Advances in High Precision Laser Micromachining

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Outline

- Introduction to Oxford Lasers
- Effect of wavelength & Pulse duration
- Process is the KEY!
- Examples of ns, ps and fs second micromachining
- Summary

Oxford Lasers Ltd

- Didcot, Oxon (UK), Boston (USA), Paris (France)
- Founded in 1977 (Excimer and Copper Laser Manufacturer)

  Oxford University spinout
- Two divisions: (a) Laser micromachining

  (b) High-speed imaging
- Markets: microelectronics, solar, healthcare, automotive, biomedical, telecoms, R&D etc

We offer:

- **Turn-key Laser Micromachining Systems**
- **Sub-contract Laser Micromachining Service**
  - **Proof-of-Concept Trials**
  - **Contract R&D**
  - **Small and medium volume production**

Oxford Laser Range of Systems

E Series

A Series

Advanced R&D System

Compact Micro-Michining System

C Series

Alpha Series

Robust Full production System

Ultra Compact Micro-Machining System

J Series

Ultra fast System

Oxford Lasers' Workstation

Configurations can include:

- Different lasers (ns, ps, fs, IR, green, UV)
- Different motion control
- Beam conditioning
- Camera systems
- Auto Align
- Auto Focus
- Power measurement
- Cimita Software
- Part handling/automation

Importance of wavelength

The laser wavelength and material optical properties determine **light absorption** (i.e. the extent to which the material takes up the deposited energy)

Incident laser light on surface = [reflected] + [absorbed] + [transmitted]

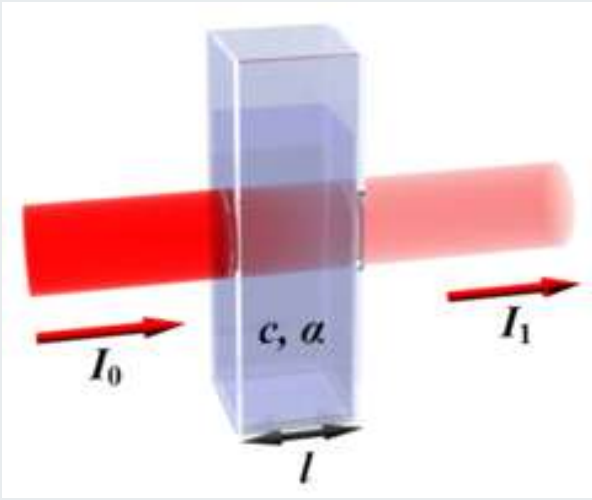
Only [absorbed] light in the material is useful for *Laser Micromachining* and the optical penetration (absorption) depth defines the process resolution

Linear Absorption requires high material absorption coefficient

difficult to achieve if materials transparent

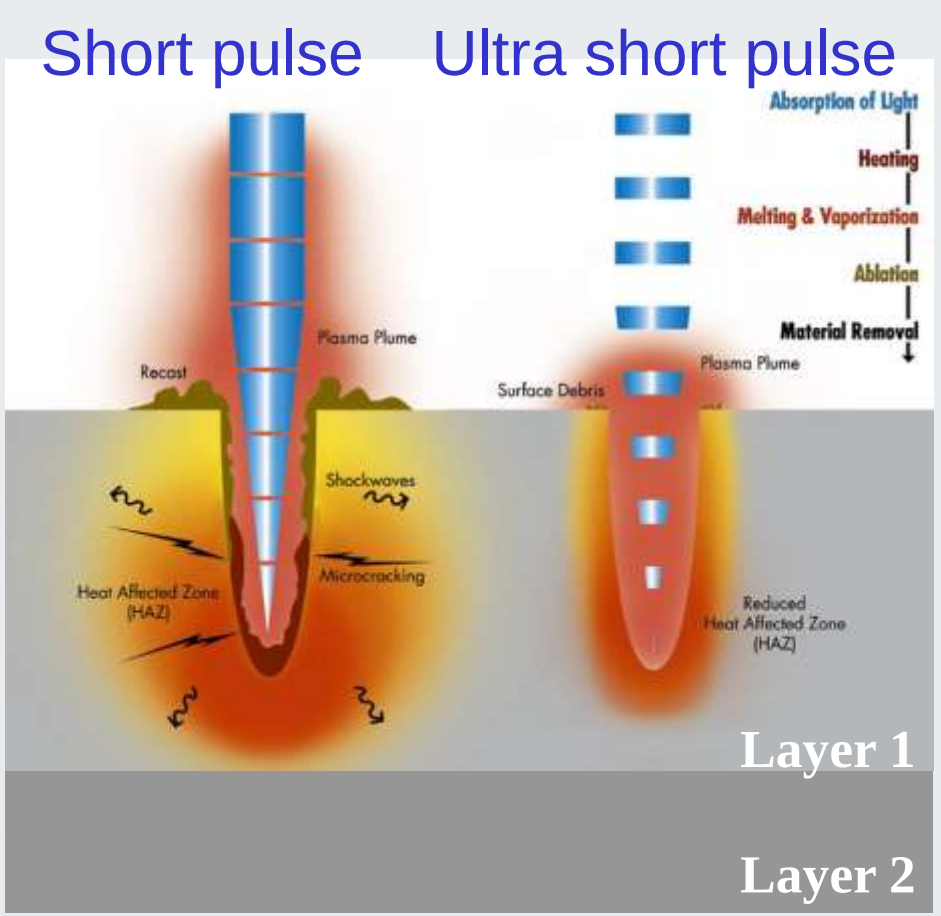
- requires deep UV wavelengths

Beer-Lambert law
(assuming linear absorption)



