Pulsed Laser Micromachining of Metallic Materials

ME6320

Internal Seminar Presentation

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Roadmap of Presentation

START

1. **Introduction**
   LASER
2. **Requirements in Micro-Machining**
   Special properties
3. **Pulsed Laser**
   Key concept
4. **Working of PLM**
   Difference between CLM and PLM
5. **Applications (Industrial)**
6. **Advantages**
   References & Acknowledgement

End

LASER

Light Amplification by Stimulated Emission of Radiation

Laser technology is at the core of the wider area of **Machining Applications**, essentially because laser light has a number of very **special properties**:

It is usually emitted as a well directed laser beam which **can propagate over long lengths** without much divergence and can be focused to very small spots, where a high intensity is achieved.

It can have **a very narrow optical bandwidth**, whereas e.g. most lamps emit light with a very broad optical spectrum.

It may be emitted **continuously, or alternatively** in the form of short or ultrashort pulses, with durations from microseconds down to a few femtoseconds.

The **temporal concentration of energy** – in addition to the potential of strong spatial confinement in a beam focus – allows for even far higher intensities to be generated.

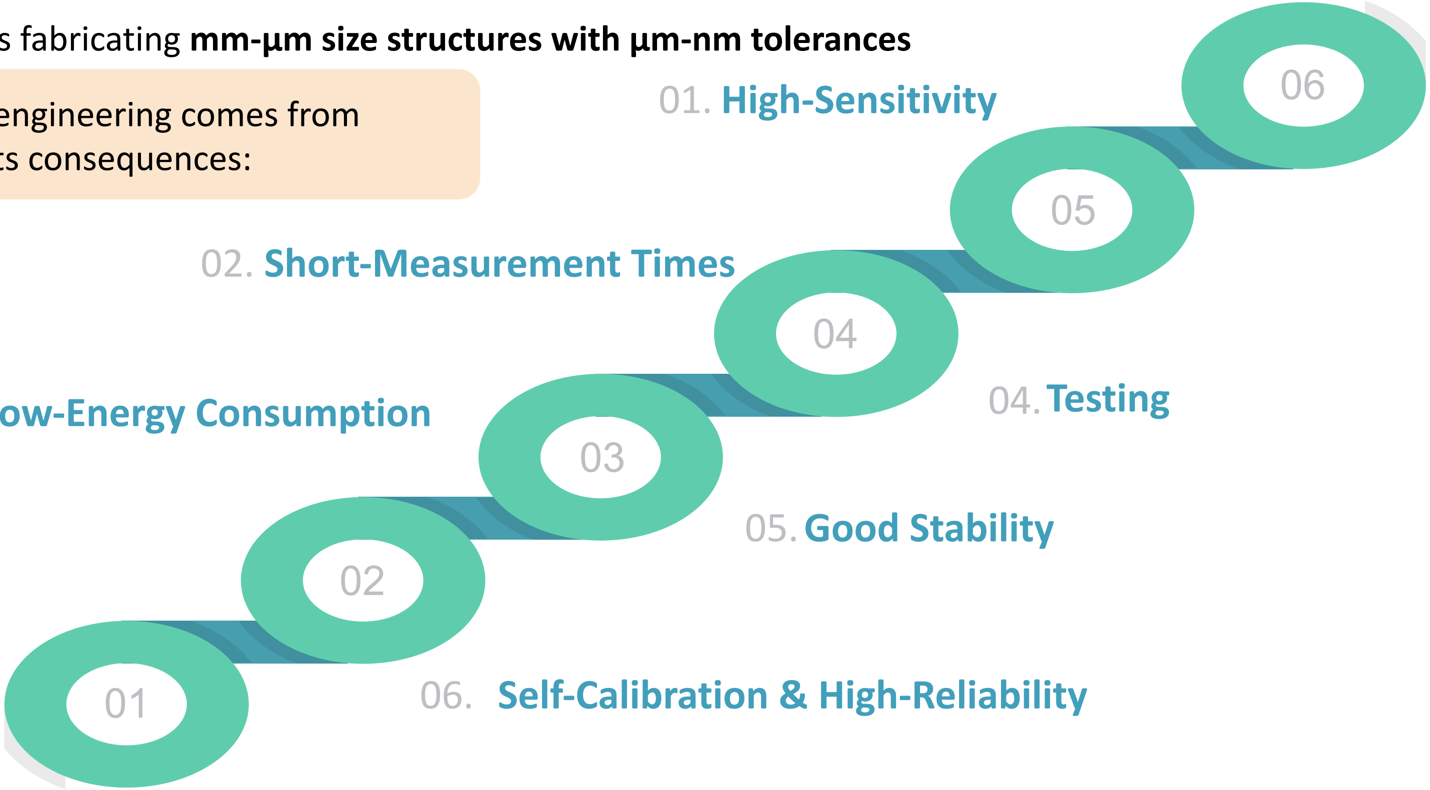
Key Parameters

'Micro-electro-mechanical systems' (MEM's) or 'Microsystems technologies' (MST) bring together mechanical, electrical and optical technologies to create an integrated device that employs miniaturization to achieve high-complexity in a small volume

