Lasers in Advanced Packaging

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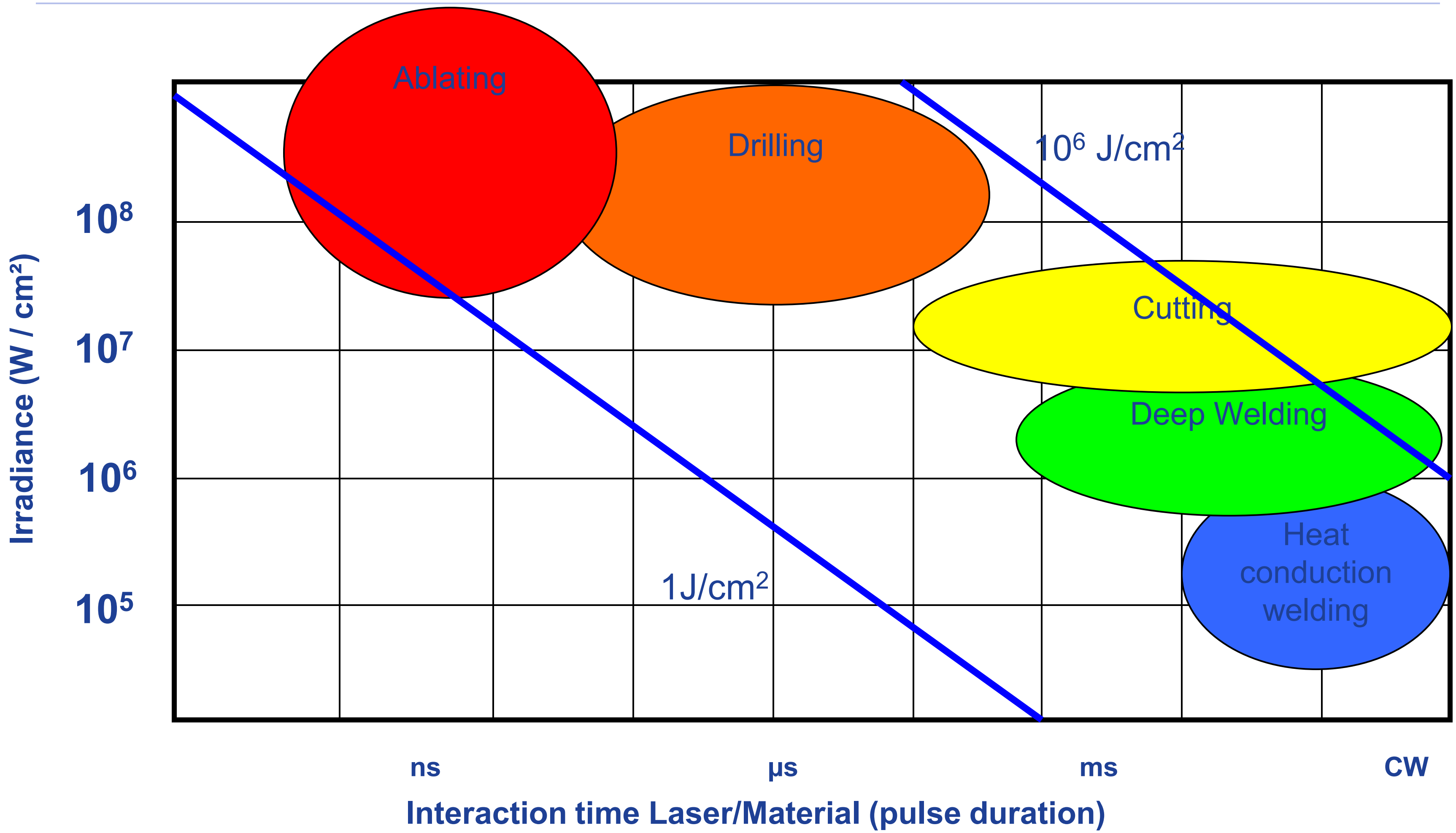
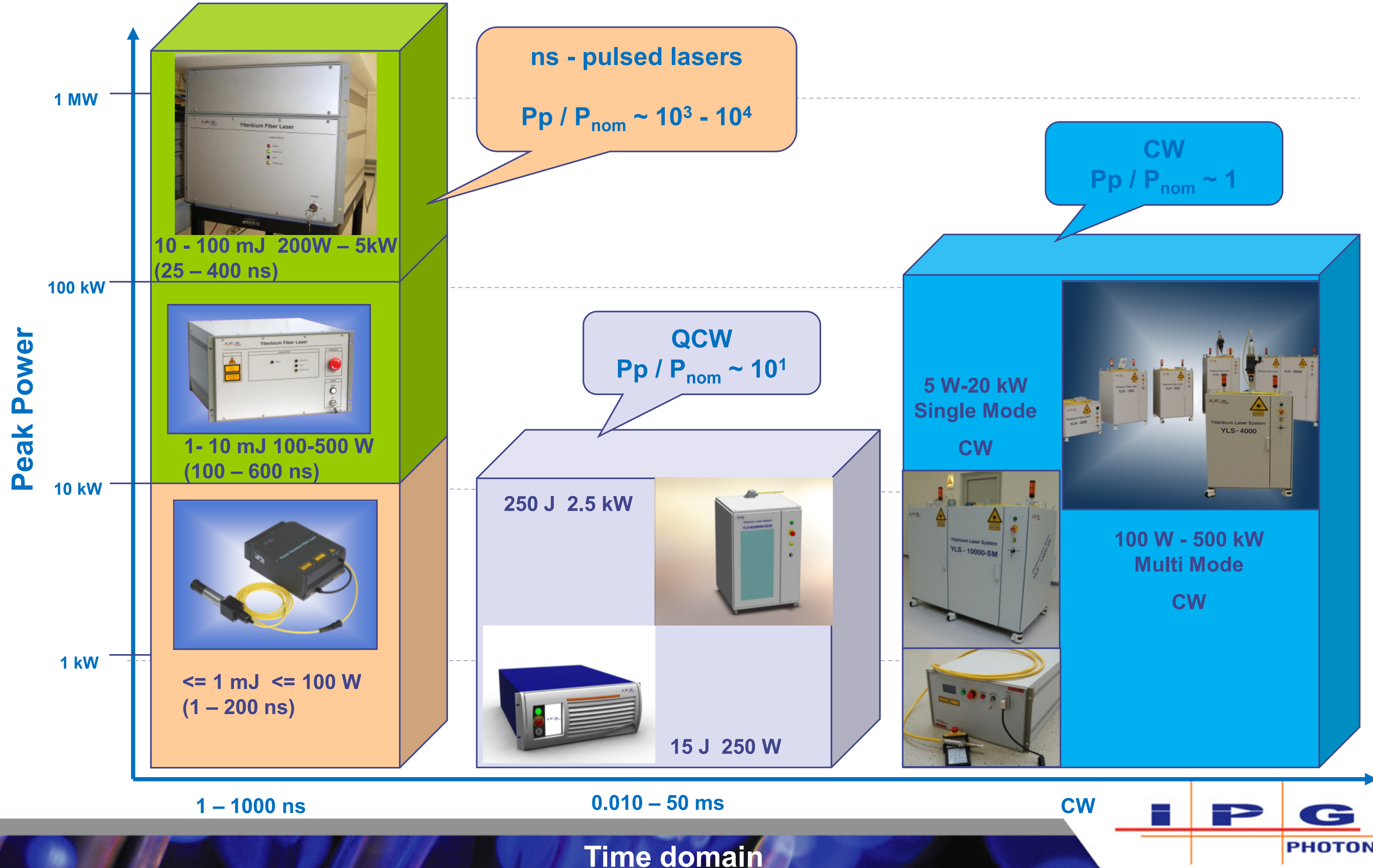
Outline