Importance of laser pulse duration

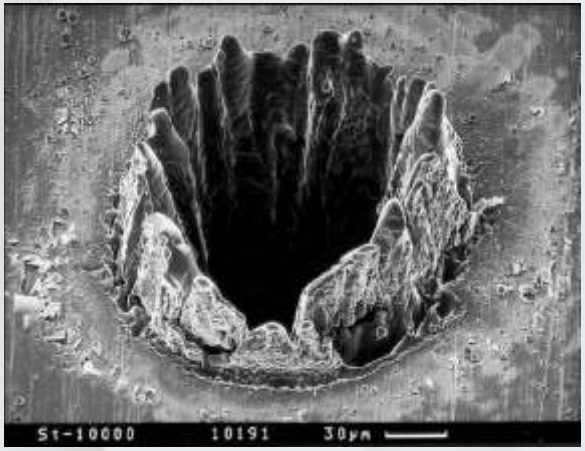
- Short pulses (>10ns) associated
  - Thermal ablation processes
  - Prolonged laser+plasma heating
  - Beam attenuation losses
  - Melting and recast debris (evident)
  - Heat affected zone, HAZ (hidden)
  - High removal rates
- Ultra short pulses (<0.01ns)
  - “Cold” ablation processes
  - Shorter plasma lifetime
  - Rapid energy deposition (less debris)
  - Deterministic ablation thresholds
  - Restricted HAZ
  - Low removal rate



The laser pulse duration determines the “**heat spreading**” in the material. Crucial for micromachining is minimal thermal damage.

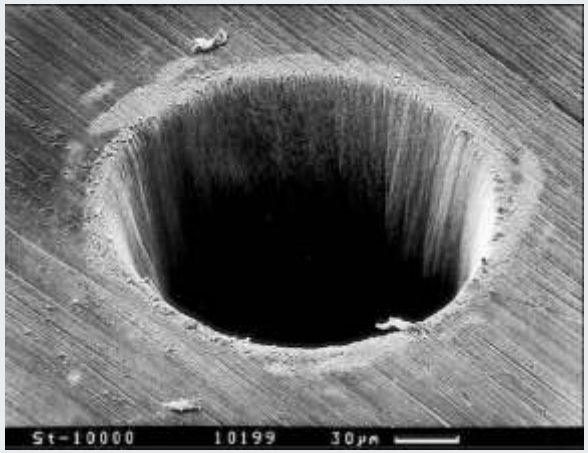
How short is short?

ns pulses



- Melt, burr, HAZ
- Limited accuracy
- High throughput

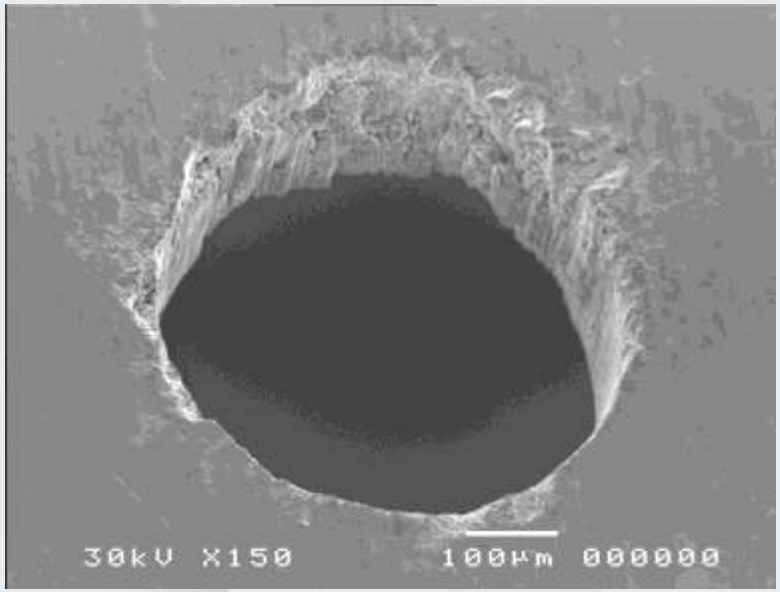
fs pulses



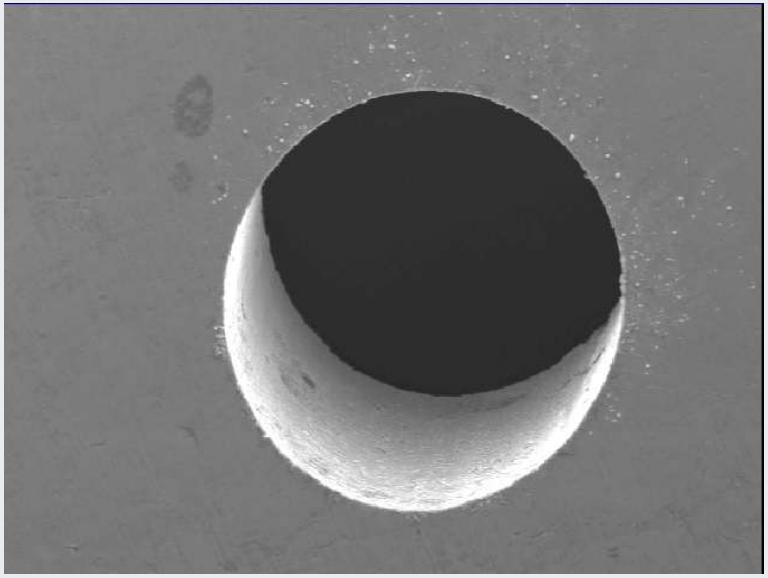
- Perfect quality
- High accuracy
- Slow

C. Momma, B.N. Chichkov, S. Nolte, F. von Alvensleben, A. Tünnermann, H. Welling, B. Wellegehausen, “Short-pulse laser ablation of solid targets”, Opt. Commun. **129**, 134 (1996)

Which one was drilled with a ps laser?



