LASER WELDING

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Laser Fundamentals

LASER

- **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation

Active Laser Media (the most common for industrial manufacturing)

- **Nd:YAG (Rod Laser)**
  - **N**eo**d**ymium: **Y**ttrium **A**luminum **G**arnet
- **Yb:YAG (Disk Laser)**
  - **Y**tter**b**ium: **Y**ttrium **A**luminum **G**arnet
- **CO_2 (Gas Laser)**

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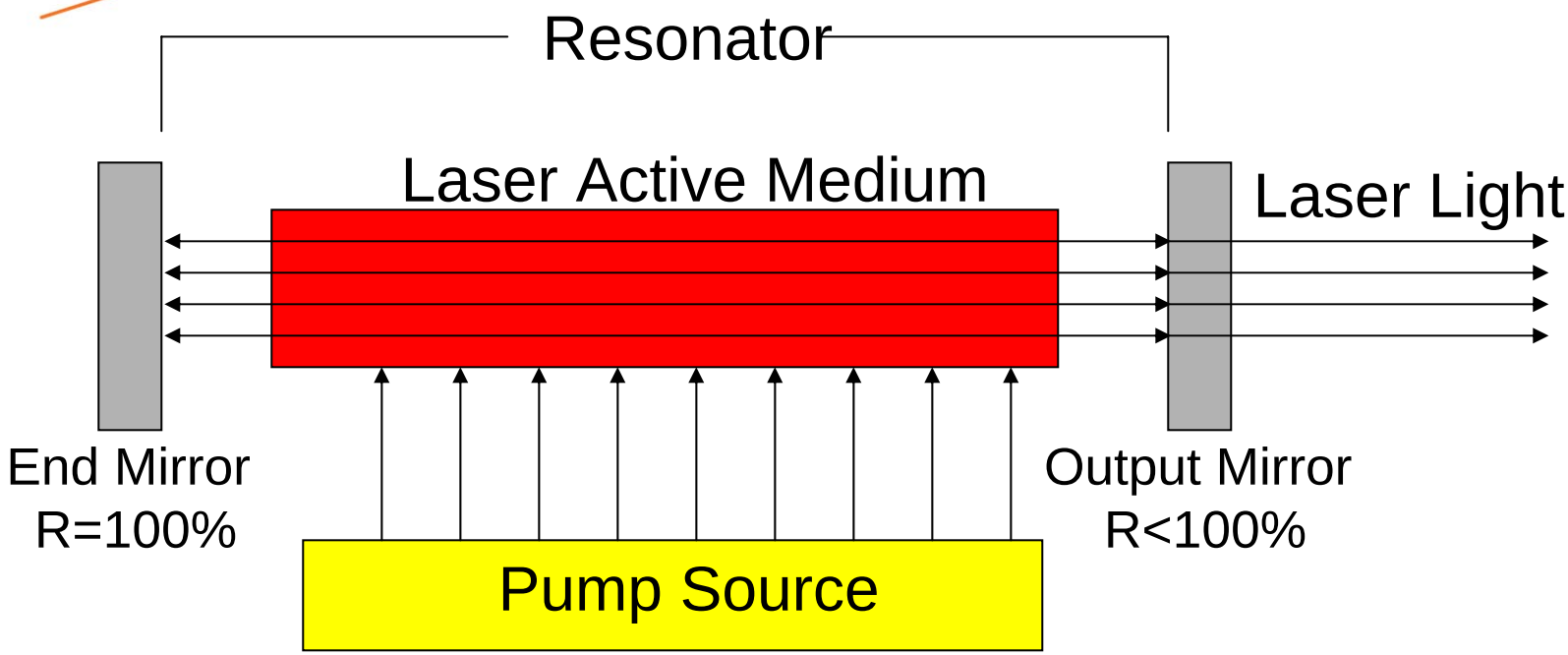
Principle of LASER