- Introduction
- Laser Applications in Packaging:
  - Cutting (metals, ceramics, PCBs, foils, polymers)
  - Scribing
  - Drilling
  - Welding
  - Milling, Surface Patterning and Ablation
  - Marking
  - Laser Lift Off
- Summary

Power Density and Interaction Time in Material Processing



IPG Ytterbium Fiber Lasers for Material Processing, 1 micron CW and Long Pulsed Lasers



Extending Fiber Lasers Pulse Durations and Wavelengths

- Shorter pulse duration lasers below 1 ns into sub ps, ps and fs regimes
  - Minimizes heat conduction into bulk material
  - Peak power increase leads to increased non linear coupling

- Shorter wavelength lasers down from Near IR (1064 nm) into green (532 nm) and UV (355 nm)
  - Increases photon energy which tends to increase linear absorption; typically reflectivity decreases
  - Minimum possible feature size reduces (varies linearly with wavelength)

- Longer wavelength lasers at 1550 nm (Erbium Fiber Lasers) and 1940 nm (Thulium Fiber lasers), other wavelength ranges
  - Allows matching particular materials properties

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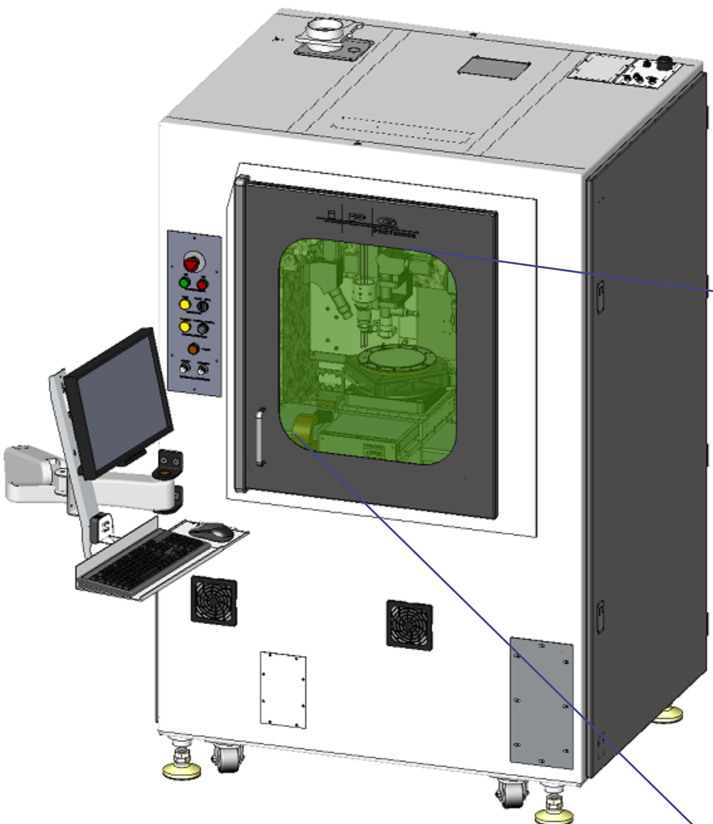
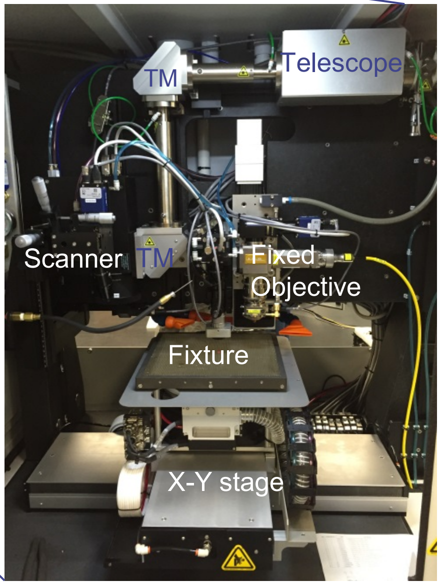
IPG Laser Workstations



