LASER WELDING
LASER

- Light Amplification by Stimulated Emission of Radiation

Active Laser Media (the most common for industrial manufacturing)

- Nd:YAG (Rod Laser)
  - Neodymium: Yttrium Aluminum Garnet
- Yb:YAG (Disk Laser)
  - Ytterbium: Yttrium Aluminum Garnet
- CO₂ (Gas Laser)
Principle of LASER

Resonator

Laser Active Medium

End Mirror R=100%

Output Mirror R<100%

Pump Source

Pump Sources:
- High Voltage
- Flashlamp
- Diode

Laser Active Medium:
- Gas
- Rod
- Fiber
- Disk

Wavelength:
- CO₂ 10.6 µm
- Nd:YAG 1.064 µm
- Yb:YAG 1.030 µm
Fiber Optics

Fiber Multiplexer

Resonator

Cavity

Pilotlaser

Fiber Optic Processing Head

Workpiece

Scanning Head

Fiber
## Principle of Laser Processing

<table>
<thead>
<tr>
<th><strong>Laser beam</strong></th>
<th><strong>Wavelength (μm)</strong></th>
<th><strong>Power (W)</strong></th>
<th><strong>Irradiance (W/cm²)</strong></th>
<th><strong>Energy (J)</strong></th>
<th><strong>Interaction time/ pulse duration (ms)</strong></th>
<th><strong>Beam quality (mm mrad)</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Optics</strong></td>
<td><strong>Focussing length/distance to surface</strong></td>
<td><strong>Fiber core diameter</strong></td>
<td><strong>Beam shaping</strong></td>
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<tr>
<td><strong>Gas</strong></td>
<td><strong>Type/mixture/purity</strong></td>
<td><strong>Velocity/distance nozzle - surface</strong></td>
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<tr>
<td><strong>Material</strong></td>
<td><strong>Surface</strong></td>
<td><strong>bulk properties</strong></td>
<td><strong>Absorption</strong></td>
<td><strong>material type</strong></td>
<td><strong>Roughness</strong></td>
<td><strong>thickness</strong></td>
</tr>
</tbody>
</table>
Heat conduction welding

Heating of the workpiece for temperatures above the melting temperature without vaporizing, power density from $10^4 - 10^5$ W/cm$^2$

Welding depth depends on heat conduction

Characteristics
- Low welding depth
- Small aspect ratio
- Low coupling efficiency

Applications
Laser welding of thin workpieces like foils, wires, thin tubes, etc.
Deep welding

Heating of the workpiece above the evaporating temperature and creation of a keyhole because of the ablation pressure of the flowing metal vapor, power density of $10^5 - 10^6 \text{ W/cm}^2$

Characteristics
- High welding depth
- Large aspect ratio
- High coupling efficiency

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Advantages of 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
  - continuous weld possible

- **Ability to weld in areas difficult to reach with other techniques**
  - non-contact, narrow access, single sided process

- **Easily automated with accurately located welds**
  - consistent weld penetration / weld geometry / weld quality
  - ability to integrate into existing equipment / production lines
Advantages of laser welding

- **Flexibility ...**
  > beam manipulation (beam switching and sharing)
  > variety of part & weld geometries and materials
  > ease of back-up (especially YAG)

- **Often faster than other techniques ...**
  > high power density weld process
  > high laser uptime (>98%)

- **Cost savings ...**
  > high productivity >> faster cycle time = less stations
  > reduction of scrap and re-work
  > reduction of manual labor
  > reduction of component material and weight
  > can eliminate secondary processes
Laser Welding Aneurysm Clip

(Alternating) Spot welding with scanner optics

Material: Titanium

Laser parameters:
- Average power $P_{av} = 60$ W

Benefit:
- Distortion-free weld connections
- Optimal clip guidance
- Perfect shape and smooth surface
- Best possible biocompatibility

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Laser Welding Ophthalmic Device

40um wide weld on 50um thick wires
for ophthalmic device

Material: Stainless Steel
Energy: 50 mJ/pulse
Speed: 8 mm/min

Slide provided by GSI Group, www.gsiglasers.com
Material: Cu
Comments: Special Pulse Form

Slide Provided by LASAG / www.lasag.com
Laser Welding Retrieval Basket

**Materials:** Stainless + Nitinol
- Ø 650 µm (Stainless jacket)
- Ø 400 µm (Stainless wire)
- Ø 150 µm (Nitinol wire)

**Laser pulse parameters:**
- \( P_p = 700 \, \text{W at} \, \tau = 4 \, \text{ms} \)

**Benefits:**
- Low heat input
- High stability of all joints (up to 70 N test pressure)
Vascular Clamps

Material: Stainless Steel
Energy: ~ 2 Joules
Single Pulse

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Laser Welding
Heat Sinks on Lead Frames

**Material:** CuFe2P
**Parameters:** 20Hz, 3 ms, 2 Joules
**Spot Size:** 300µm (0.011”)
**Comments:** Special Pulse Form

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Laser Welding Pacemakers

**Material:** Titanium Grade 2

**Feed Rate:** 1.2 m/min (47.2 in./min.)

**Comments:** Pulse form, modulated, low HAZ

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Marker Bands- spot welded over lead

**Material:** Platinum

**Energy:** ~ 0.5 Joules

Single Spot

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Laser Welding
Markers on Stents

Material: Nitinol and Tantalum
Pulse Energy: 0.065 Joules
Feed Rate: 100 mm/min (4 in./min.)
Comments: Pulse form, modulated, trailing edge
Laser Welding Endoscope

Two smaller tubes are welded simultaneously on one big tube

**Material:** Stainless 1.4301

**Laser parameters:**
- Average power $P_{av} = 120$ W
- Speed 150 mm/min

**Benefit:**
- Virtually distortion-free welds
- Free motion of the guide wires
Laser Welding Endoscopes

Material: Nitinol and Stainless Steel
Laser Parameters: 20Hz / 2 ms / 1.6 Joules
Spot Size: 400um (0.015“)
Cycle Time: 6 sec.

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Laser Welding Pacemaker Battery

**Material:** Stainless Steel

**Energy:**
- ~0.3 Joule (lid)
- ~0.25 Joule (feed-through)

**Speed:**
- ~75 in/min (lid)
- ~10 in/min (feed-through)
Laser Welding
Radioactive Prostate Seeds

**Material:** Titanium

**Wall Thickness:** 0.04 mm (0.0015“)

**Tube Diameter:** 0.8 mm (0.0315“)

**Comments:** Hermetic Sealed

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Laser Welding
Radioactive Prostate Seeds

Material: Titanium
Wall Thickness: 0.1 mm (0.004“)
Tube Diameter: 0.75 mm (0.0315“)
Comments: Hermetic Sealed
Keys to success

- Design components for laser welding
  (flange widths, gauge thicknesses, single sided access)
- Maximize laser “beam on” time
  (i.e. time sharing of beam to multiple stations)
- Good part fit-up via part tolerances & fixturing
  Butt weld: edge preparation, gap <10% of $t_{\text{min}}$, seam location
  Overlap weld: gap < 10% of $t_{\text{min}}$
- Parts must be clean & dry for optimum results
  (no dirt, rust, grease, heavy oils, sand residue, paint/primer, adhesives, sealers, water, solvent)
- Assign laser welding champion at using plant
  (engineer, attitude/aptitude, teachable, can teach others)
- Early involvement of production personnel
  (ownership, design for service & maintenance)
- Commitment to training & spare parts
  (ownership, design for service & maintenance)
- Partner with suppliers that have proven expertise, longevity & reputation