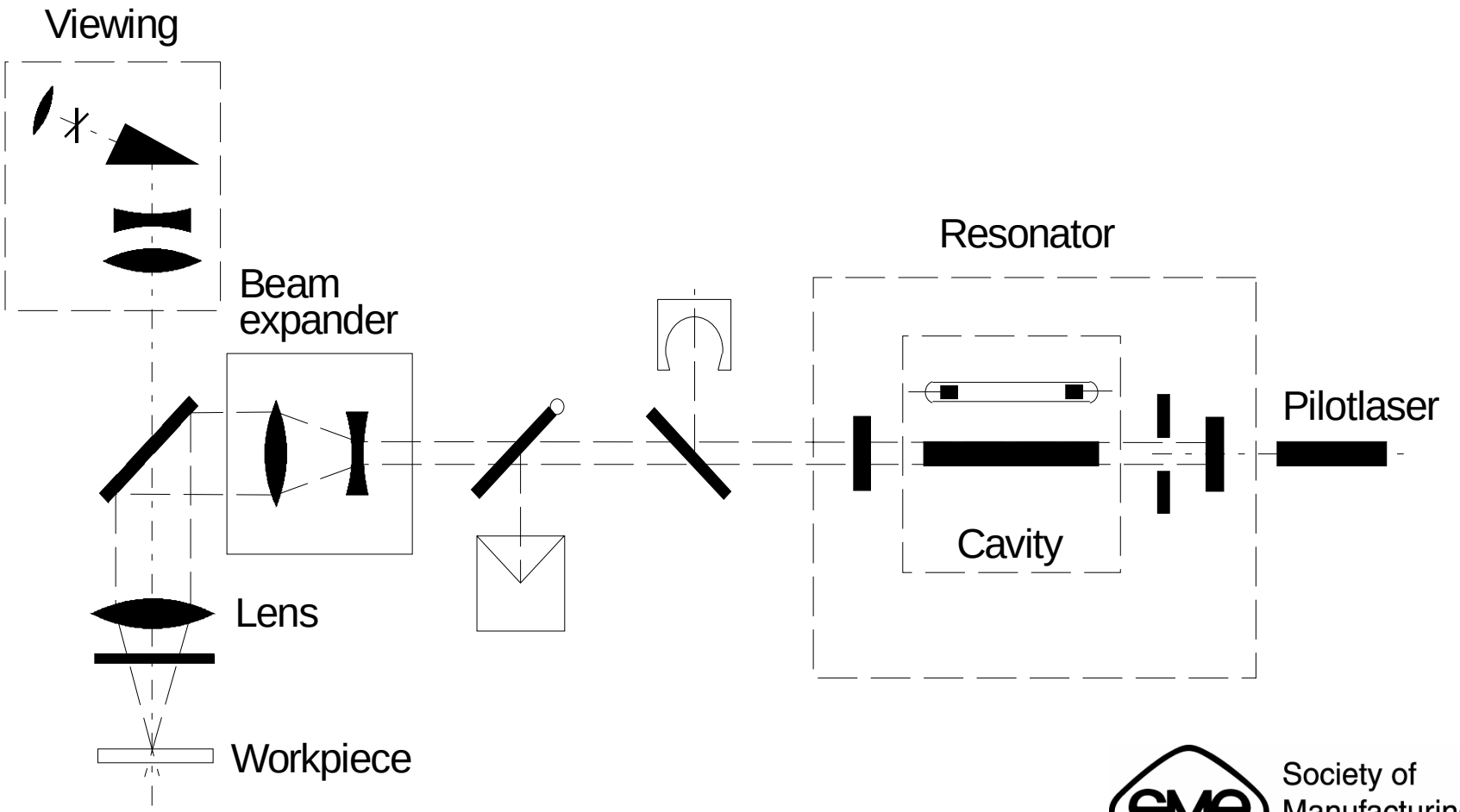


Pump Sources:
High Voltage
Flashlamp
Diode

Laser Active Medium:
Gas
Rod
Fiber
Disk

Wavelength:
CO_2 10.6 µm
Nd:YAG 1.064 µm
Yb:YAG 1.030 µm

Conventional Optics



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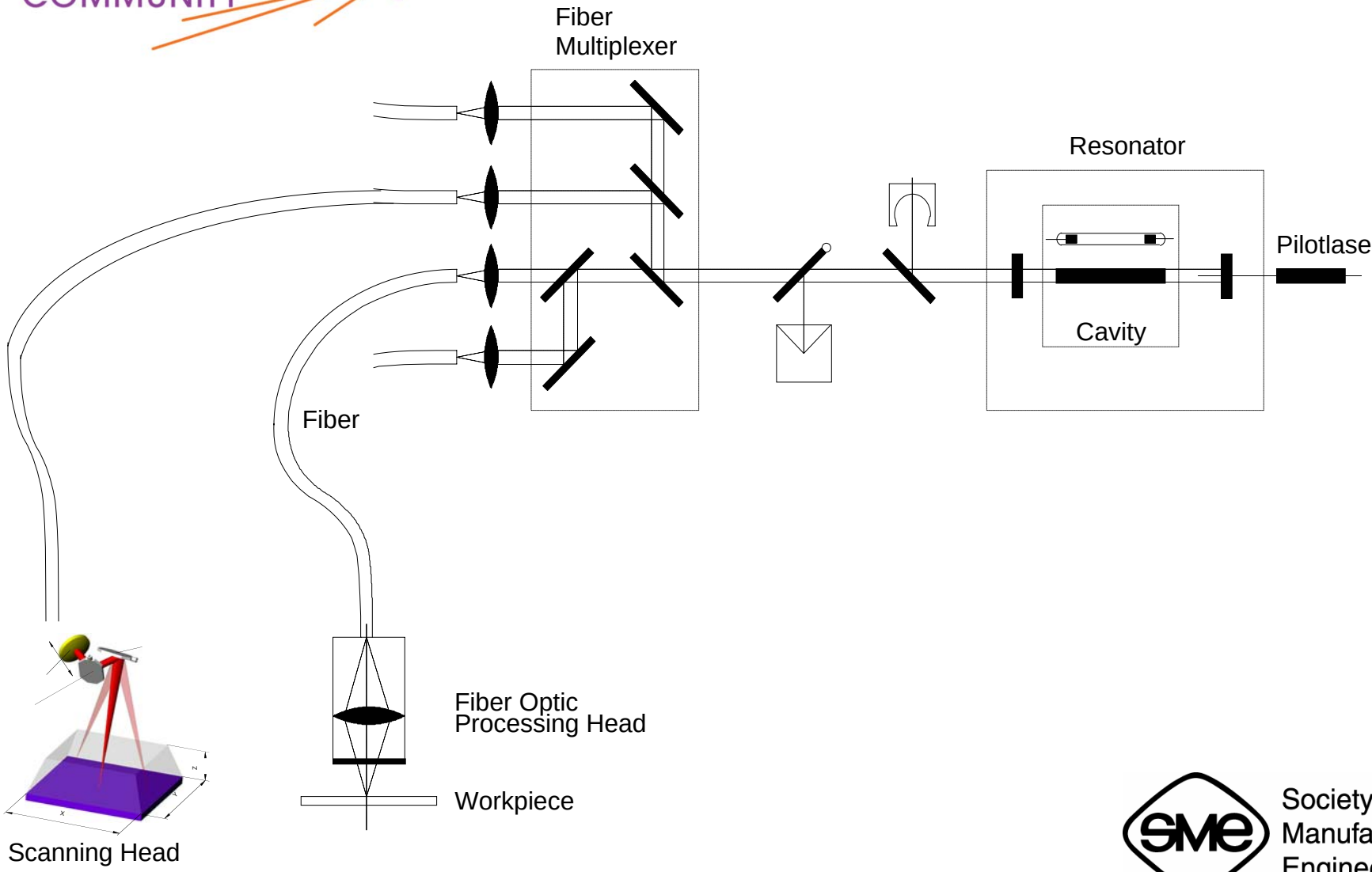
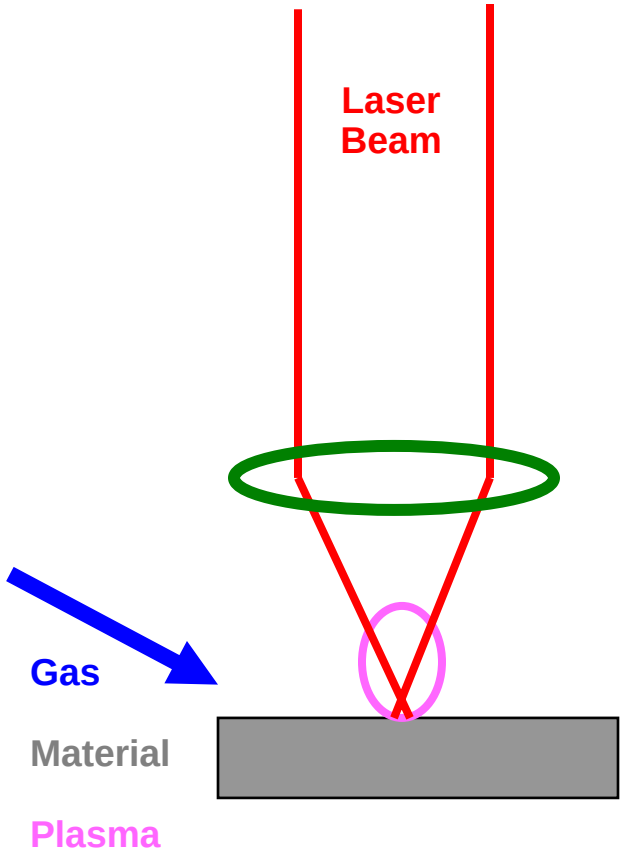
Fiber Optics