A

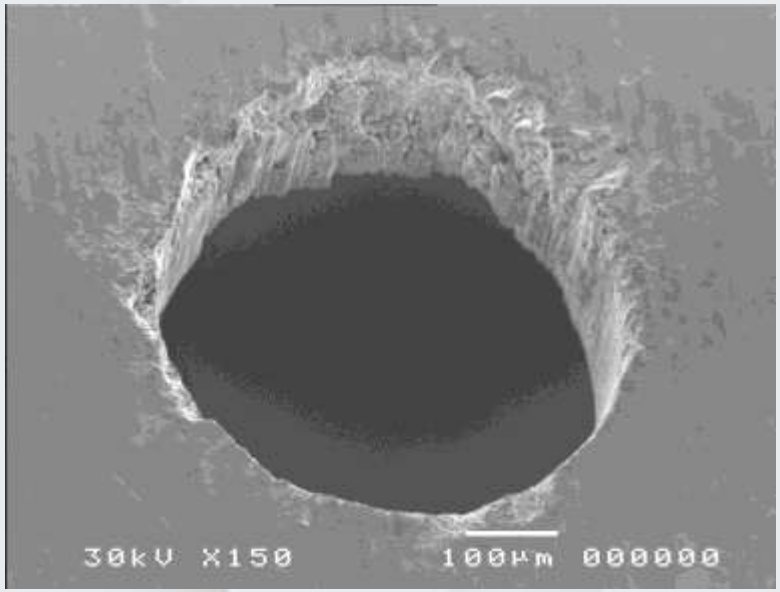


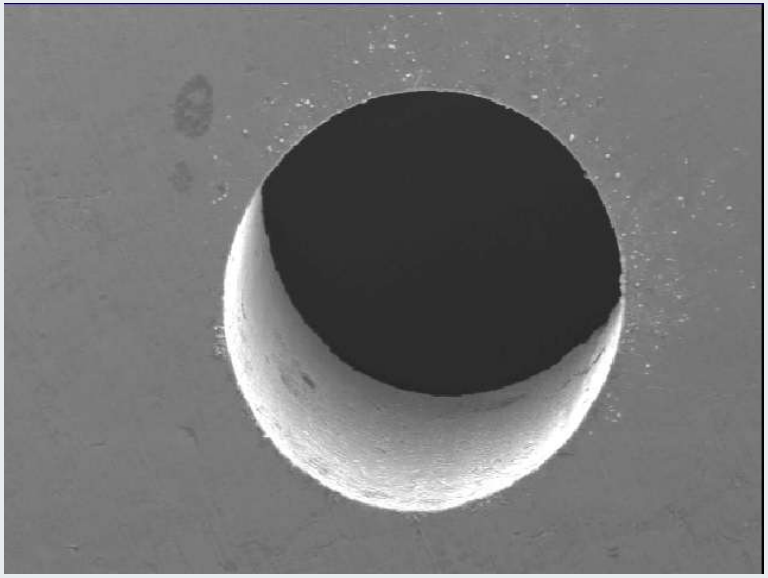
B

500um diameter holes drilled in steel:

- one drilled with a nanosecond laser,
- one drilled with a picosecond laser

Answer…..



