

Precision Fiber Laser Cutting of Thin Metals; Fundamentals and Capability

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AGENDA

- Introduction
- Benefits of laser cutting
- Elements of a laser cutting system
- Key Process Parameters
- Materials
- Geometry & Applications
- System examples

Introduction to Miyachi Unitek

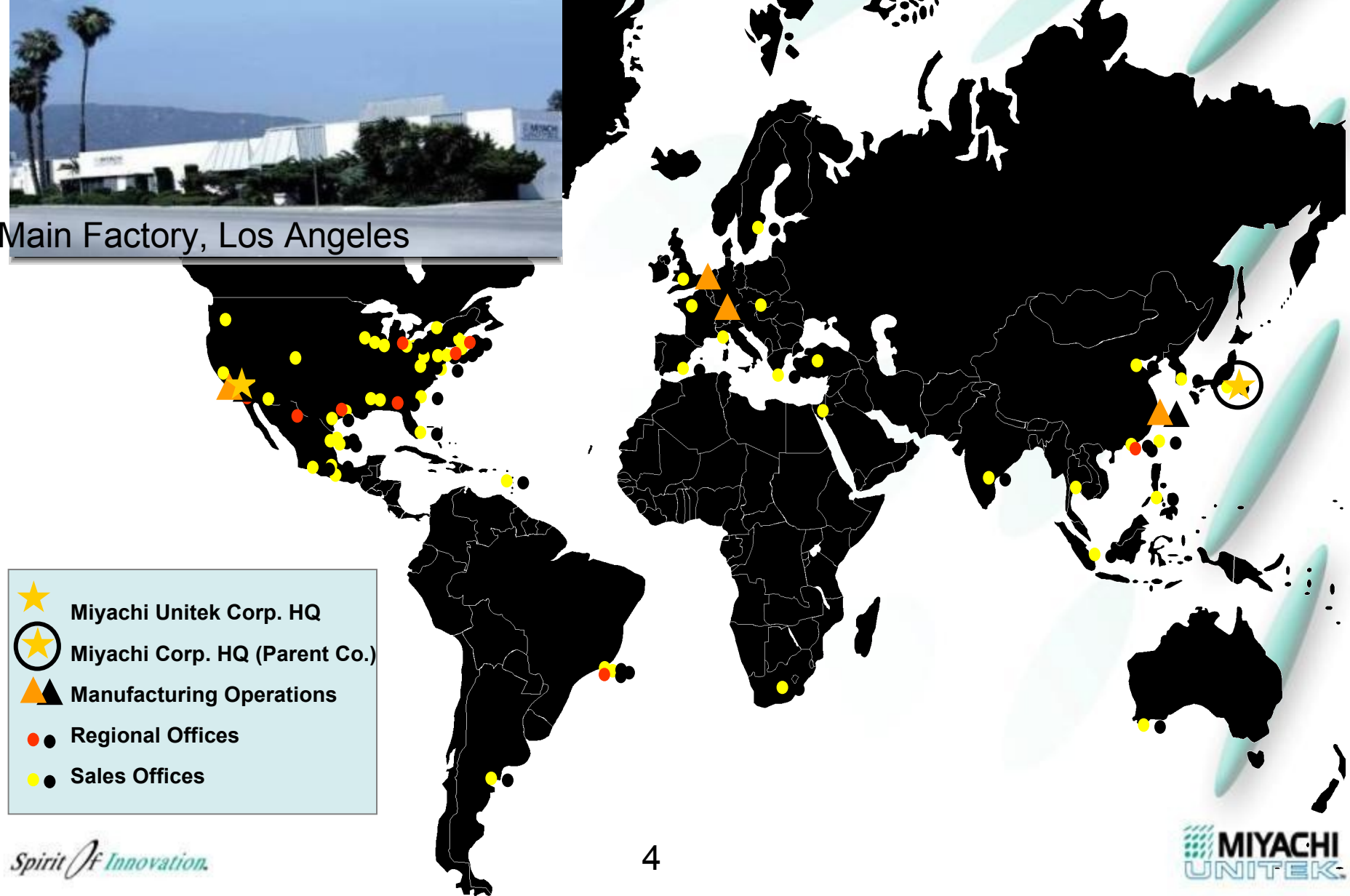
- Supplying manufacturing solutions since 1948
 - Resistance welding equipment
 - Reflow soldering equipment
 - Seam sealing / gloveboxes
- Laser and Laser Systems
 - Established mid 1990's
 - 1000's lasers
 - 750+ systems installed
 - Application to System