Principle of Laser Processing



Laser beam

Wavelength (μm)
Power (W)
Irradiance (W/cm^2)
Energy (J)
Interaction time/ pulse duration (ms)
Beam quality (mm mrad)

Optics

Focussing length/distance to surface
Fiber core diameter
Beam shaping

Gas

Type/mixture/purity
Velocity/distance nozzle - surface

Material

Surface	bulk properties
Absorption	material type
Roughness	thickness
Temperature	heat conduction
Dirt	heat capacity
Melt property -tension -chem. reactions	microstructure

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Principles of Laser Welding

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

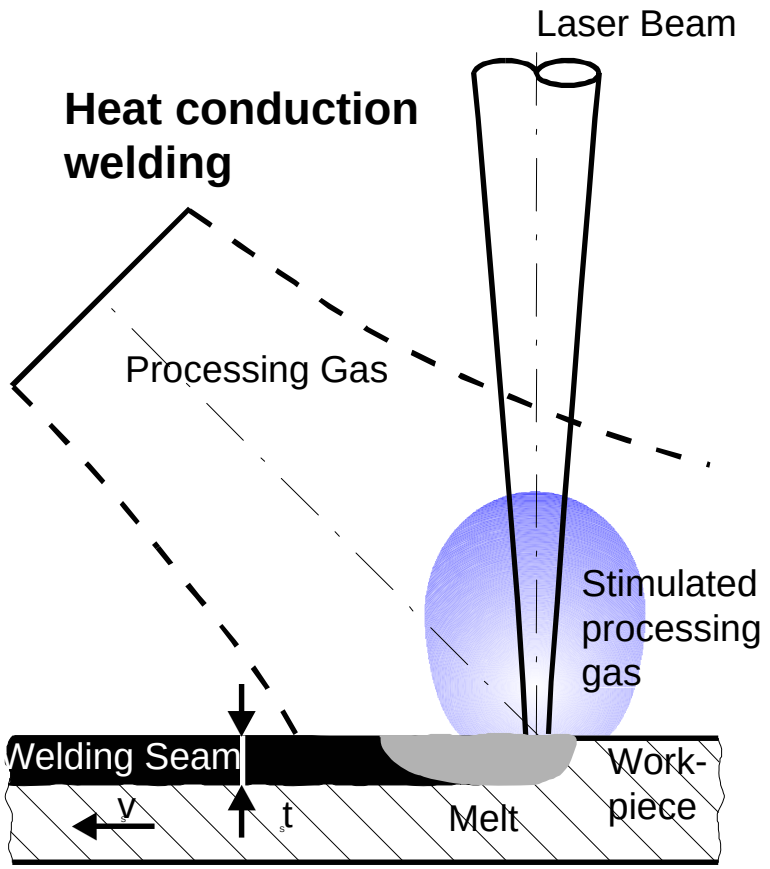
Welding depth depends on heat conduction

Characteristics

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

Applications

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



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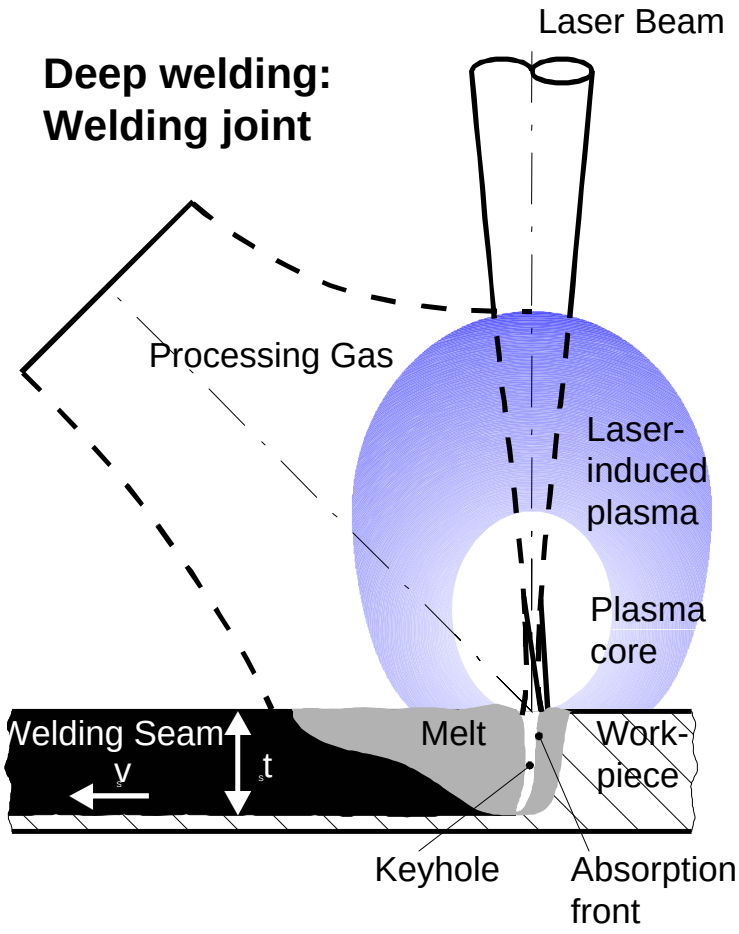
Principle of laser processing