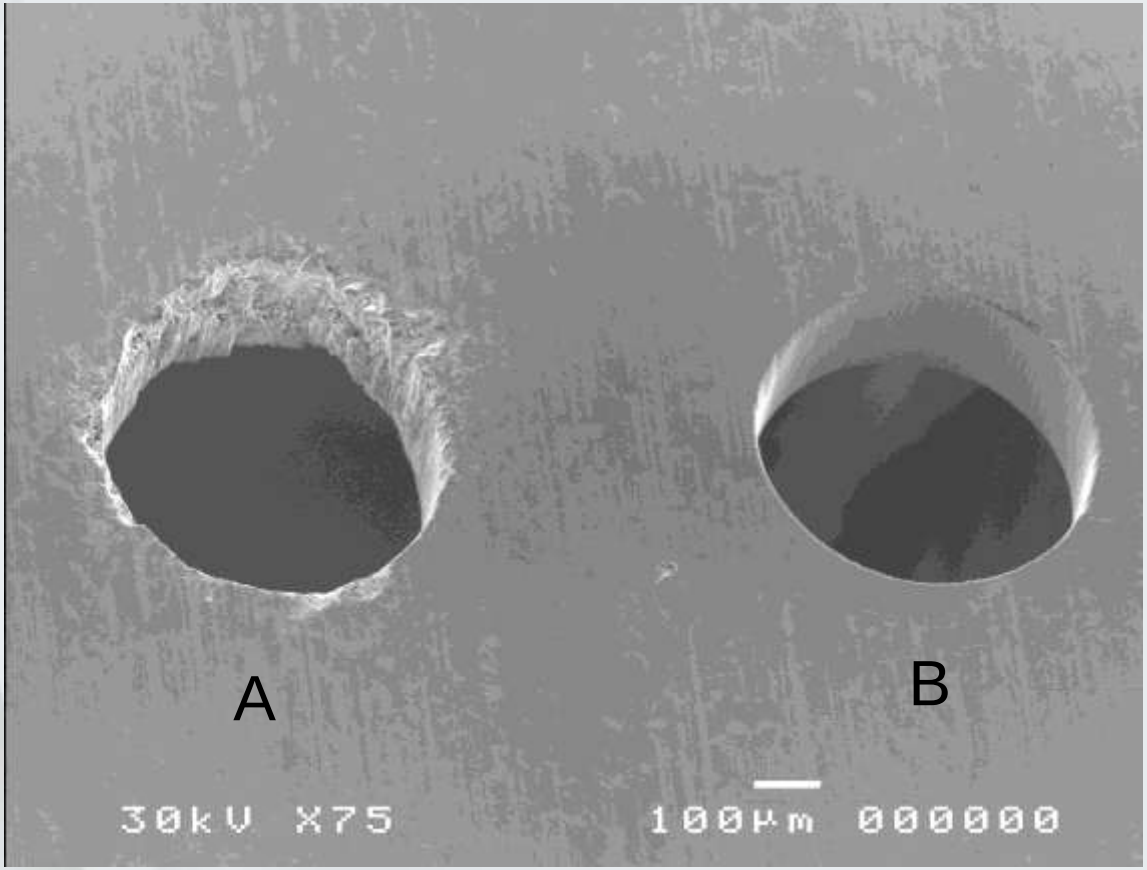


Picosecond

Nanosecond

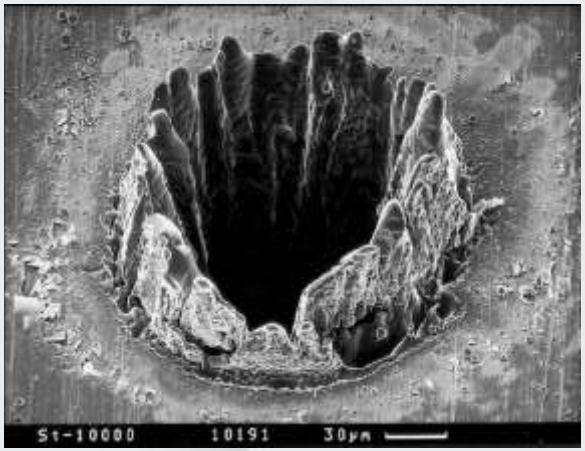
500um diameter hole in steel

Which one was drilled with a Ps laser?

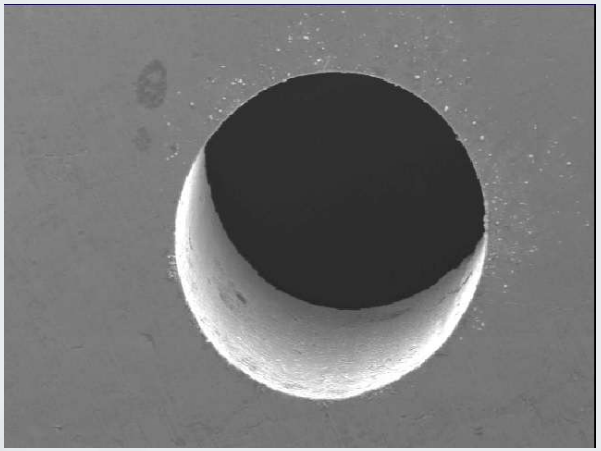


500um hole diameter in Steel

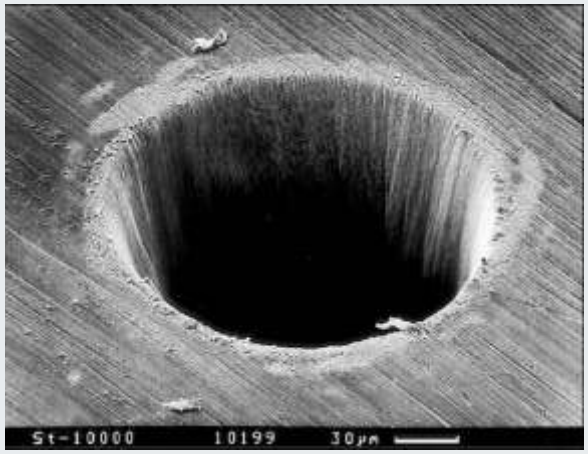
Process first, pulse duration second



Nanosecond



Nanosecond



Femtosecond

- Ultrashort pulse lasers can produce ***poor*** quality
- Nanosecond lasers can produce ***superb*** quality
- Process is **key**
- In comparing lasers and sources it is **vital** that processes are optimised

Example 1 - Drilling Silicon Nitride

Task is to drill arrays of holes in Silicon Nitride

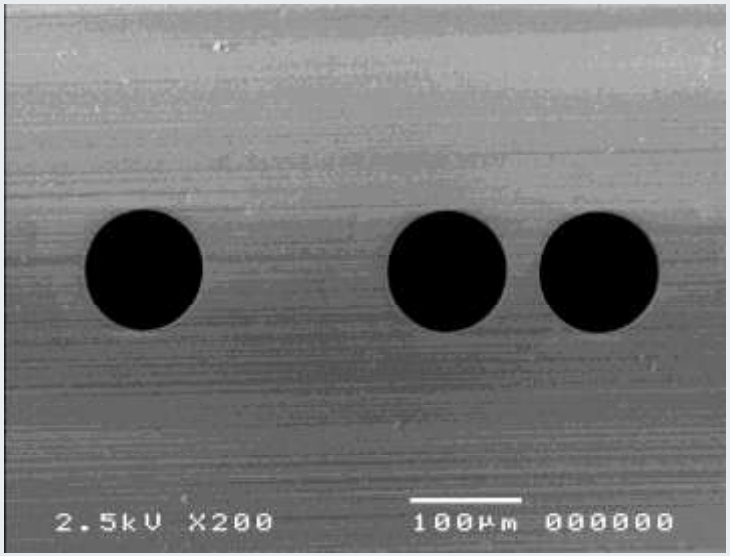
Good absorption with green nanosecond light

Key Components : - high quality air bearing stages,

- optical trepan head

- fast optical attenuator

High quality drilling requires use of optical trepan head

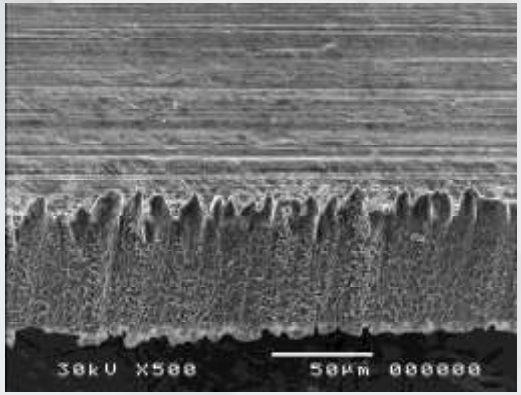


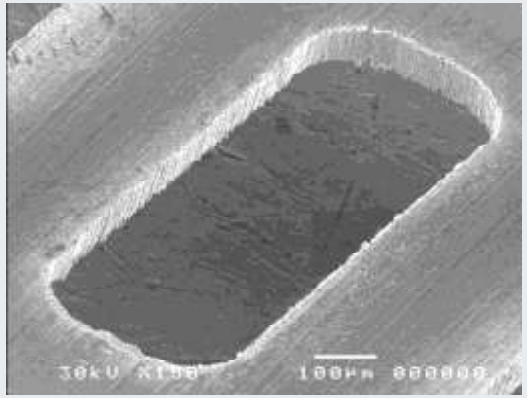
Case Study 2 - Cutting Nickel Foil Electronic Components