- Example IX280: Supports 2 different lasers & 2 separate beam deliveries
- Free space and Fiber Delivery Lasers
- Galvanometer Scanner
- Thermal Cutting Head

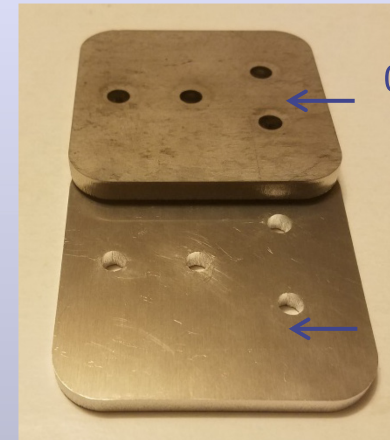


Cutting of Metal Frames

- Cutting of Copper, Brass, Aluminum, Stainless, Mild Steel up to 6 mm thick
- Thermal cutting approach

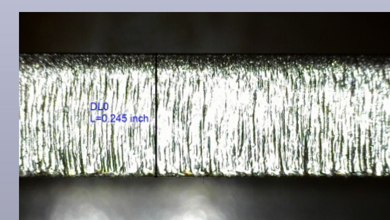
- Cutting of 1 mm thick aluminum frame

0.25” cutting



0.25” SS

0.25” Al

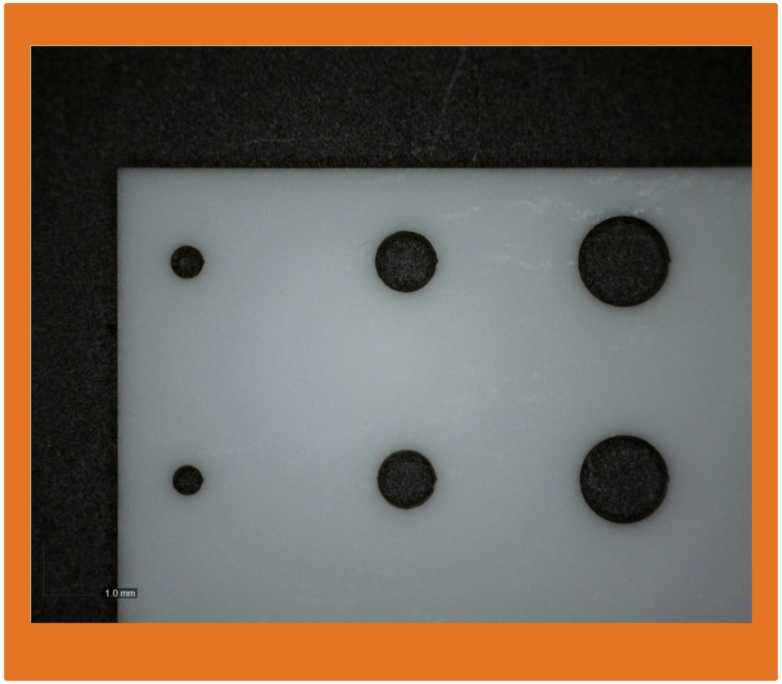


0.25” SS

0.25” Al

Cutting of Ceramic Frames

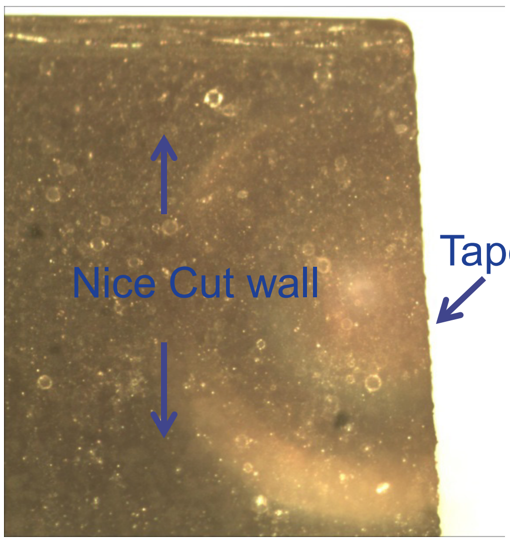
Cutting of 0.025” thick alumina ceramic

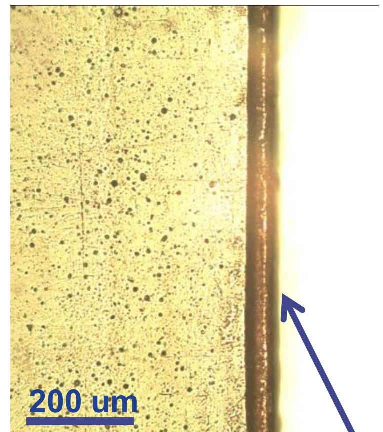


- Thermal Cutting

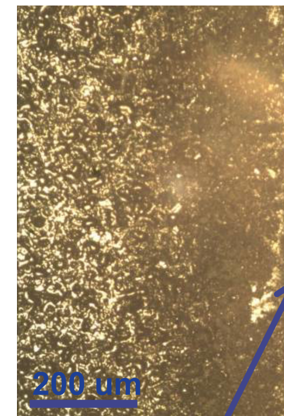
Cutting of Epoxy/Metal PCB

Material: Epoxy (1.3mm) + Metal (0.1mm)