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 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*

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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*

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Laser Welding Aneurysm Clip

(Alternating) Spot welding with scanner optics

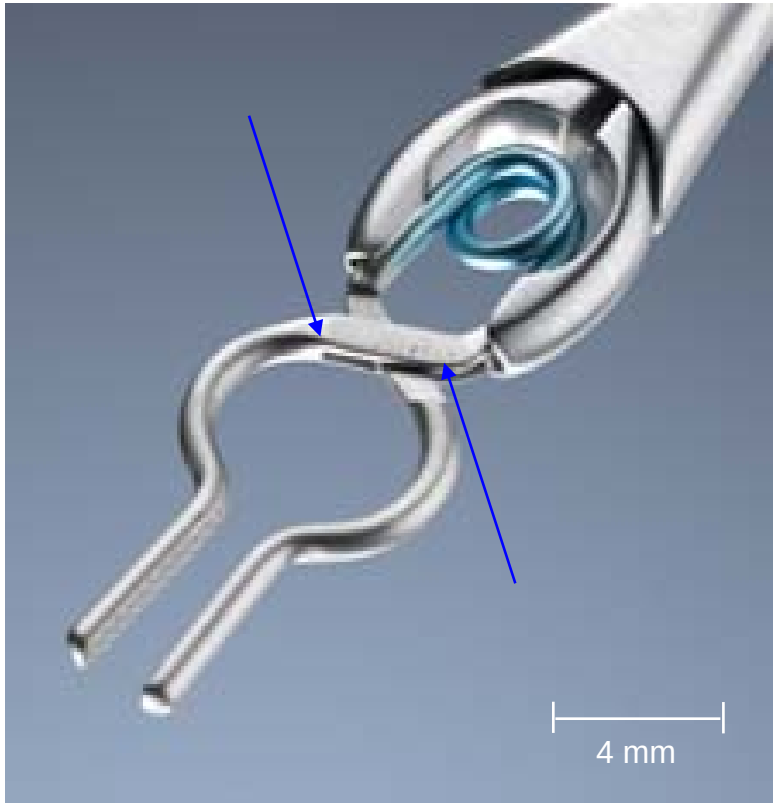
Material: Titanium

Laser parameters:

- Average power P_{av} = 60 W

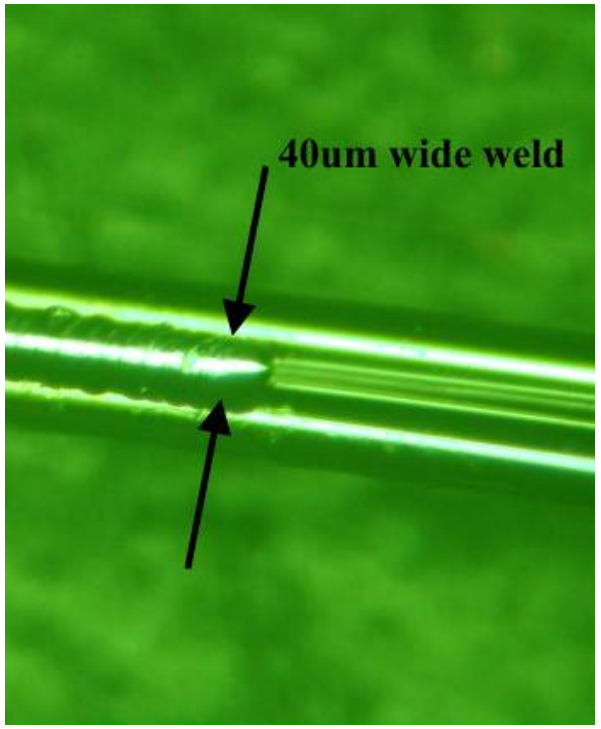
Benefit:

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



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

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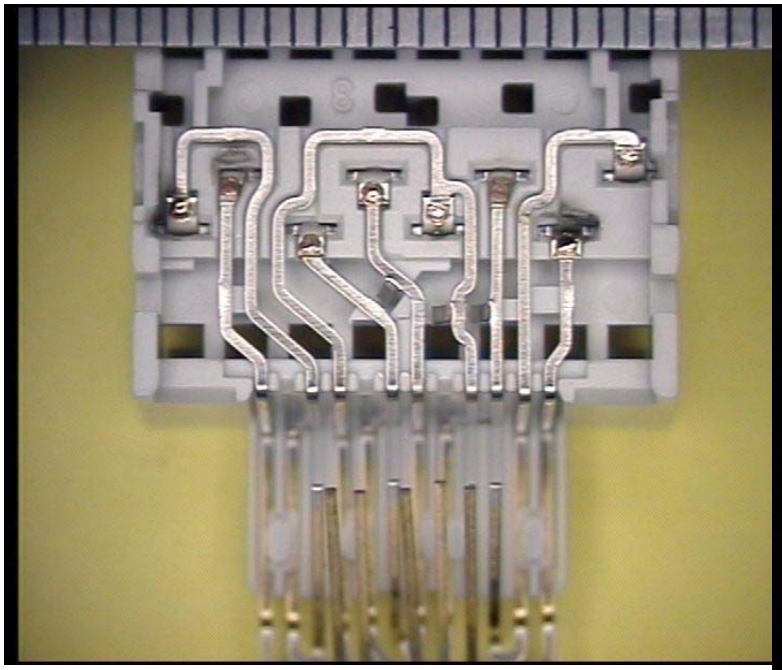
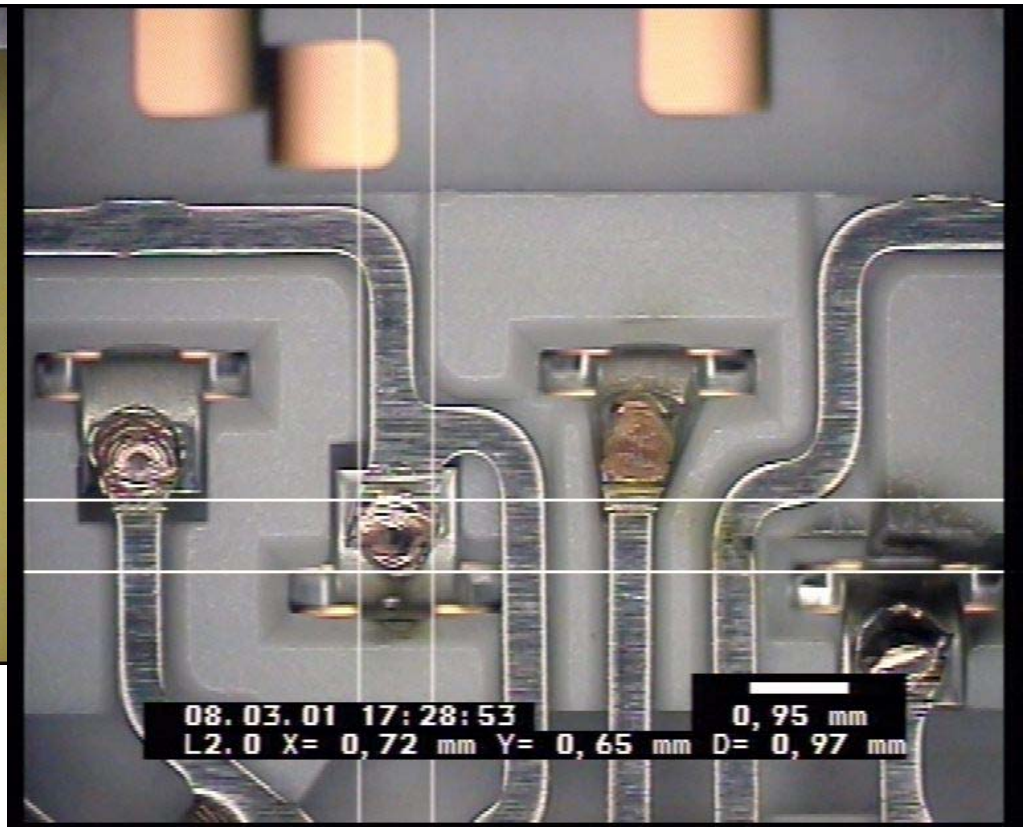
Laser Welding
IT Plugs