Task is to cut a variety of shapes from sheets of Nickel

Material shows good absorption with Visible or UV light

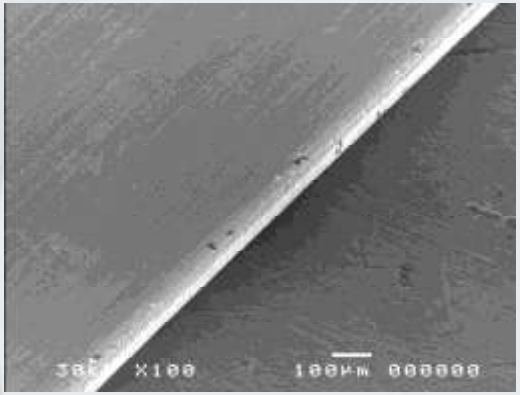
Key Components : High quality Galvo Scanner, fast optical attenuator

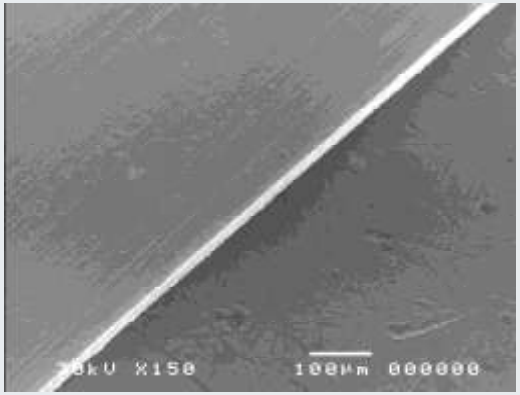




Nanosecond Processing

Example 2 - Cutting Nickel





Picosecond Processing

Conclusion :

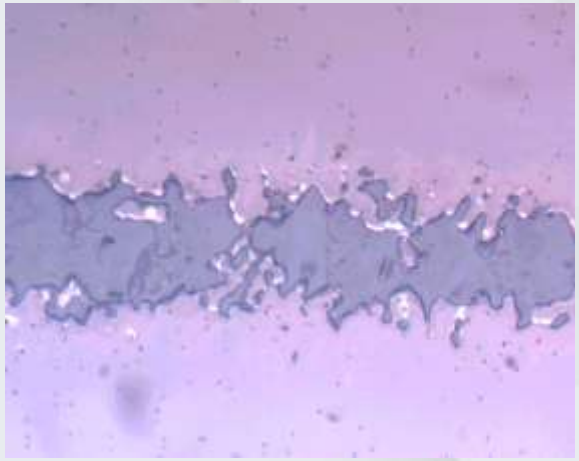
- Pico second laser - pulse duration 10ps
- Wavelength UV - good choice

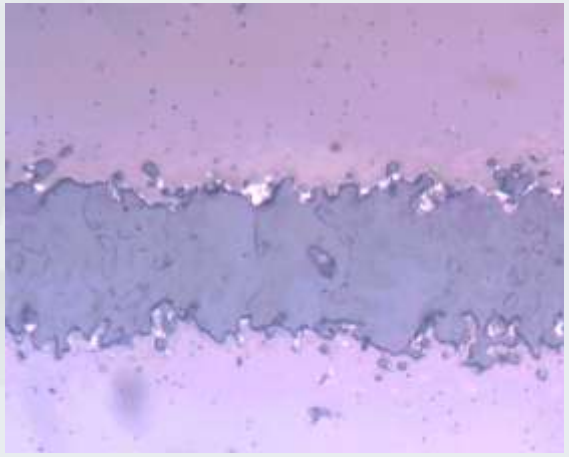
Example 3 - ITO on polymer

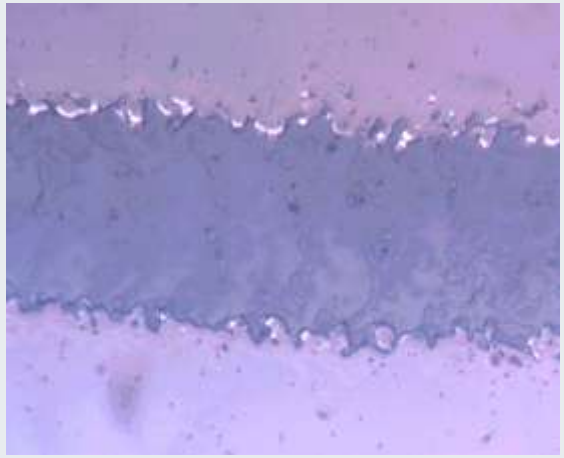
Task is to pattern ITO on polymer film

Material to be removed is only 100nm thick

Key Components : - picosecond laser,
- fast optical attenuator,
- direct writing ?