This generally involves fabricating **mm-µm size structures with µm-nm tolerances**

The success of microengineering comes from miniaturization and its consequences:

01. **High-Sensitivity**
02. **Short-Measurement Times**
03. **Low-Energy Consumption**
04. **Testing**
05. **Good Stability**
06. **Self-Calibration & High-Reliability**



Pulsed LASER

Pulsed operation of **lasers** refers to any **laser** not classified as continuous wave, so that the optical power appears in pulses of some duration at some repetition rate...

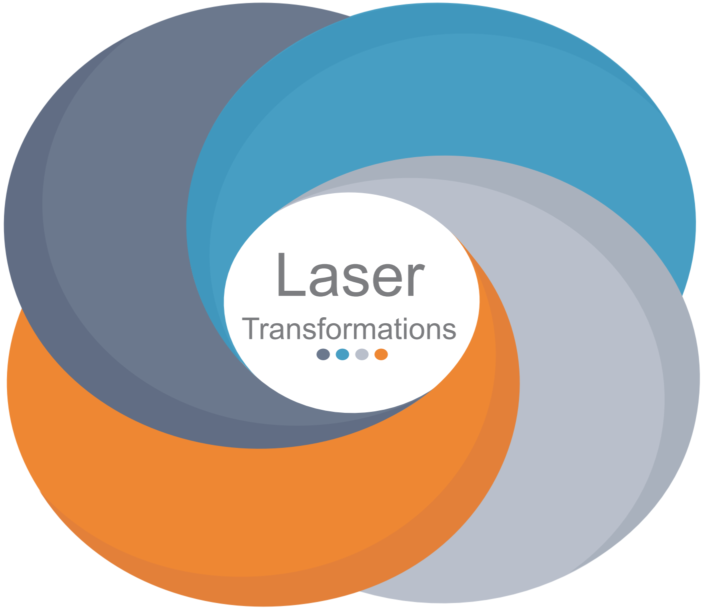
For a given **pulse** energy, this requires creating pulses of the shortest possible duration utilizing techniques such as **Q-switching**.