Material: Cu
Comments: Special Pulse Form

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Laser Welding Retrieval Basket

Materials: Stainless + Nitinol

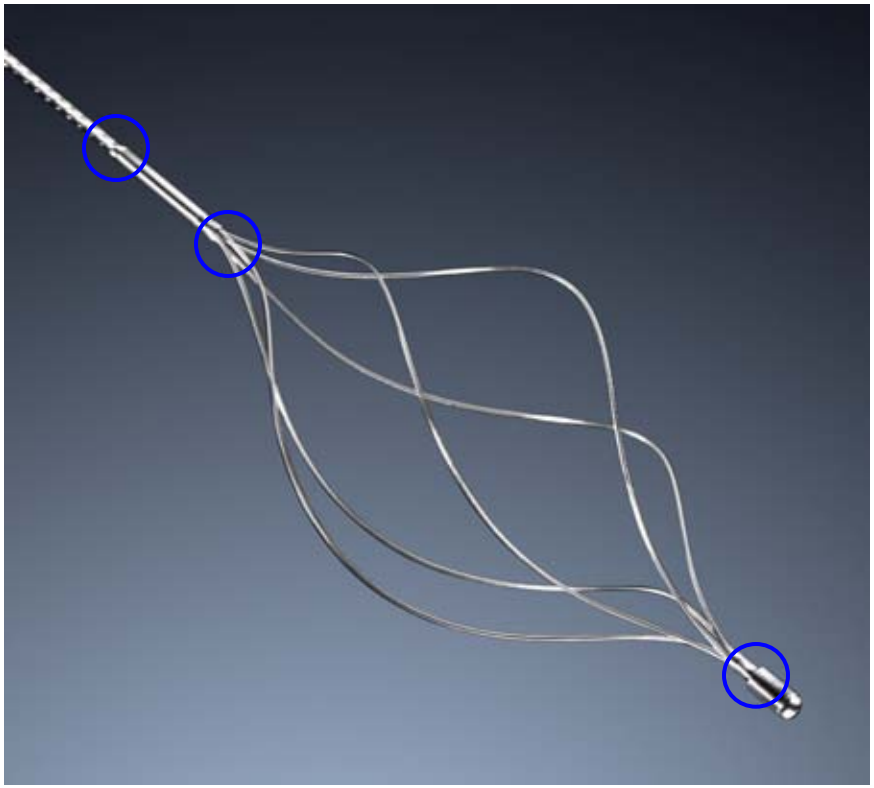
- Ø 650 µm (Stainless jacket)
- Ø 400 µm (Stainless wire)
- Ø 150 µm (Nitinol wire)

Laser pulse parameters:

- P_P = 700 W at τ = 4 ms

Benefits:

- Low heat input
- High stability of all joints (up to 70 N test pressure)



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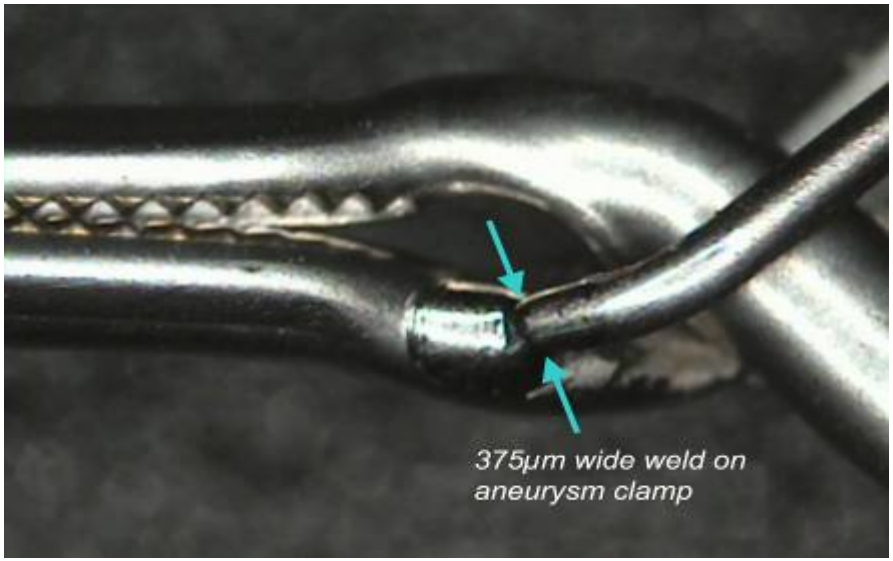
Vascular Clamps