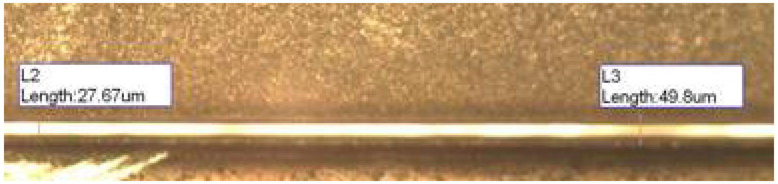
Top view of Cut edge, entrance



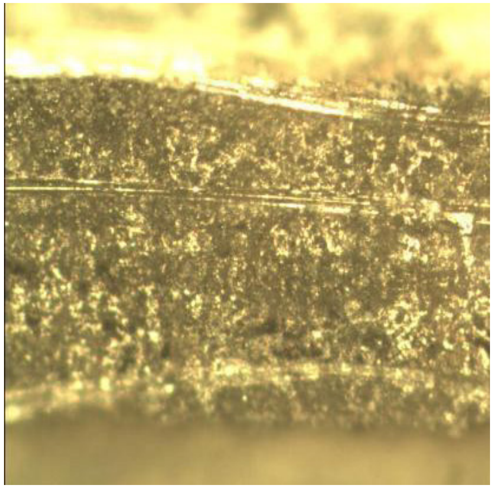
Cut edge, exit

- Ablation Cutting

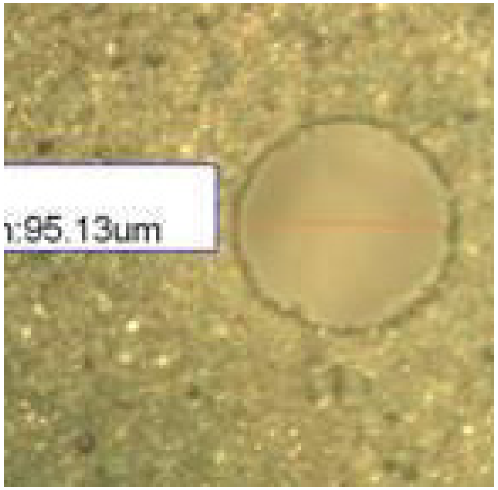
Cutting of FR4 PCB



Top view, high cut quality



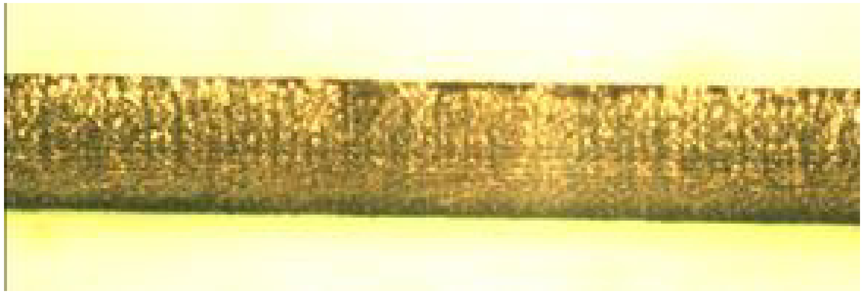
Side view of cut
on 300 microns thick FR4



Exit hole on 200 microns thick FR4,
> 50 holes/sec

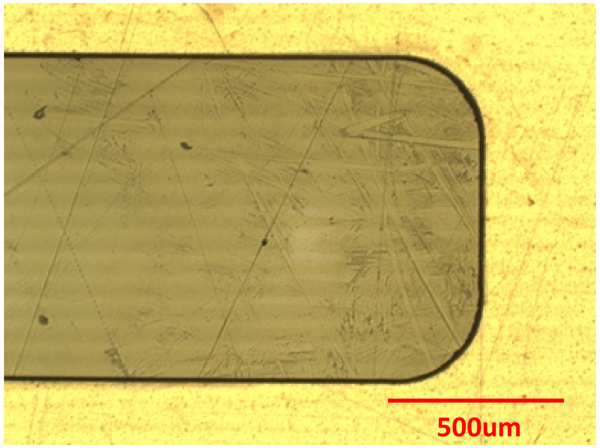
- Ablation Cutting

Thin Metal Foil Cutting



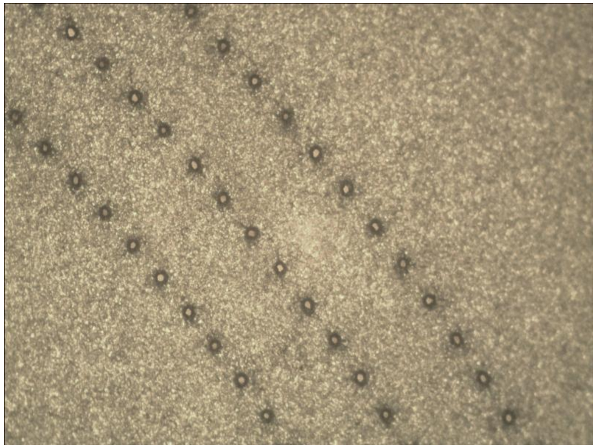
Copper alloy cutting with ultrashort laser - 50 microns thick,
clean cross section with fringes typical of ultrashort ‘cold’ process