.01

Spatial
Transformation

.02

Amplitude
Transformation



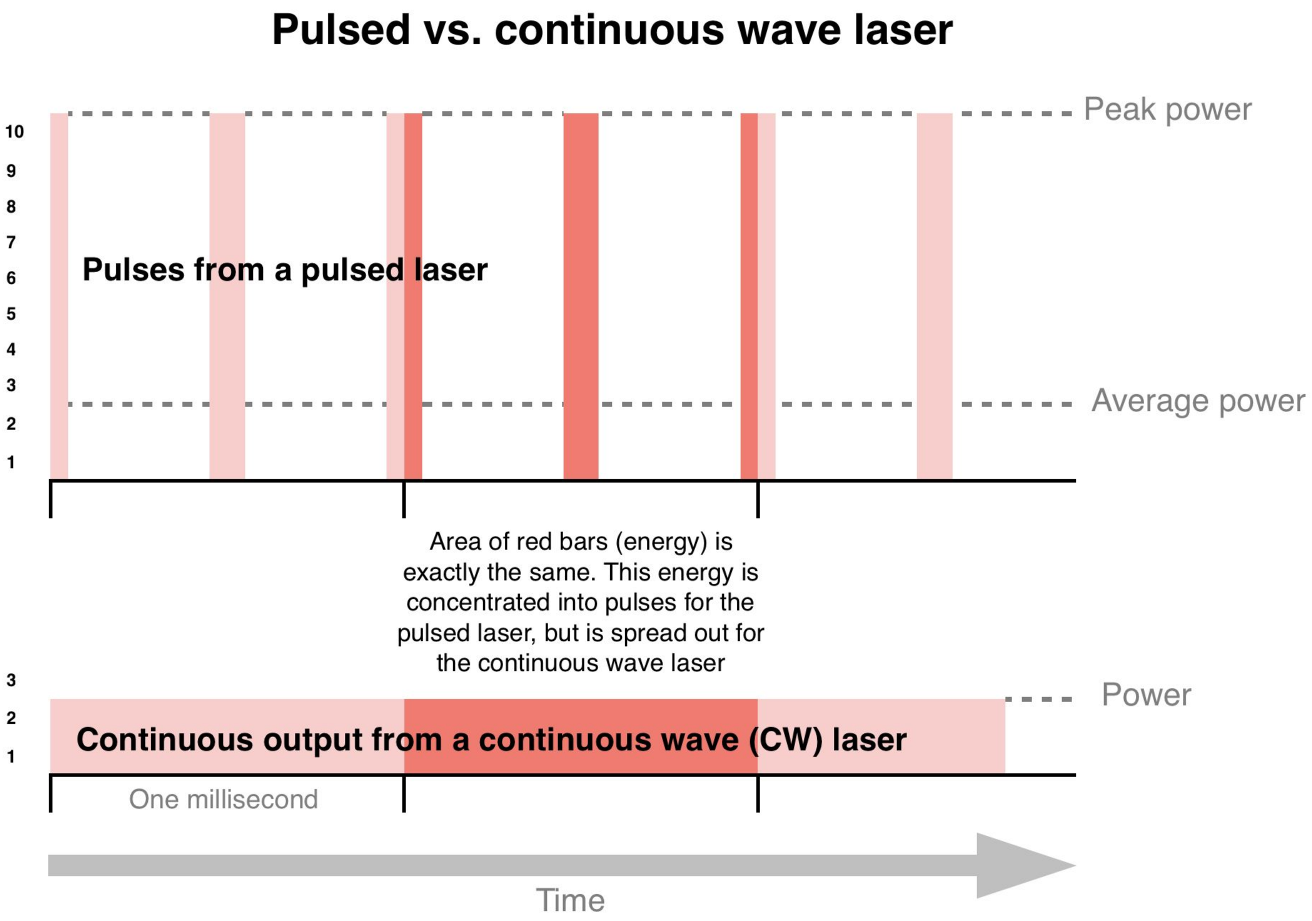
.03

Wavelength
Transformation or
Frequency *Conversion*

.04

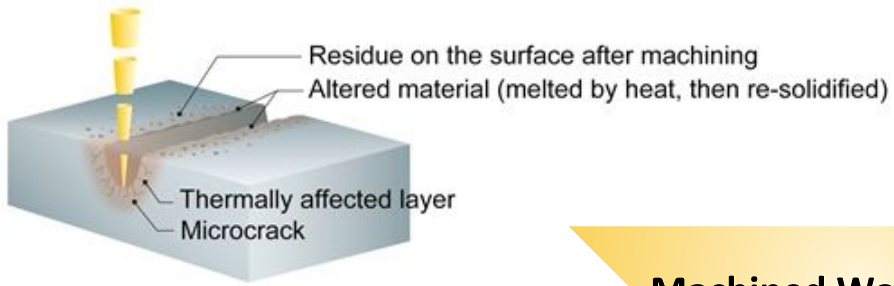
Time
Transformation

Working of Pulsed LASER

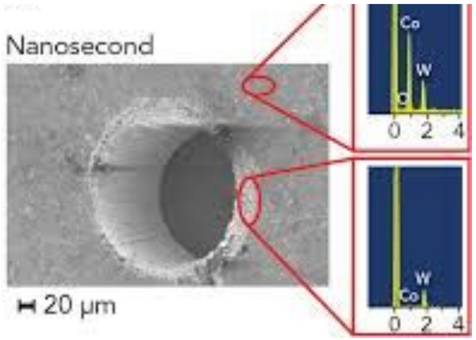


Working of Pulsed LASER

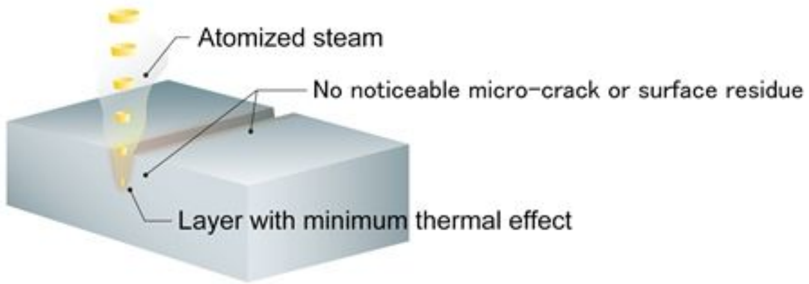
- Conventional laser machining (nanosecond laser)