Worldwide Organization

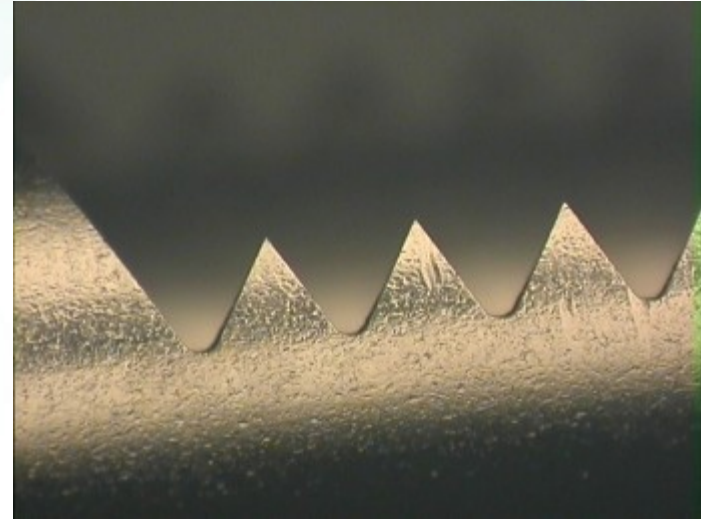


Main Factory, Los Angeles



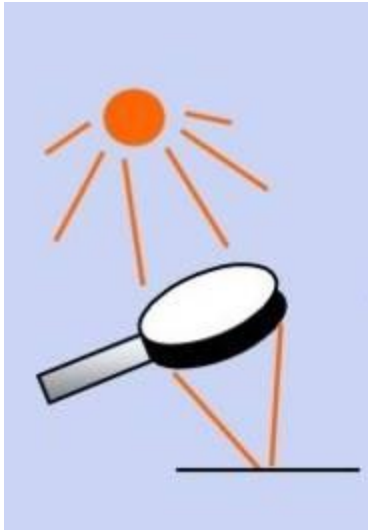
Benefits of laser cutting

- Fast
- Flexible
- High quality
- High dimensional accuracy



Quick Laser Calibration

- How the laser works as cutting heat source

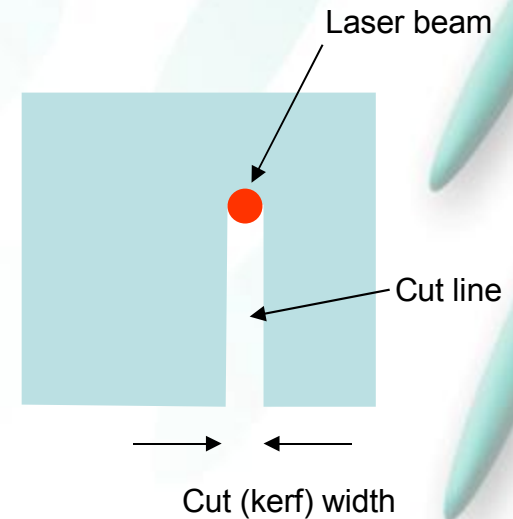
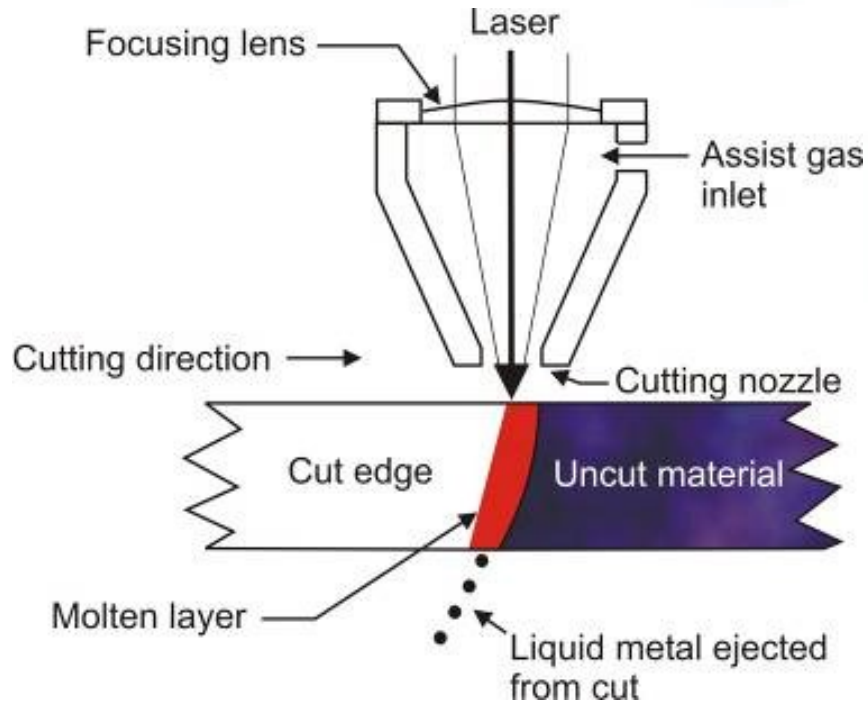
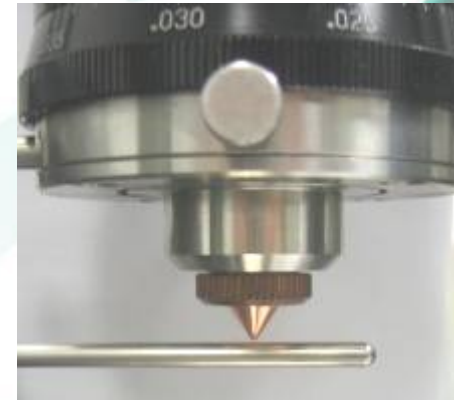


x 10000000+ = laser

Sunlight	.1 W/cm ²
Light Bulb	1 W/cm ²
Soldering Iron	100 W/cm ²
Focused laser	10,000,000+ W/cm ²
Steel vaporization	1,000,000 W/cm ²

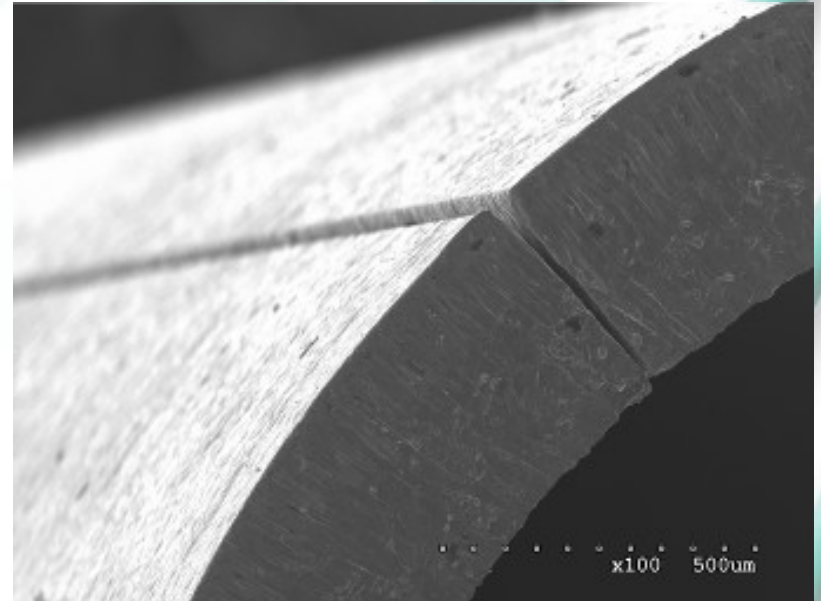
Process: Fiber Laser Cutting with Assist Gas