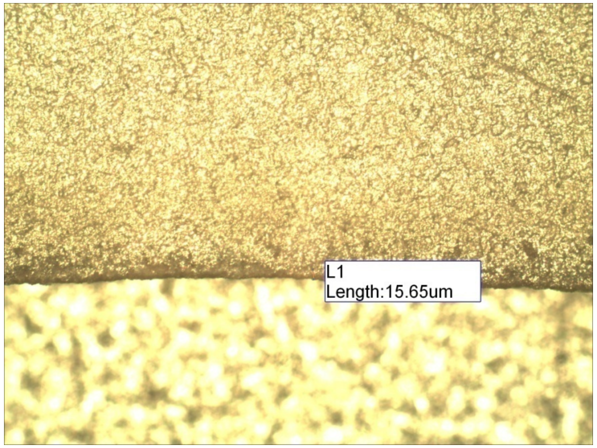
Polymer Cutting



- 75 µm thick Polyimide

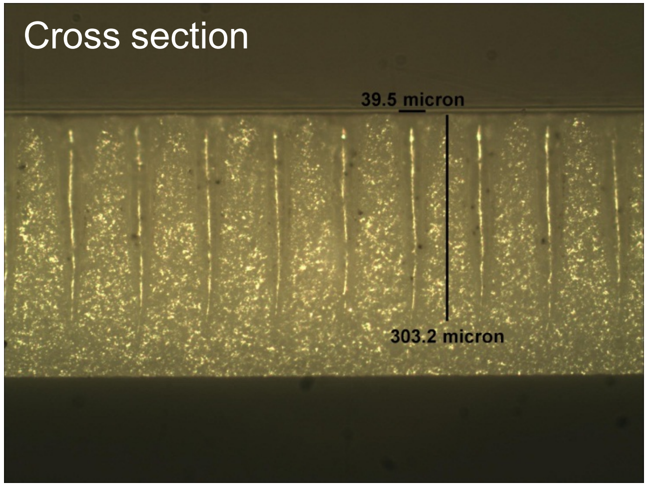
- 75 µm thick PEEK
- 20 mm/sec cutting
- drilling 25 µm holes at 100 holes/sec

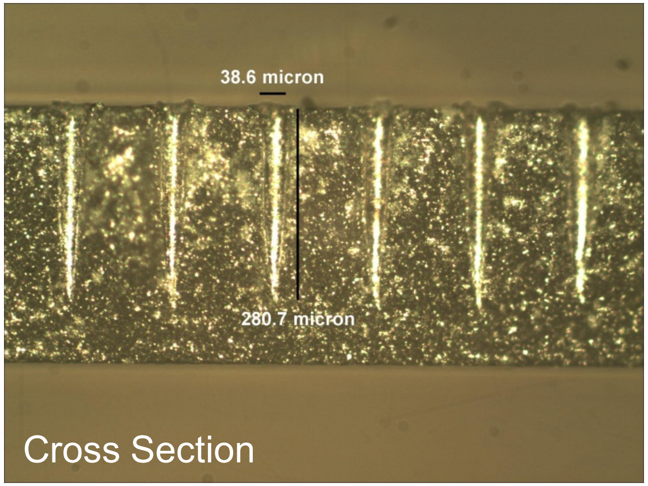




Scribing of Ceramic Frames

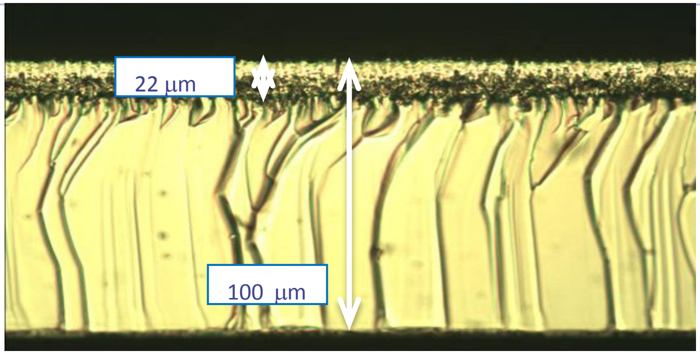
Material:	Alumina, 96%	Material:	AlN
Thickness:	381µm	Thickness:	381µm
Speed:	**300 mm/sec**	**Speed:**	**300 mm/sec**



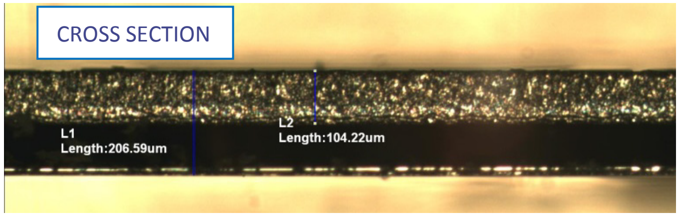


- High Speed single shot scribing – allows breaking

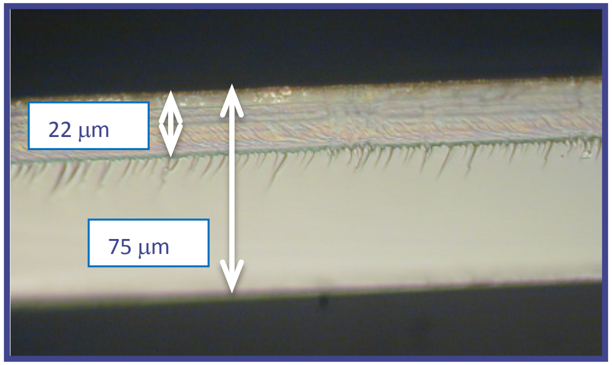
Scribing of Wafers



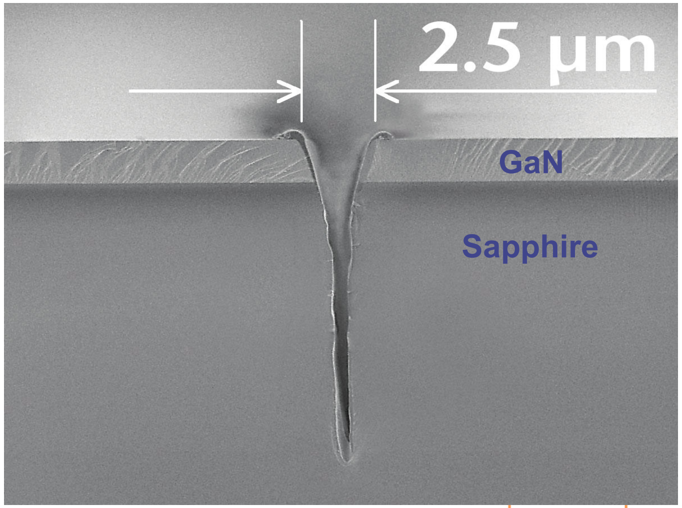
- Scribe and Break for SiC wafer
- 100 mm/sec