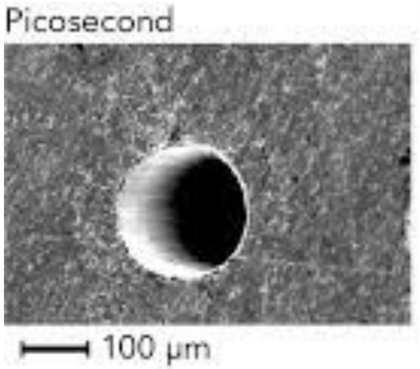


Machined Workpieces

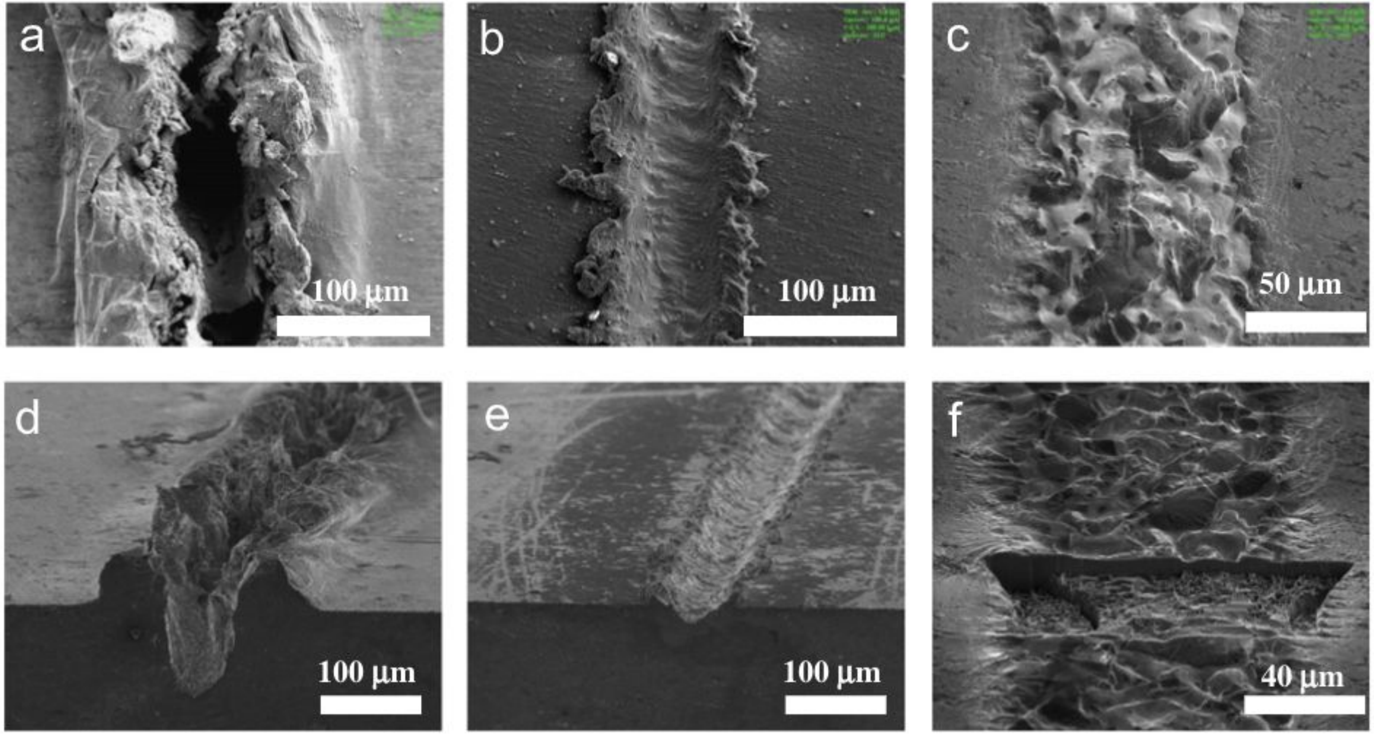


- Short-pulse laser machining (picosecond laser)