Material: Stainless Steel

Energy: ~ 2 Joules

Single Pulse



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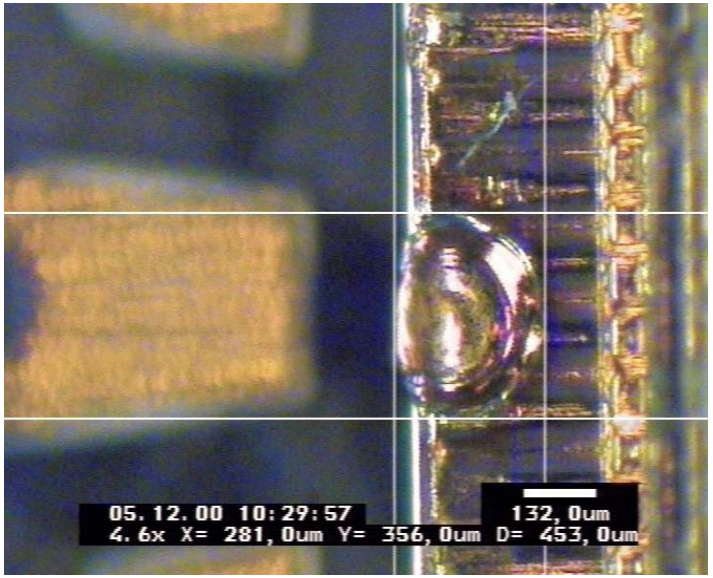
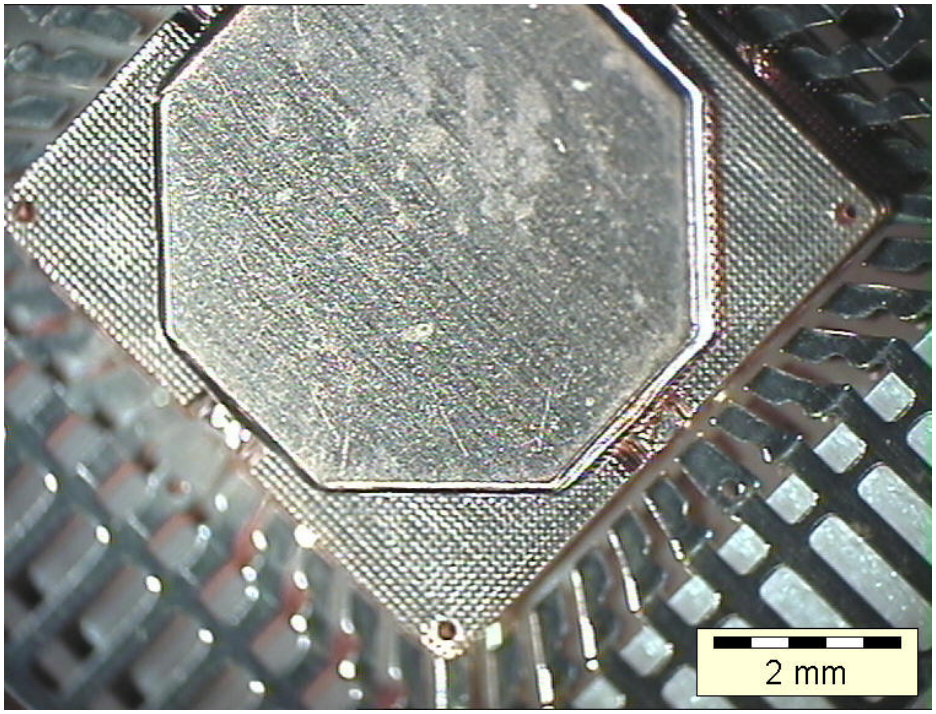
Laser Welding
Heat Sinks on Lead Frames





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

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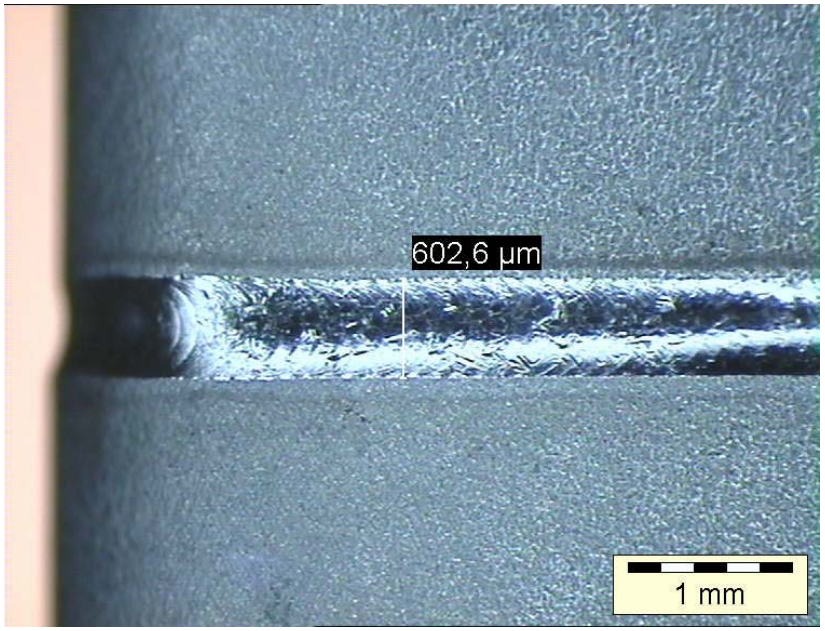
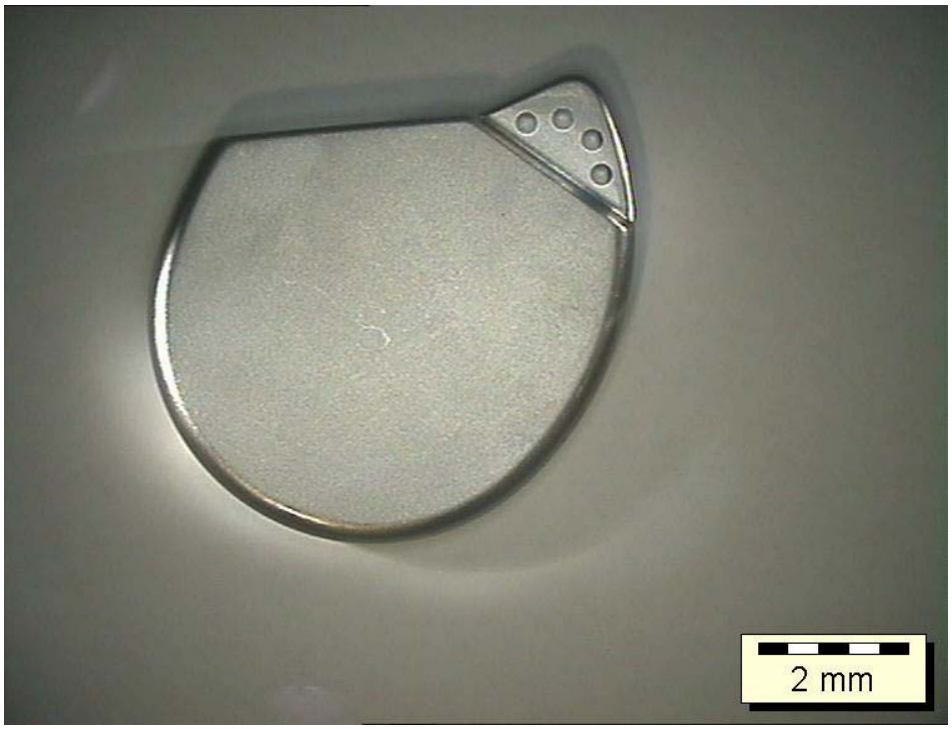
Laser Welding Pacemakers