- Scribe and Break for Silicon wafer
- 100 mm/sec



- Scribe and Break for GaN/Sapphire
- 150 mm/sec



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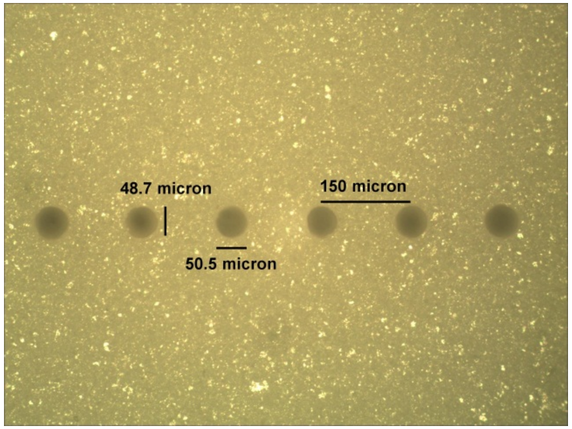
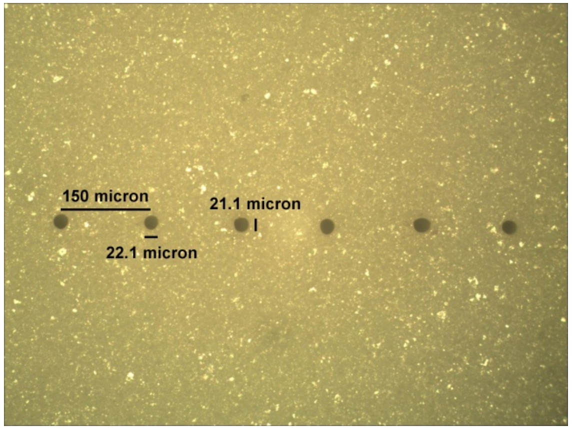
Drilling of Alumina Ceramic

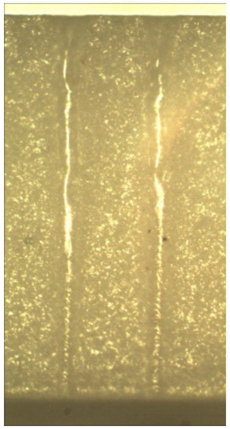
Entrance



Exit



Cross section



- 635 microns thick Alumina
- "micromachining" like quality at high throughput

- 1 Laser Pulse per Hole
- 300 holes/sec
- ~ 20 microns diameter

Drilling of Silicon Nitride

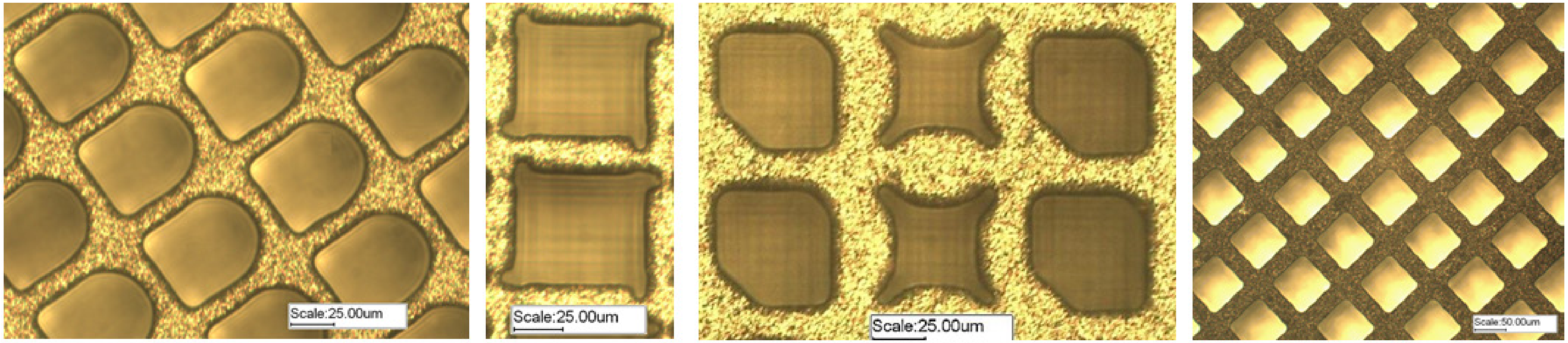
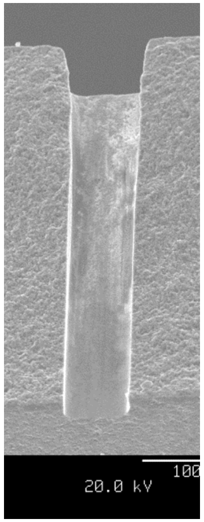


Figure 1: a) Shaped holes in Si_3N_4 b)Shaped holes c) Chamfered and shaped holes in Si_3N_4 d) Rectangular holes in Si_3N_4



- Time per hole: < 1 sec in 200 microns thick, < 2 secs in 381 microns thick
- Shaped Holes: Can switch between round, rectangular, and novel shapes without hardware changes
- ‘Taper less’ holes (used for guide plates in Probe Cards)

