling.
- Clamping pressure typically ranges from 2-4 Mpa.
- This pressure will be supported by lower component clamp tooling, often called nests or workpiece holders.

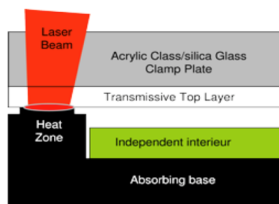
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Transparent clamp tooling

- Transparent clamp tooling – a flat, clear piece of glass or acrylic which applies pressure to the entire top layer.
- Pros: simplest method, good for prototyping and small runs
- Cons: component surface must be entirely flat, tooling is easily contaminated by dust or particles which can result in burning of the component.



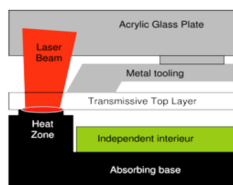
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Metal Clamp Tooling

- Metal tooling is created specific to the joint pattern, flanking the seam on each side. The tooling is attached to a transparent glass or acrylic piece where force is applied through it to the metal tooling.
- Pros: component can have 3D surface attributes, better clamping pressure at seam, metal tooling will last longer
- Cons: contamination of acrylic/glass is still possible, more complicated tooling



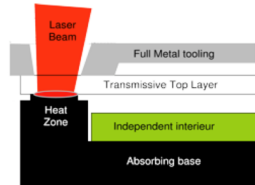
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Dual clamping device (all metal)

- The dual clamping device provides clamping on both sides of the weld seam and requires no acrylic/glass piece
- Pros: component can have 3D surface attributes, best clamping pressure at seam, metal tooling will last longer, no acrylic/glass means no contamination.
- Cons: most complicated tooling design



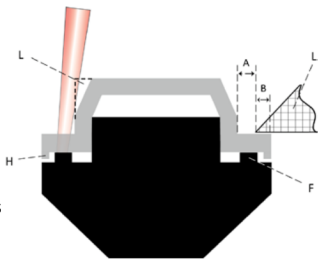
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Fixed-part/moving laser

- In this method clamping pressure is applied, top-down, using clamp tooling from the side of the joint
- This method is not ideal, because clamping pressure can not be produced on both sides of the weld seam, which is preferred, as it is blocked by the top layer's side wall.



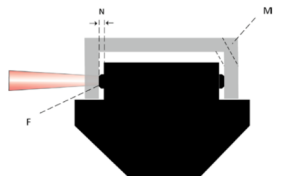
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Fixed Laser/Moving Part (preferred)

- In this method the stationary laser beam enters from the side, while the part is rotated.
- Clamping pressure is not required, because the contact and pressure requirements are solved by "tapering" the two pieces so the transmissive layer is larger in diameter than the transparent layer.
- Like a sleeve, the transparent piece is forced onto the lower absorbing piece, the difference in size causes outward pressure.
- Also, notice that tapered side-walls are not required



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