- Laser is “assisted” with a co axial gas
- Laser heats up metal, gas blows the molten metal out

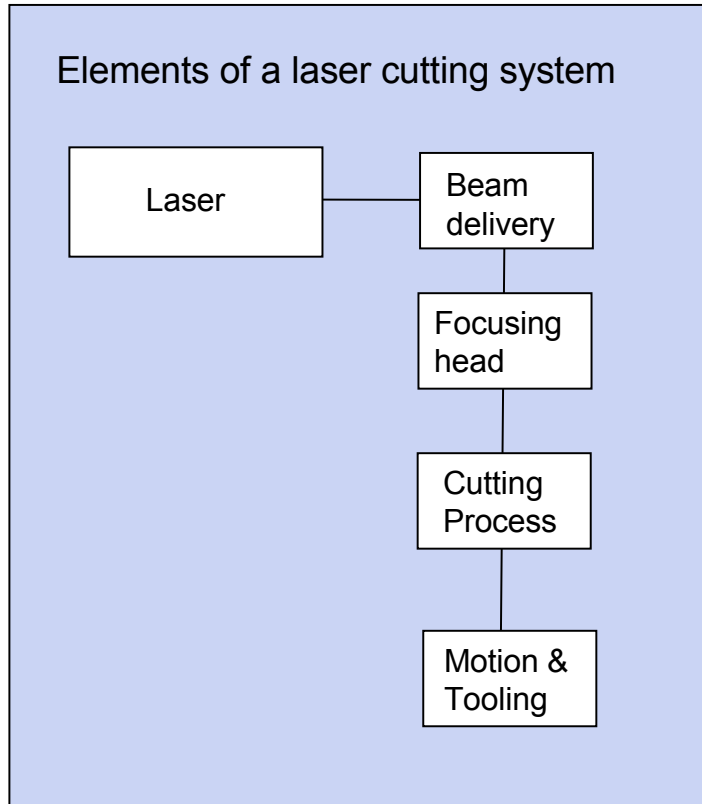


Close Up of Laser Cutting

- Stainless steel tube, 0.015" thick
- No post processing



Laser Cutting System



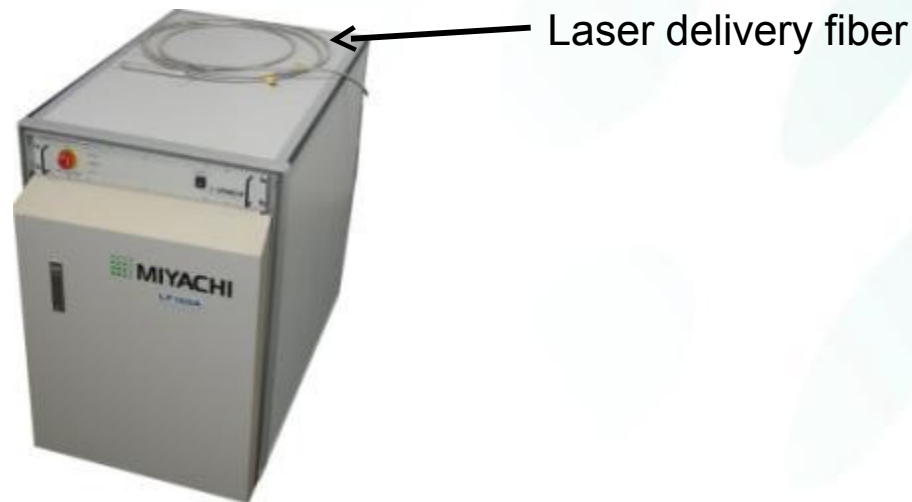
Laser

- Fiber laser source
 - 100 to 500W
 - Focused spot size to 0.0005”
 - $\pm 1\%$ power stability
 - Air cooled
 - Small footprint
 - No laser consumables



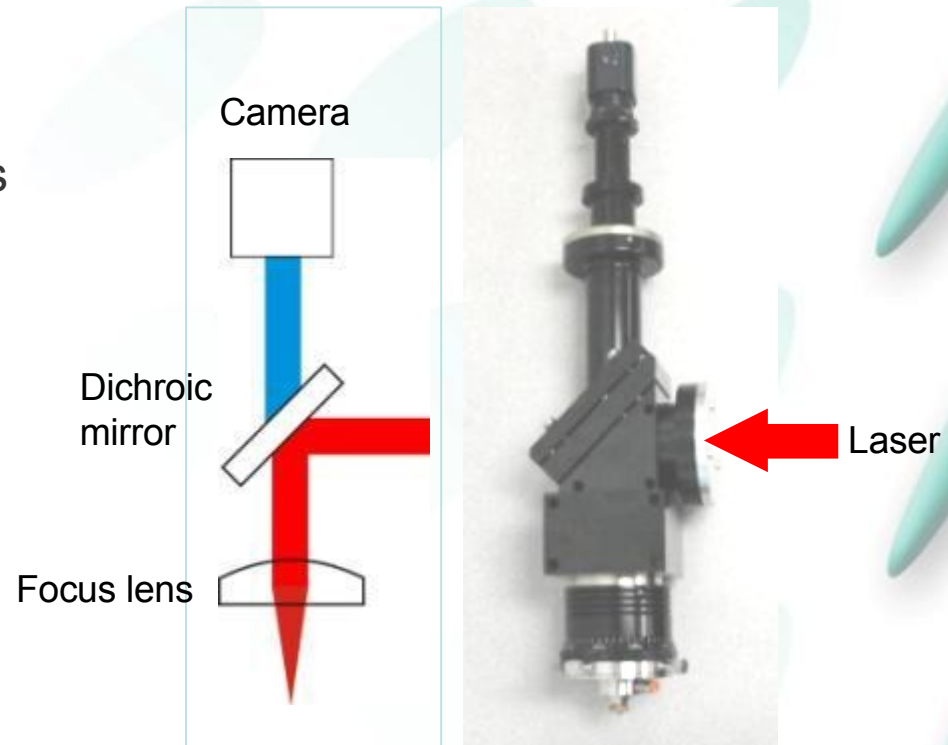
Beam delivery

- Fiber laser is fiber delivered!
- Flexible cable around 20 – 40ft long
- Easy & convenient setup and connectivity
- Laser can be positioned anywhere around system
- Totally enclosed beam path – no maintenance