Machined Specimens



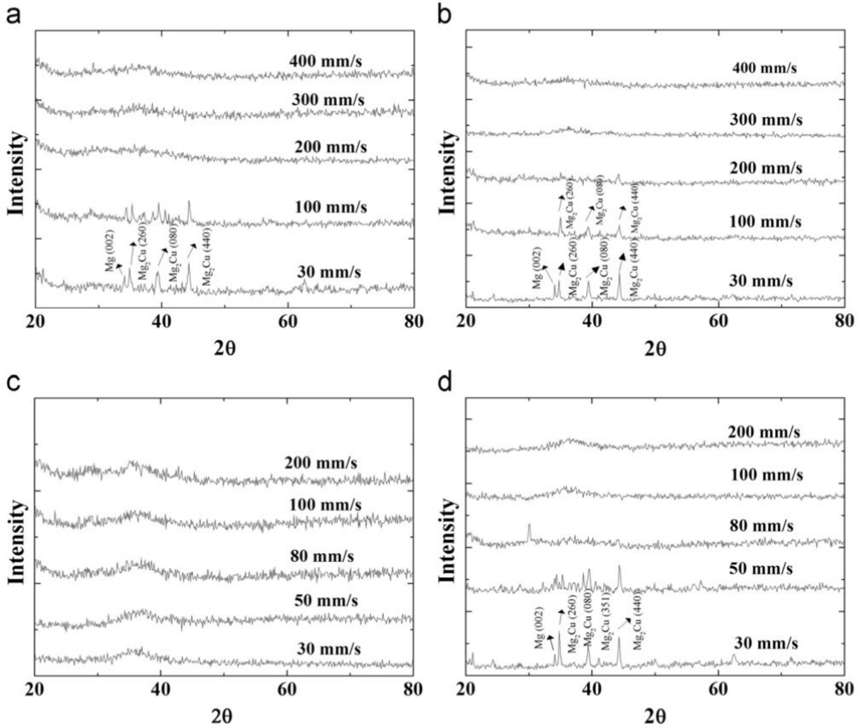
Top view and cross-sectional view of Mg-based BMG after laser micromachining with (a) and (d) a UV laser with a fluence of 12 J/cm2 and a scan speed of 30 mm/s,(b) and (e) a UV laser with a fluence of 12 J/cm2 and a scan speed of 300 mm/s, and (c) and (f) an IR laser with a fluence of 19 J/cm2 and a scan speed of 30 mm/s.

Smooth Operation

XRD patterns of specimens obtained using (a) a UV laser with a fluence of 6 J/cm2, (b) a UV laser with a fluence of 12 J/cm2

XRD Pattern:

X-**Ray Diffraction Pattern**



XRD patterns of specimens obtained using (c) an IR laser with a fluence of 9.5 J/cm2, and (d) an IR laser with a fluence of 19 J/cm2 at various scan speeds

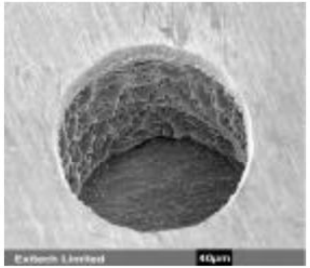
Applications of Pulsed LASER

CW laser		
Pulse laser	Femtosecond laser	Ultra precision micromachining in nm order without heat effect. For science and industrial use.
	Picosecond laser	Fast micromachining in μm order with less heat effect. Latest industrial laser.
	Nanosecond laser	YAG laser, Excimer laser. Micromachining for industrial use.
	Microsecond laser	CO_2 laser. Drilling, cutting, welding for industrial use.

Industrial Applications

Microvia hole drilling in circuit interconnection packages

- There's a demand for an ever-increasing packing density of interconnections in PCBs
- Since copper is highly reflective at 10μm, Q-switched YAG lasers (fundamental or 3rd-harmonic) are used to drill the metal, while either CO2 (rf-excited or TEA) or 3rd-harmonic YAG lasers drill the dielectric material.