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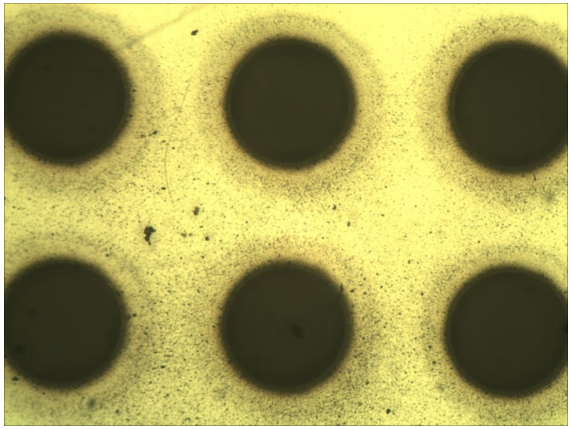
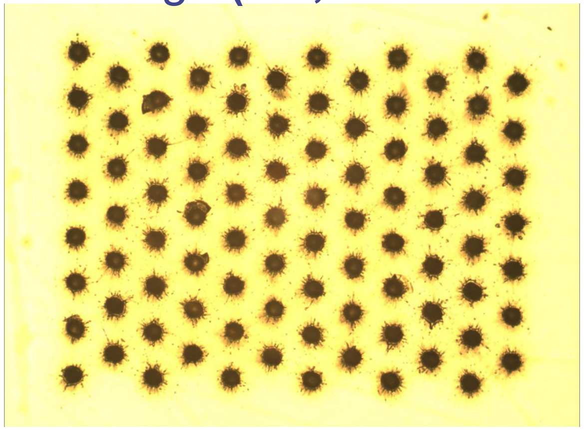
Drilling of Glass

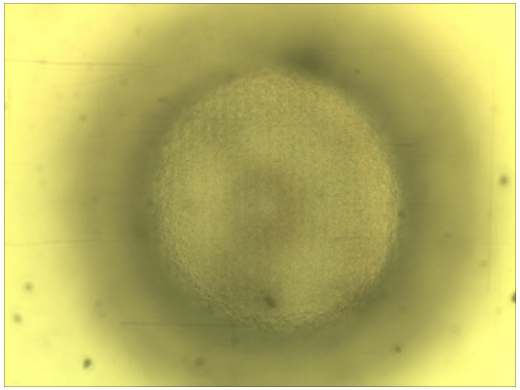
- Blind Holes
- Through **(~ 1,000 vias/sec)**



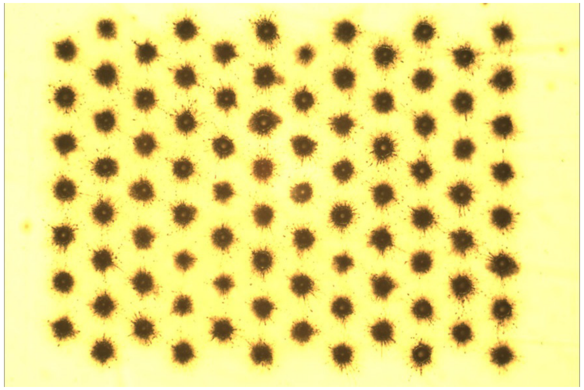
Glass, 400 μm diameter holes at entrance



Glass vias, 26 μm diameter at entrance



Close up, showing flat bottom, ~ 300 μm deep, ~230 μm in diameter



18 μm diameter at exit, 130 μm thick

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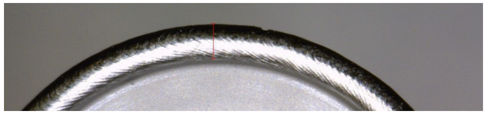
Welding Metals with Fiber Lasers

- Welding of electrodes to terminals.
- Sealing of individual cells.
- Cell to cell terminal welding.
- Welding of modules cases.
- Welding of safety relief valves and other terminals.
- Various dissimilar material combinations.
- Beam wobbling technique if appropriate.
- 100’s of watts to KW power.

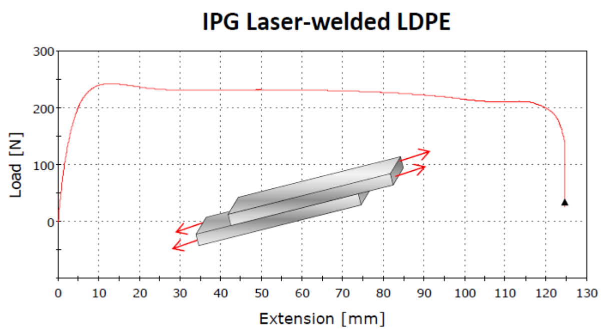
Copper to Nickel alloy

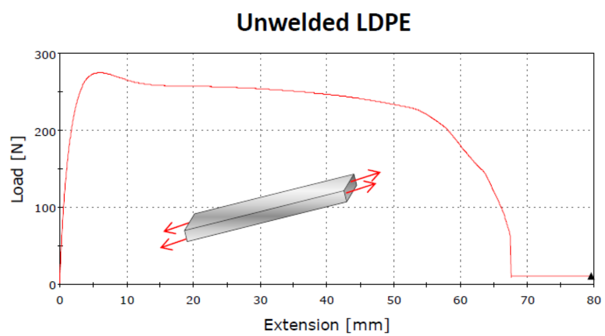


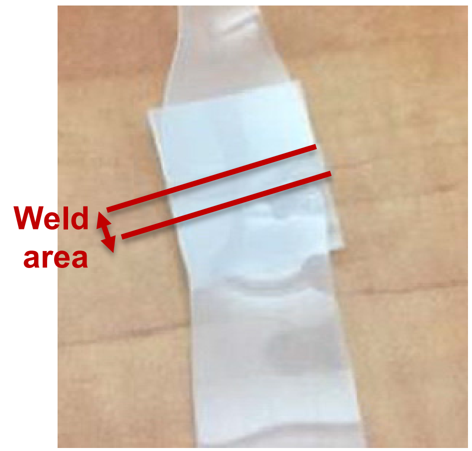
Al and Steel sealing lids

Welding Polymers with Fiber Lasers

- Match laser wavelength to material properties
- Most common thermoplastics can be welded to themselves, acrylics, polycarbonates (PC), polypropylene (PP), polyethylene (PE), thermoplastic copolyester (TPC)