Focusing Head

- Determines laser focus spot size
- Directs laser and assist gas through gas nozzle
- Camera option to view process



Motion & Workholding

- Motion

- G & M code programming
- Linear motors preferred for acceleration and positional accuracy
- 2 to 5 axes
- Post processor for tool path generation

- Workholding

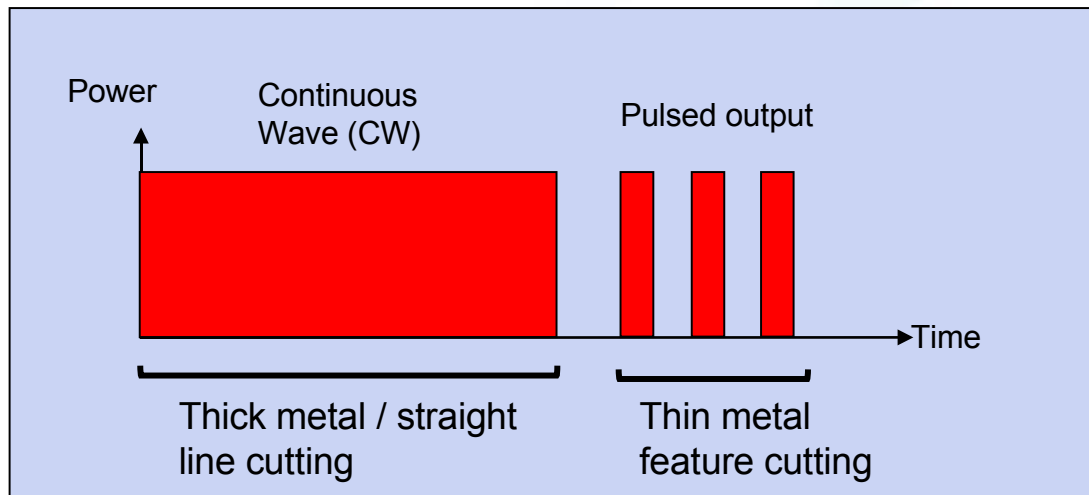
- XY
 - Self
 - Vacuum
 - Fixture
- Rotary
 - Collet
 - Chuck

Key Process Parameters

- Laser parameters
 - Power, pulse width, frequency
- Optical parameters
 - Focus spot size, depth of focus
- Gas assist
 - Gas type, pressure, nozzle type
- Speed
 - Maximize!

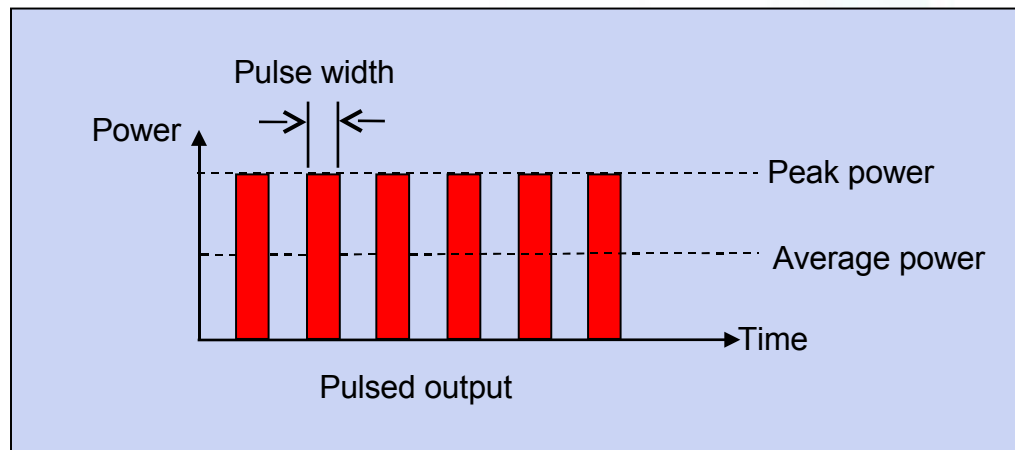
Laser Parameters

- Power
 - Continuously on (Continuous Wave or CW)
 - Pulsed output



Laser Pulsing Parameters: Power, Pulse width & frequency

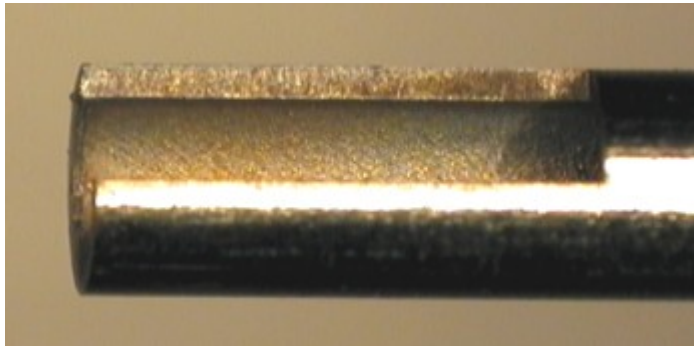
- Power
 - Peak power
 - Average power (heat input)
- Pulse width, pulse frequency



Laser Pulsing Parameters: Power, Pulse width & frequency

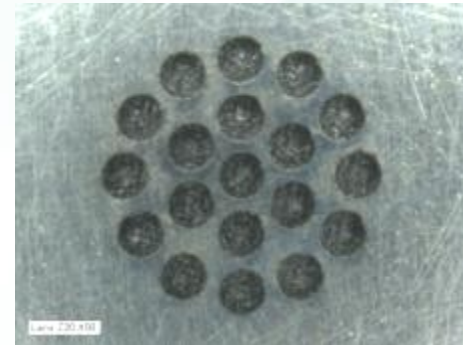
- Select for material, thickness and feature size
 - Many cuts < 100W average power
 - Pulse width range 20 – 150 μ s
 - Frequency range 0.5 – 10 kHz