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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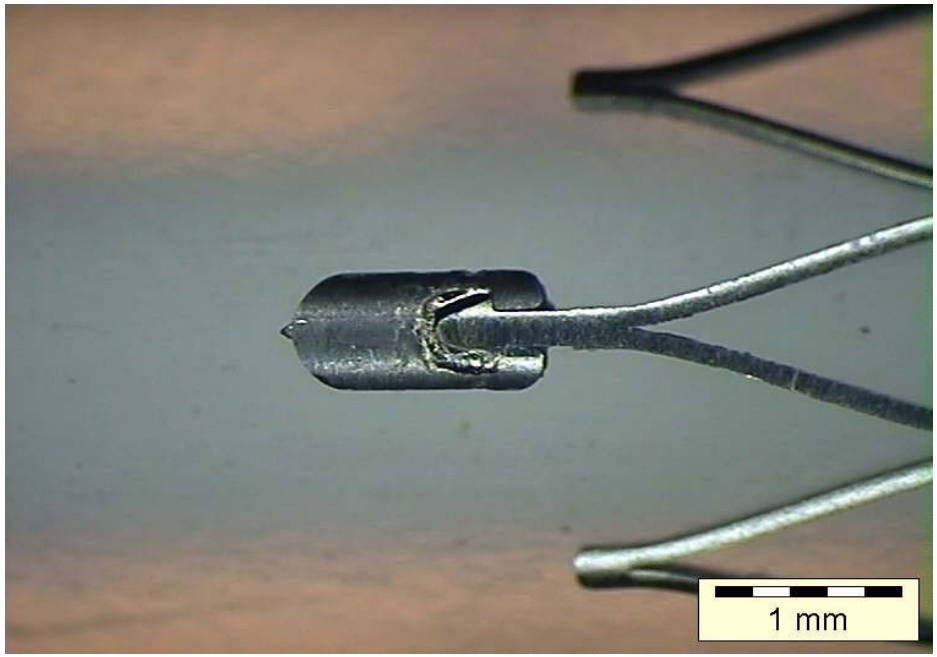
Laser Welding
Markers on Stents

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



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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

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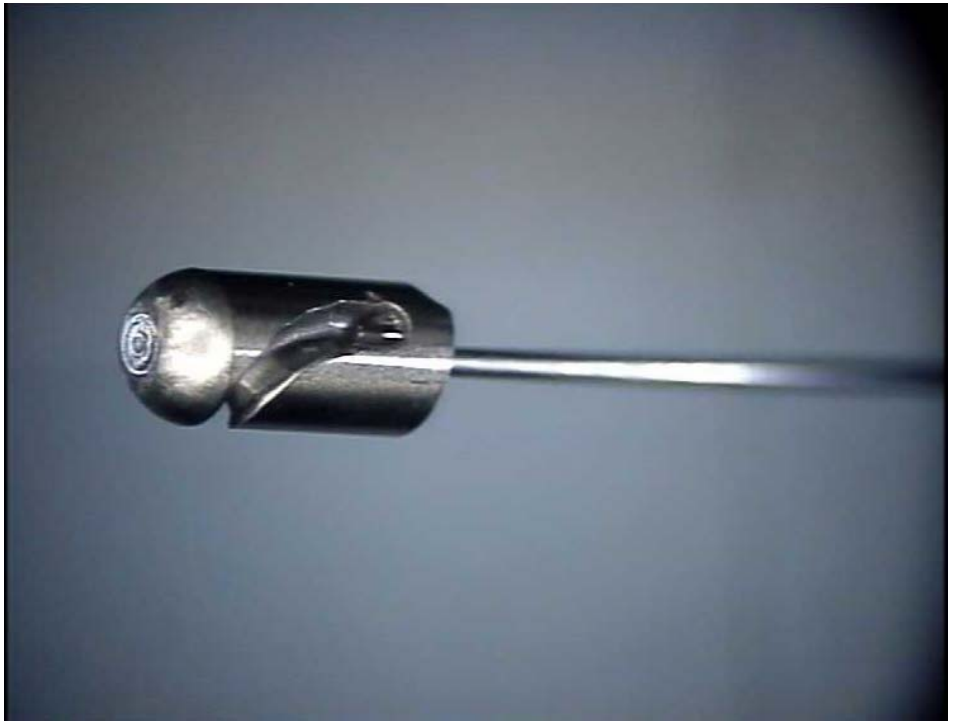
Laser Welding Endoscopes