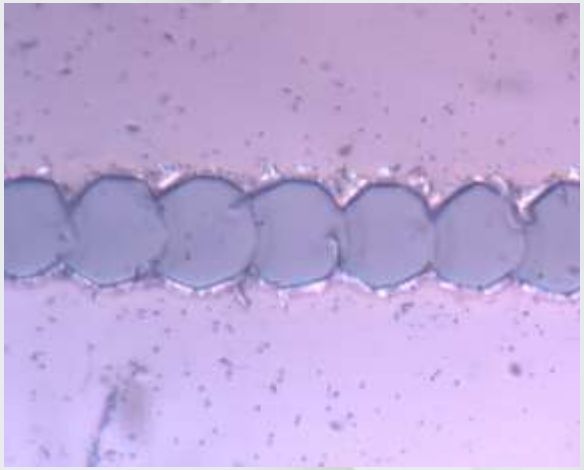
Line (A) : a) low fluence b) mid range fluence c) high fluence

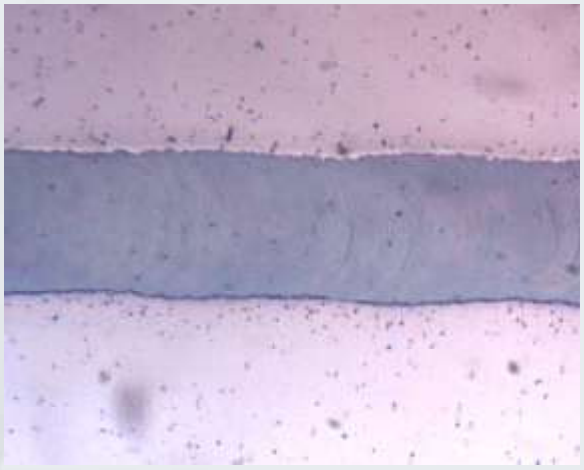
Controlling the Process: Thin Film Ablation

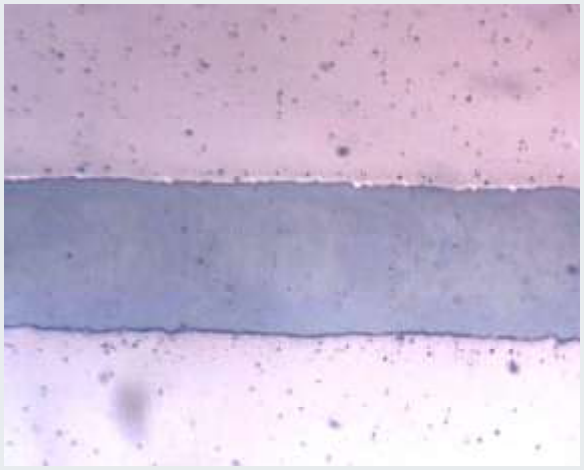
Key Components : - picosecond laser,

- fast optical attenuator,

- modified optical set-up



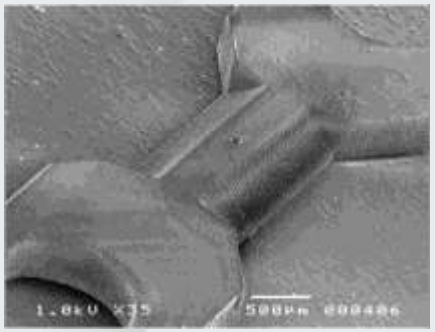




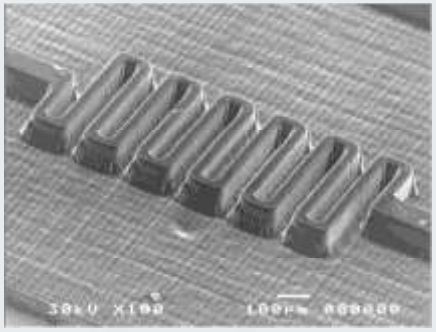
Changed optical set-up, same laser, same low fluence,