0.02" thick 304L



“Large” feature size
120° slot in 0.12” OD tube
70W, 90 μ s, 2 kHz

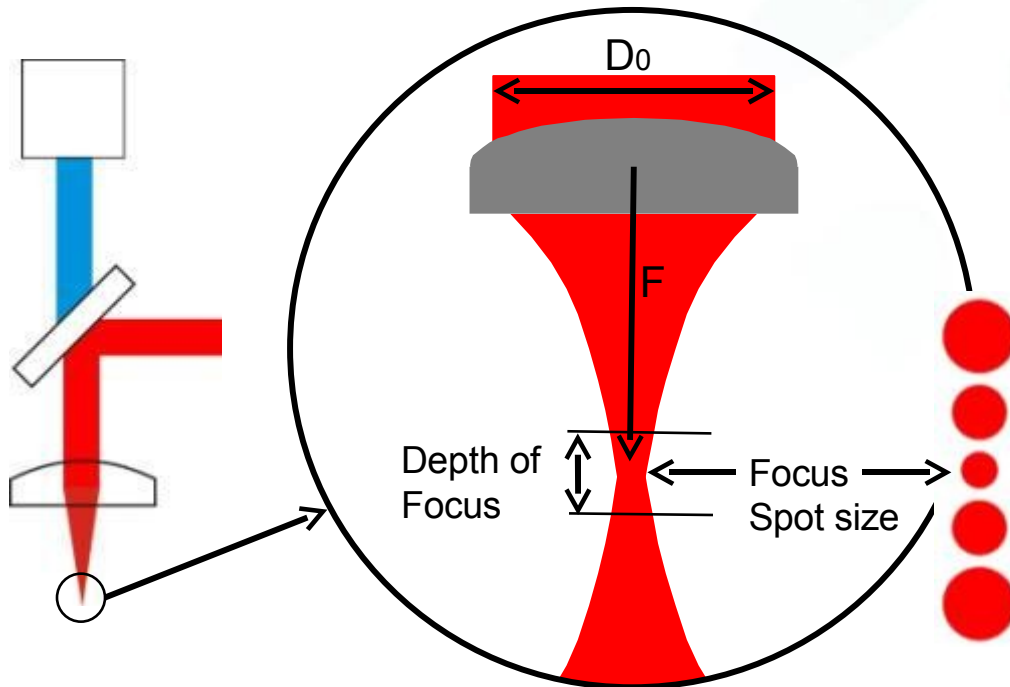
0.02" thick 304L



“Small” feature size
0.01” diameter holes
160W 20 μ s, 4 kHz

Optical Parameters

- Focus Spot size
- Depth of Focus



$$\text{Focus Spot Size (Fspot)} = \frac{1.22 FM^2 \lambda}{D_0}$$

F = lens focal length

M = M-squared² value of laser

λ = laser wavelength

(fiber laser = 1.070 μ m)

D₀ = Beam diameter at entrance to lens

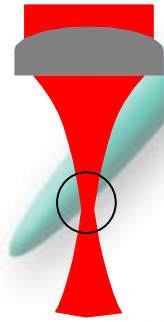
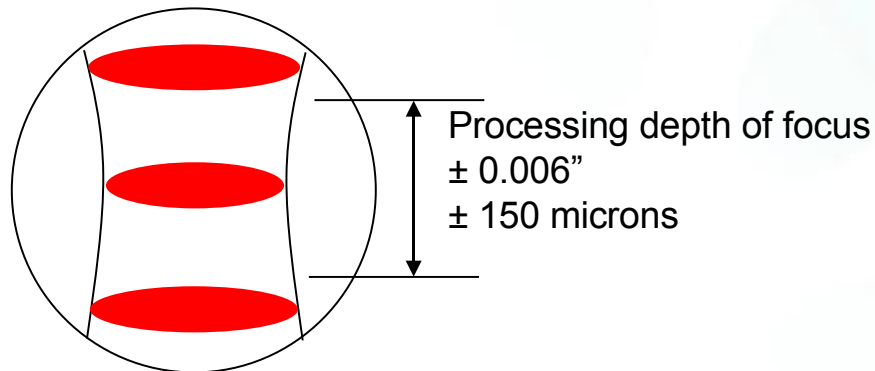
Fspot = focus spot size diameter

Optical Parameters

Focus spot size, depth of focus

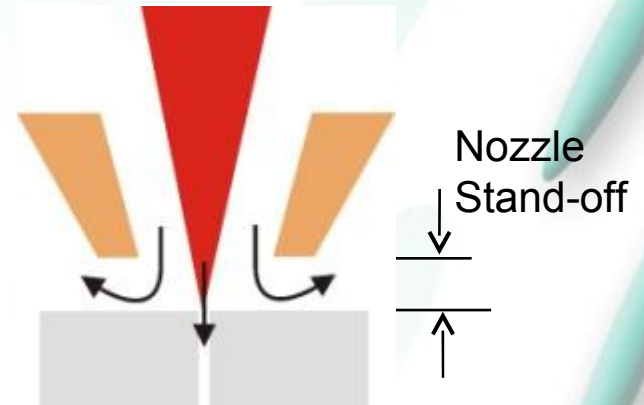
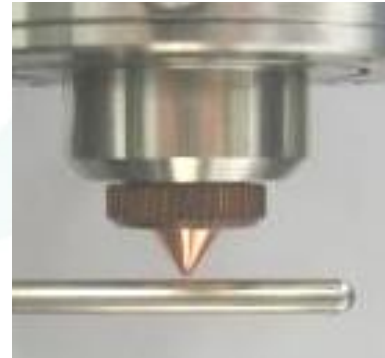
- Typical focused spot size is 0.0008" (20 μ m)
 - Cut materials 0.0005" – 0.04" thick
- "Working" depth of focus around ± 0.006 "

0.0008" spot size



Gas Assist

- Gas Type
 - Active and Non active gases
 - Oxygen / air are active, adds heat
 - Nitrogen / argon are not active, cools
- Gas Nozzle
 - Orifice diameter
 - Stand-off
 - Half orifice diameter
- Alignment of laser & nozzle key