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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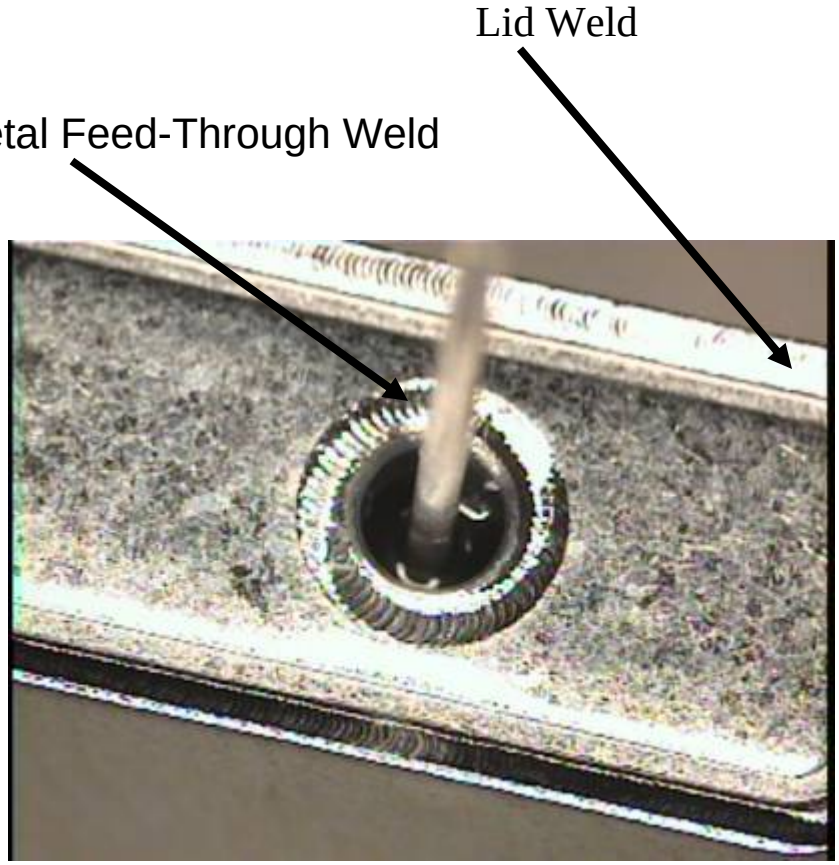
Laser Welding Pacemaker Battery

Material: Stainless Steel
Energy: ~ 0.3 Joule (lid)
~ 0.25 Joule (feed-through)
Speed: ~ 75 in/min (lid)
~ 10 in/min (feed-through)



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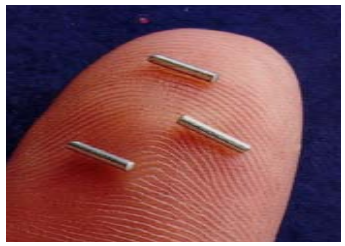
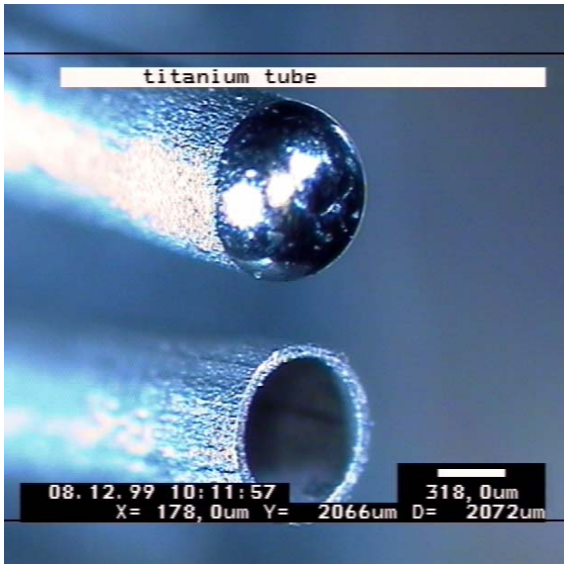
Laser Welding
Radioactive Prostate Seeds





Material: Titanium
Wall Thickness: 0.04 mm (0.0015“)
Tube Diameter: 0.8 mm (0.0315“)
Comments: Hermetic Sealed

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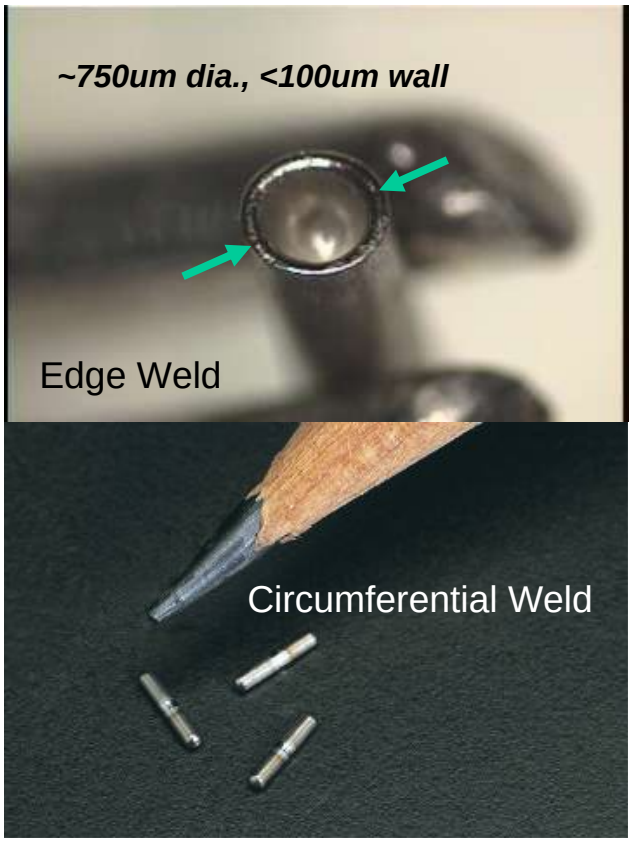
Laser Welding
Radioactive Prostate Seeds



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

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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_{min}, seam location
  Overlap weld: gap < 10% of t_{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**

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