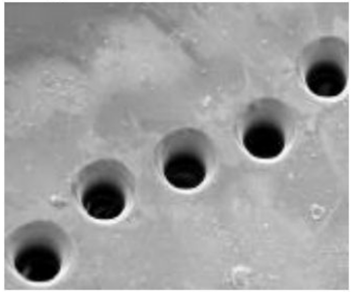


100μm diameter blind microvia drilled in a PCB

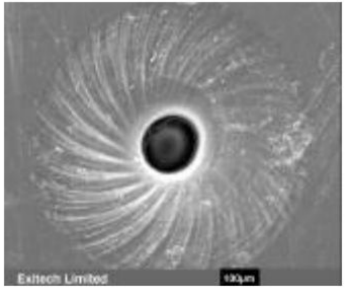
Industrial Applications

Manufacturing of Inkjet printer nozzle drilling

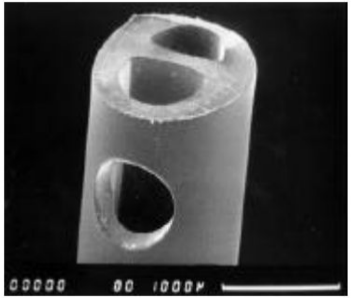
- Modern printers like HP's Deskjet 800C and 1600C have 300x 28µm input diameter nozzles giving a resolution of 600 dots-per-inch
- Laser Drilling of nozzle arrays allowed manufacturers to produce higher performance printer heads at greater yields

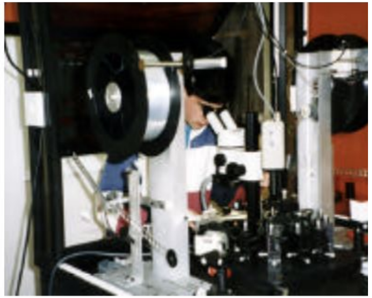


Array of 30µm diameter ink jet printer nozzles drilled in polyimide



Tapered nozzle with rifling



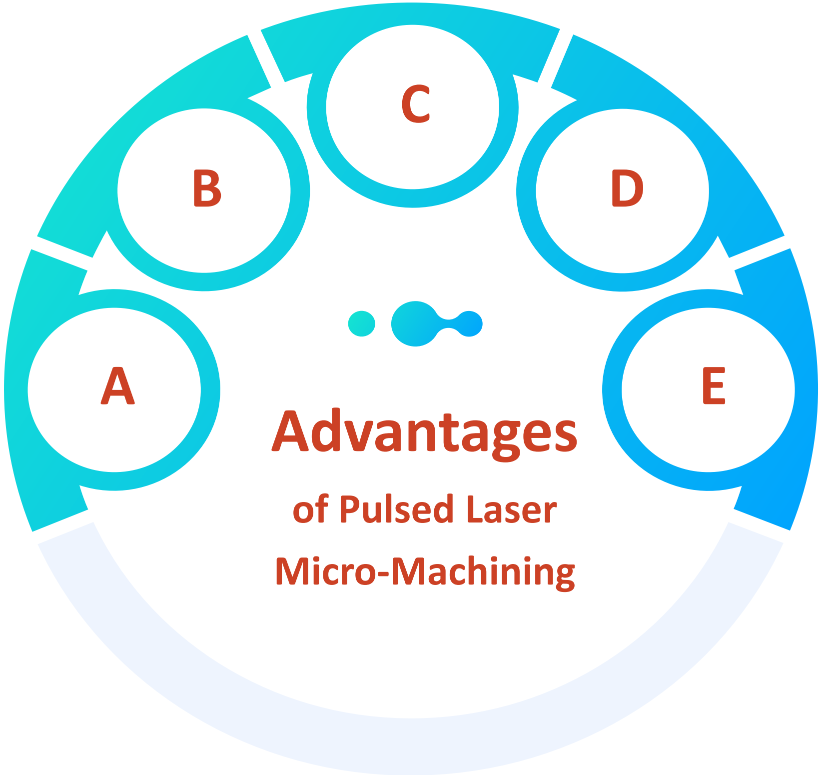


(a) Hole in the side of a bilumen catheter (b) Automated reel-to-reel excimer laser workstation for simultaneous hole drilling in optical fibers

Hole drilling in biomedical devices

- An ABG catheter for monitoring blood in prematurely born babies
- The hole at the side of the PVC bilumen sleeving tube through which blood is drawn is machined using a KrF excimer laser
- In this case the clean cutting capability of the laser provides the necessary rigidity that prevents kinking and blockage of the tube when inserted into the artery

Advantages of PLMM



A. Key Factors

An automated process is easy to achieve due to high speed, high accuracy and repeatability.

B. Wide range of Applications

The ability to machine metals and non-metals (e.g. ceramics and polymers) This can be done by adjusting laser properties such as peak power, wavelength, and pulse duration.

C. Small Features

The capability to machine very small features down to micron level

D. Multiple Axes

Machining of flat parts or complex 3D parts can be easily achieved through the use of the correct workstation, which allows processing at a variety of angles vs. the surface of workpiece.

E. No wearing of the tools

It’s a non-contact technique, which prevents contamination of the work piece or wear of the “machining tool” as is the case in traditional mechanical processes.

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THANK YOU