Gas Assist

- Selection of gas type
 - Oxygen, air for cut quality and spatter control
 - Nitrogen & argon to prevent oxidation
 - Post processing, cut edge function – visual & function
- Pressure
 - Active (5-13bar)
 - Non active (15-20bar)
- Cut width enables gas flow
 - Avoid flow constriction

0.02" thick stainless steel



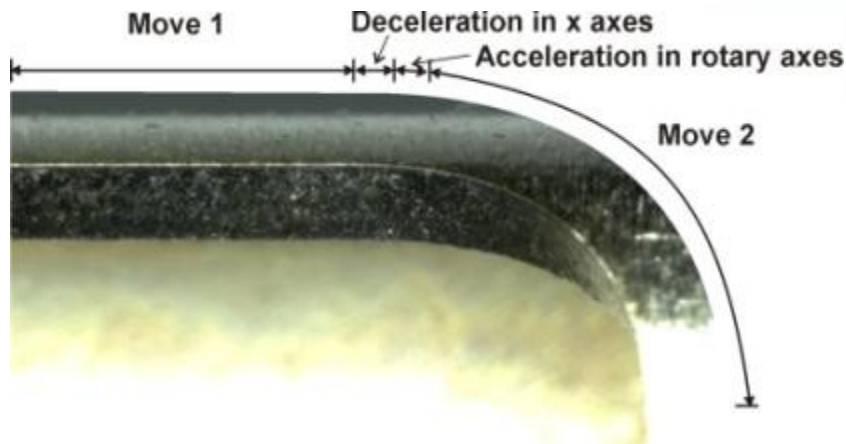
Air, 10 bar



Nitrogen, 16 bar

Cutting Speed

- Optimize all other parameters to maximize cutting speed
- Straight line cutting speeds > feature cutting speeds
- Match speed to feature
 - Maintain consistent heat input by ramping pulse frequency
 - Coordinated between linear and rotary drives



Position	Laser Pulse Frequency (Hz)
Move 1	2000
Dec in x	2000 → 1000
Acc in rotary	1000 → 1500
Move 2	1500

Material Guide

Material	Comments
Stainless steel 300 series	High quality cuts
MP35N	
Nitinol	Post processing can be challenge
Titanium	Heat balance important
Aluminum	Extra power needed
Copper	Ensure coupling, avoid back reflections
Ceramic	Absorption dependent

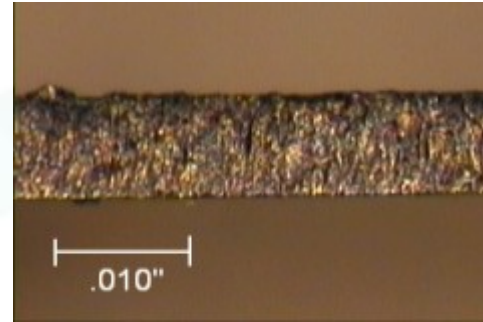
Materials



0.015" Nickel



0.01" Titanium



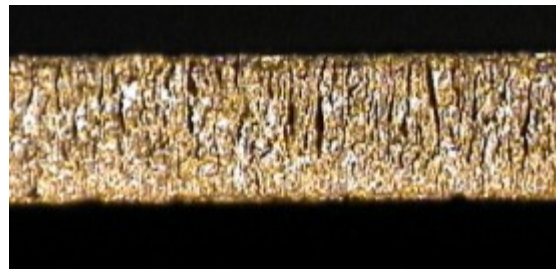
0.01" Nitinol



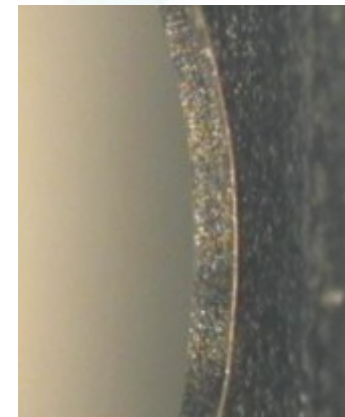
0.02" Alumina



0.02" Copper
(after polish)



0.03" Aluminum

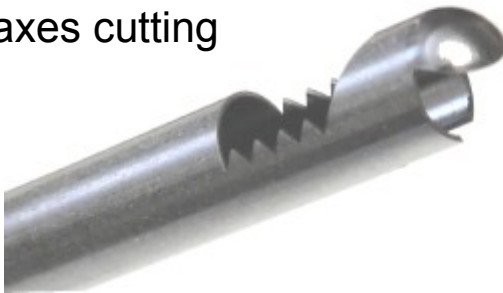


0.023" 304 SS

Cut Geometry

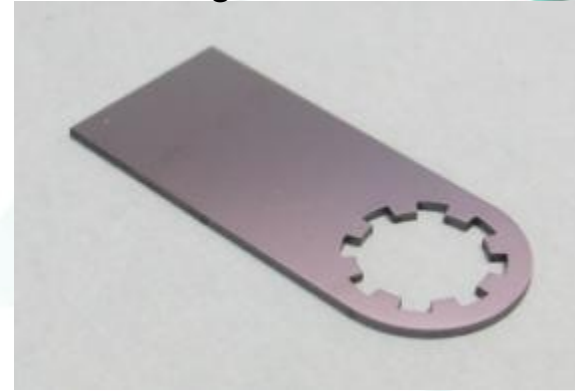
- Very flexible
- 2, 3, 4 & 5 axes cutting