Note slight wobble in path: application may need better X,Y stages

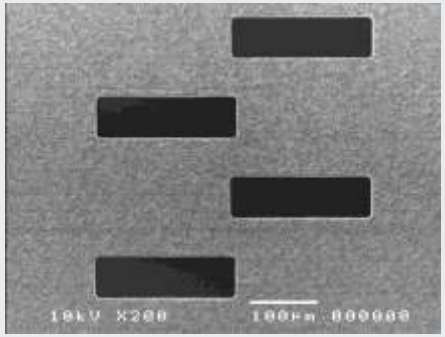
Examples of ns laser machined features



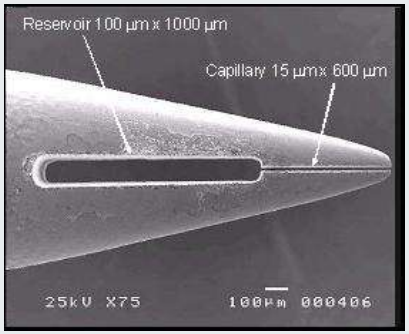
Silicon Nitride



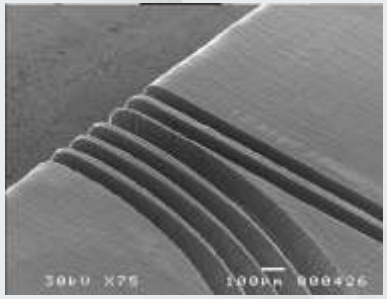
Diamond



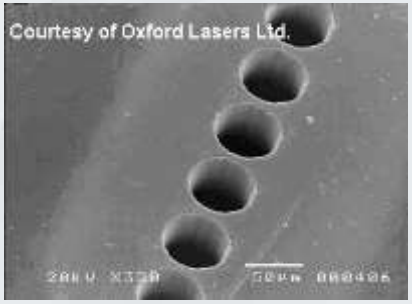
Silicon Nitride



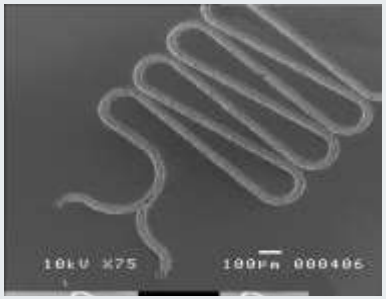
Tungsten



Polyimide



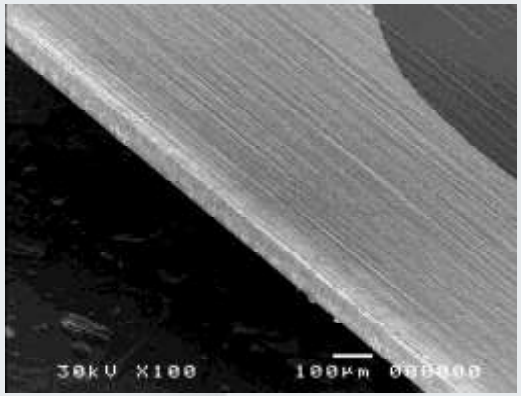
Polyimide



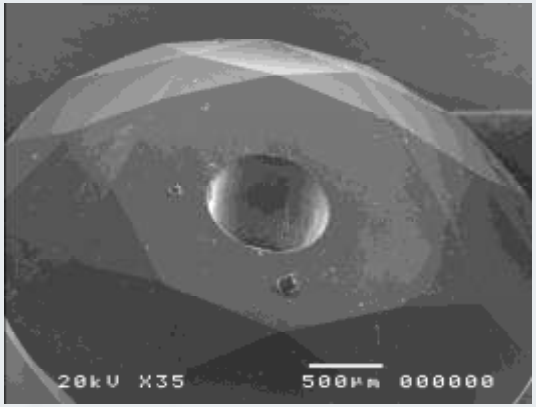
Glass

Stainless Steel

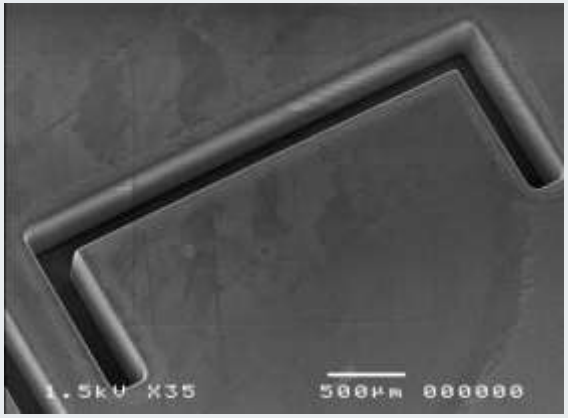
Examples of ps laser machined features



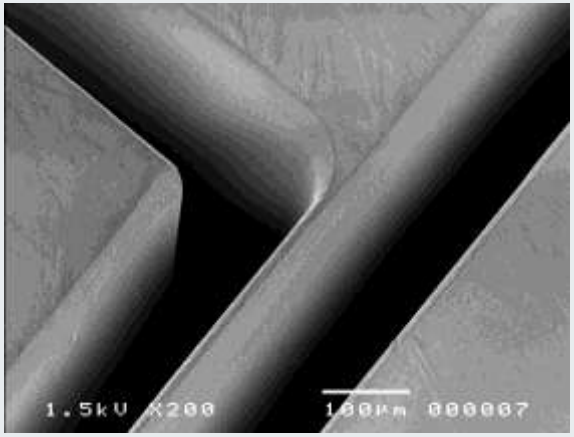
Nickel



Drilling diamond –
500 micron hole

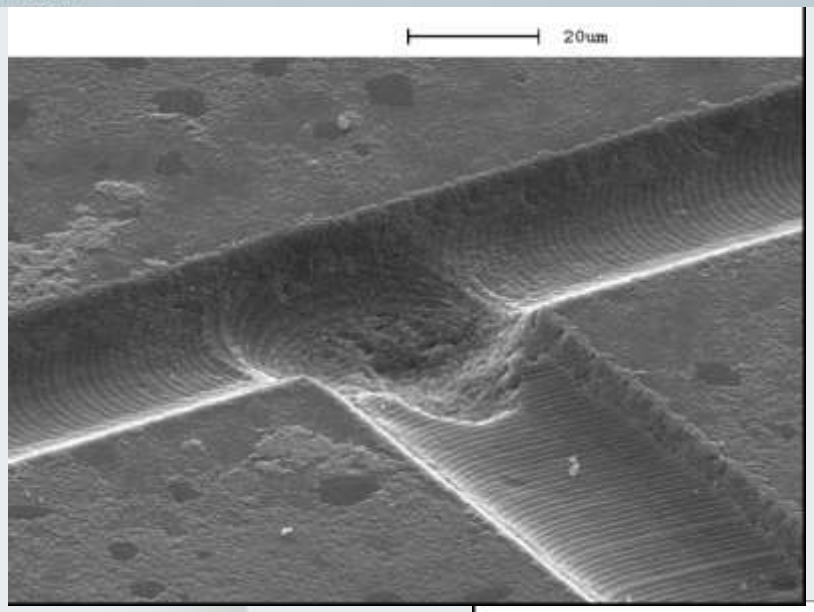


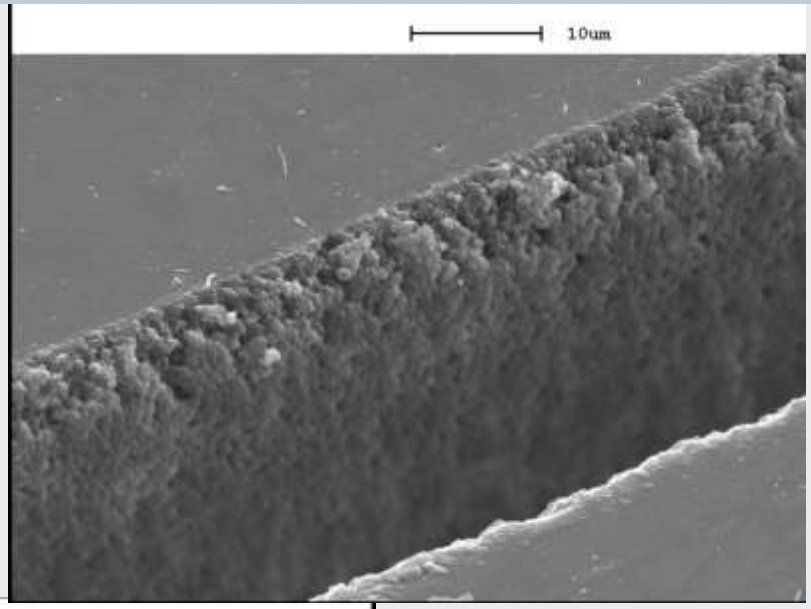
Patterning -
10 micron wide tracks on 70 micron pitch