5 axes cutting



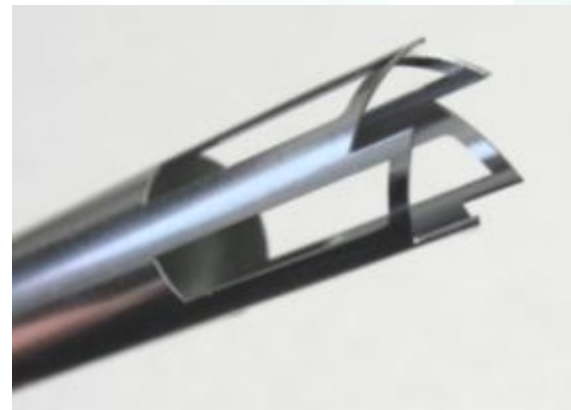
0.134" diameter steel

XY cutting



0.01" thick 304L steel

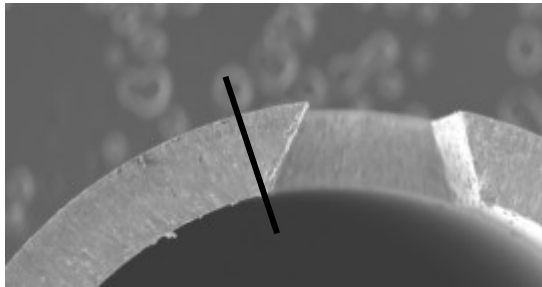
X Rotary cutting



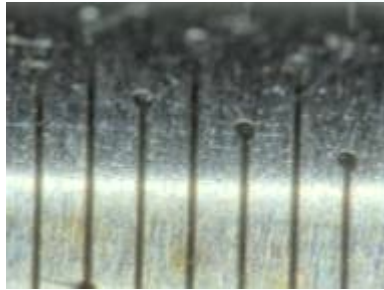
0.375" diameter steel

Cut Features

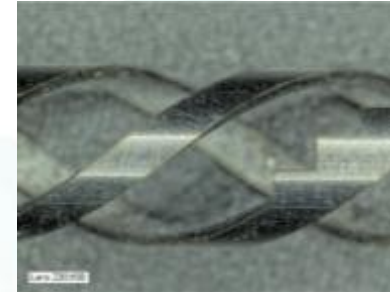
- High resolution; cut widths 0.001 – 0.002” (25-50 microns)
- Features size aspect ratio (depth/width) around 2
- Tube cutting, asymmetrical, single sided cutting, off axes, compound angles



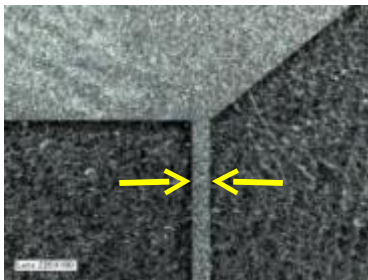
Off axes cut angles $\leq 30^\circ$
0.015” thick tube



0.0017” slots with 0.003”
diameter hole at the end



Spiral slots in 0.126” diameter
tube, 0.01” wall thickness



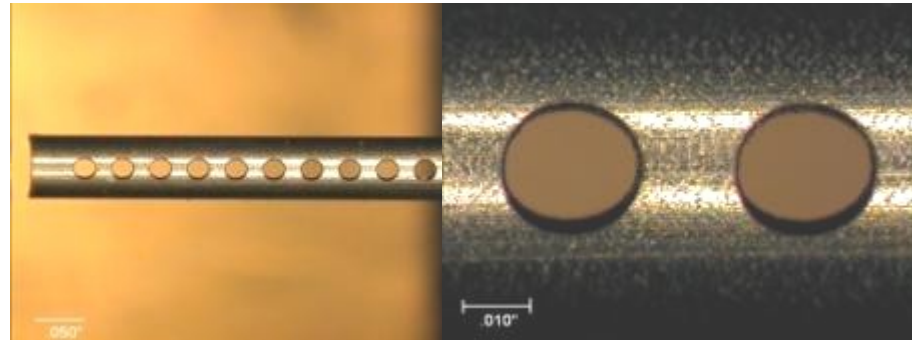
0.003” wide filament in
0.004” stainless steel

Characteristics of laser cutting

High dimensional accuracy

- Best $\pm 0.0005''$ ($\pm 10\mu\text{m}$)
- Nominally $\pm 0.001''$ ($\pm 25\mu\text{m}$)
- Factors
 - Thickness
 - Speed
 - Stage setup

0.005" (125 μm) thick 304 Steel

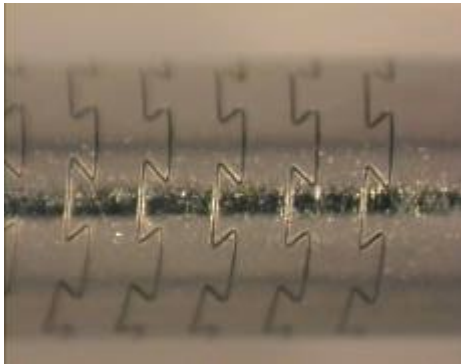


0.02" (0.508mm) diameter hole at 0.02"/s

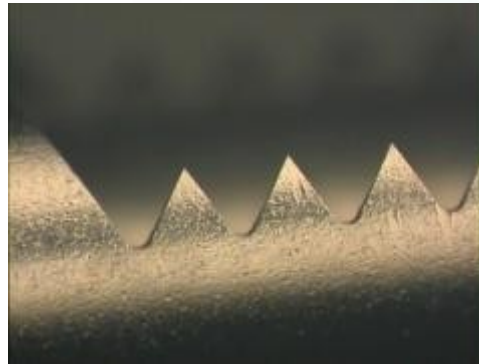
Standard deviation of hole diameter = 0.0002" (5 μm)
Standard deviation of hole position = 0.0002" (5 μm)

Applications Overview

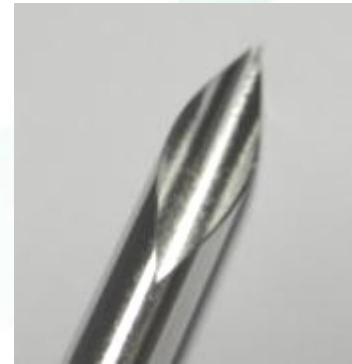
- Medical tubing
 - Flexible endoscopic tubing, cannula's, arthroscopic tools, shaver blades, bone saws



0.134" diameter steel



0.165" diameter steel

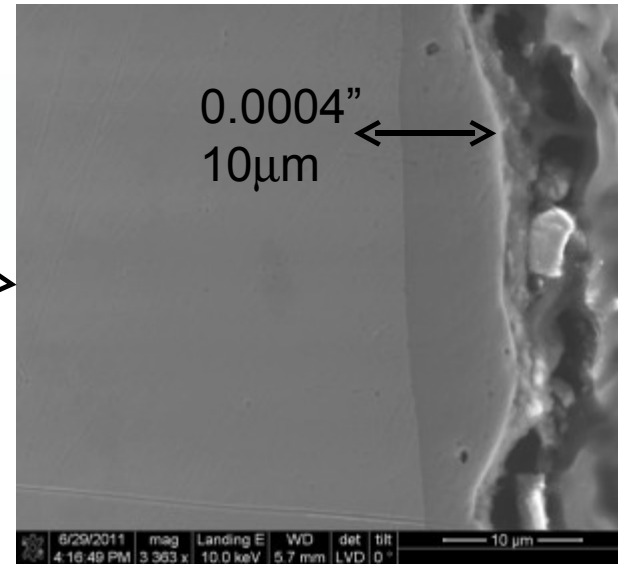
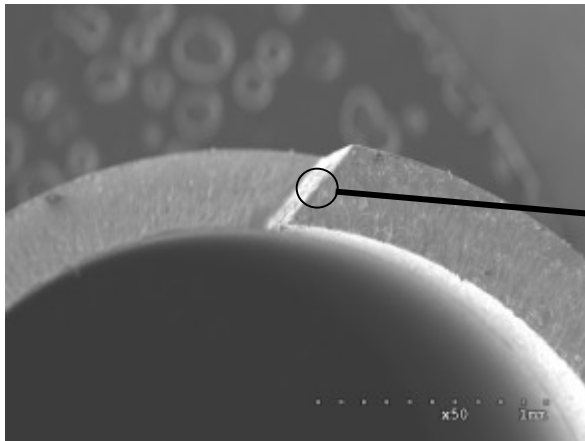


0.134" diameter steel

- Precision components for electronics / sensors
- Battery foils for Li ion cells

Cut quality

- Example for 0.01" thick stainless steel
 - Recast layer < 0.0004" (10 μ m)
 - Heat affected zone < 0.0005" (12 μ m)



Cutting System Platforms

- 2,3 axes XY cutting
- 2,3,4 axes tube cutting
- 5 Axes cutting

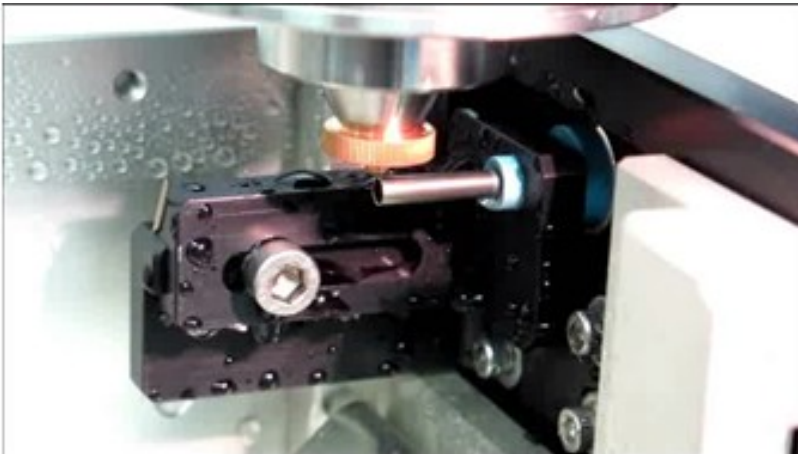
XY Cutting

- “Flying optics” system
 - Part stationary, moving focus head
- Configuration enables cutting box, auto focus control



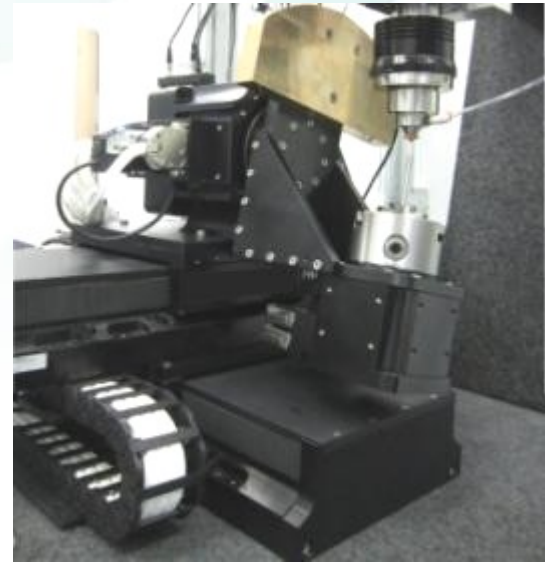
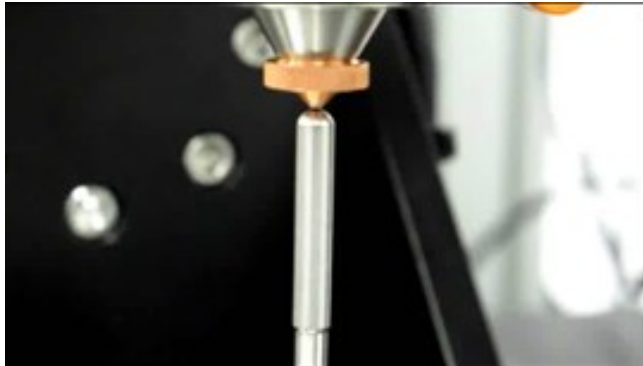
High Speed Tube Cutting

- 2,3 or 4 axes system
- High speed direct drive rotary and x axes
- Wet or dry operation
- Tube feeder
- Part collection bin



Tube and dome cutting

- 5 axes machine
- XYZ and R1, R2
- Axes configurable according to part / cut path



Summary

- The fiber laser is a competitive tool for high speed precision cutting
- Excellent cut quality in many metals
- Unique cutting capability
- Fully integrated cutting systems in 2,3,4 & 5 axes