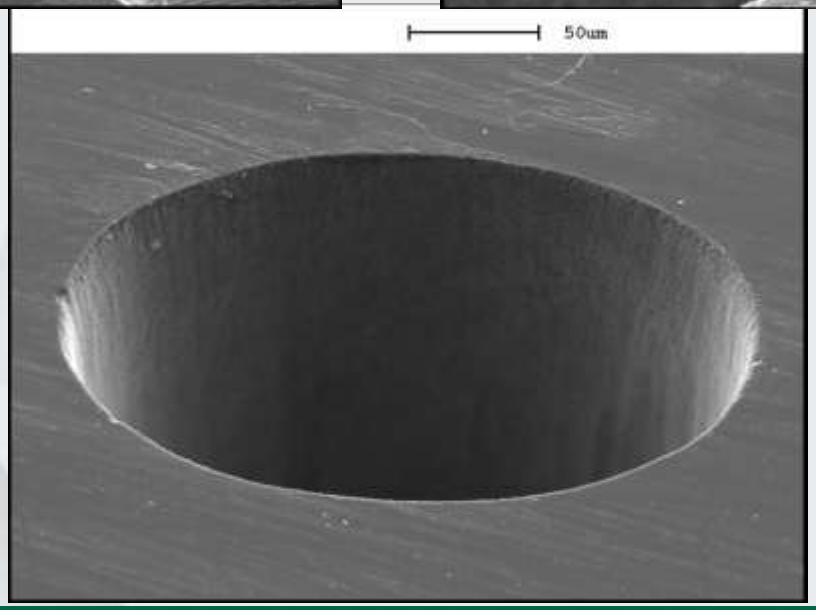


Sapphire cutting

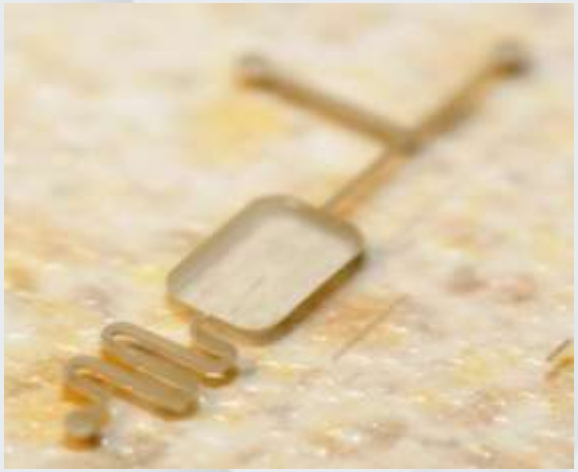
Example 5 : Fs laser Borosilicate



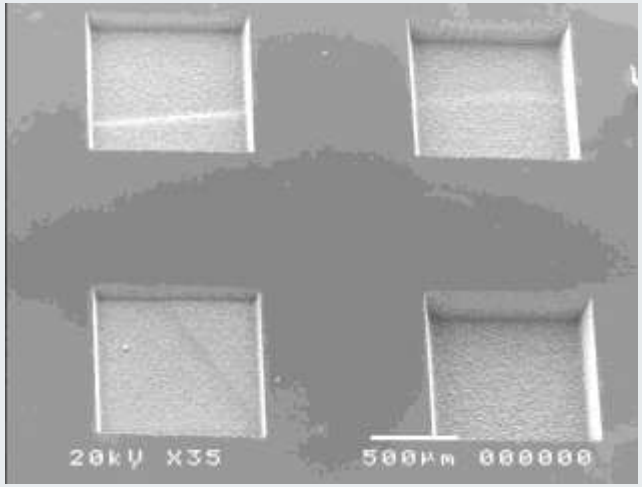




Examples of fs laser machined features



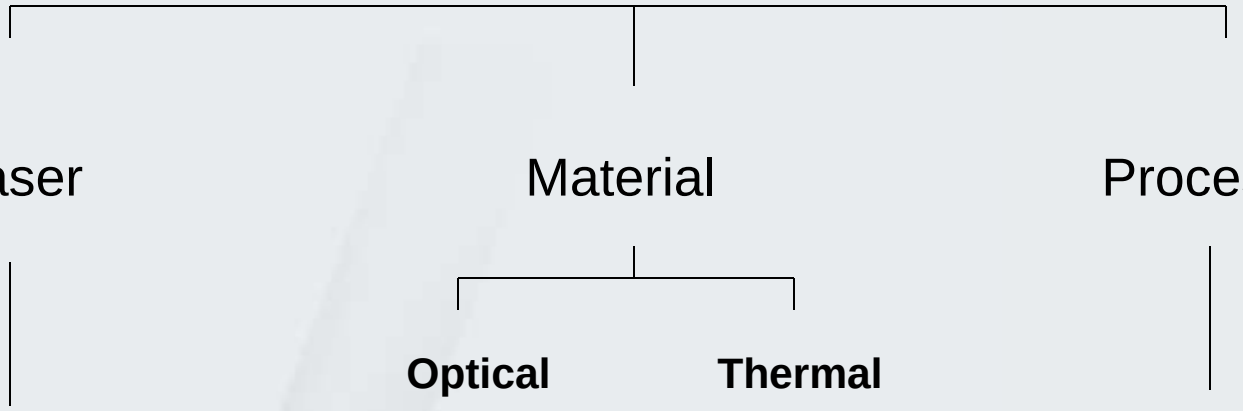
Borosilicate



Glass

Summary

Laser Machining: Important Parameters



Which laser ?

Normally given

Which Technique ?

! IMPORTANT: Most parameters are interrelated.

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