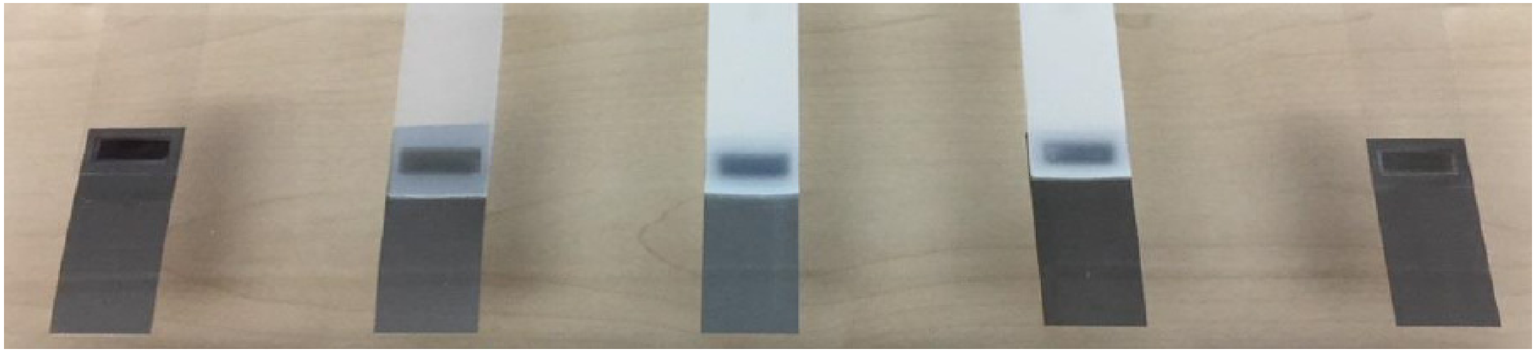


Flexible low density PE (weld area 0.75 cm by 2.5 cm, 1 mm thick)

Welding Polymer to Metal with Fiber Lasers

LDPE to stainless

HDPE to titanium



PC to stainless

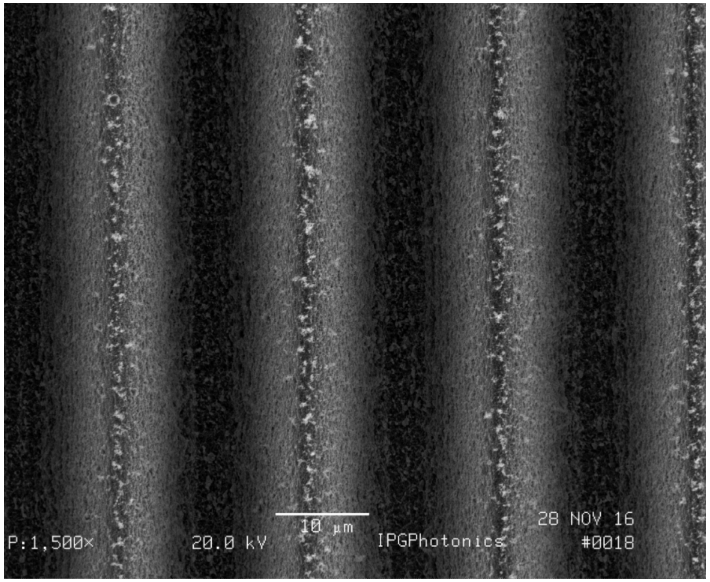
HDPE to nitinol

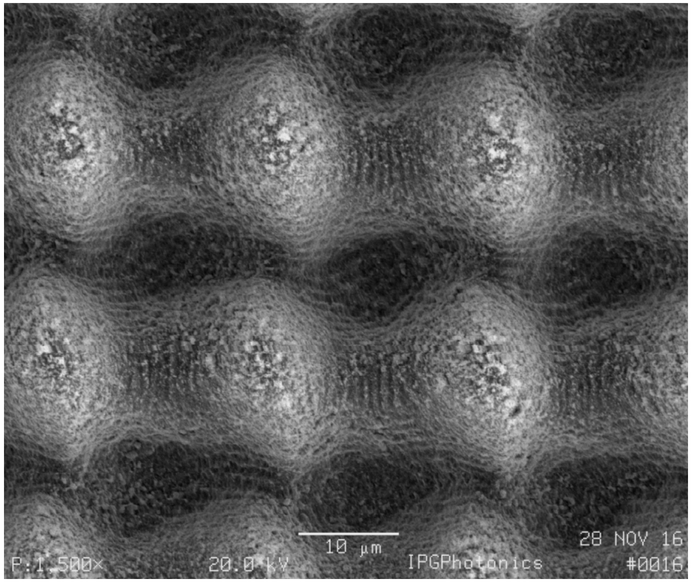
PC to titanium

- Laser transmits through polymer melting at the interface with metal

→ Could replace slow adhesive curing bonding processes in polymers with fast high precision laser bonding

Micro Structuring





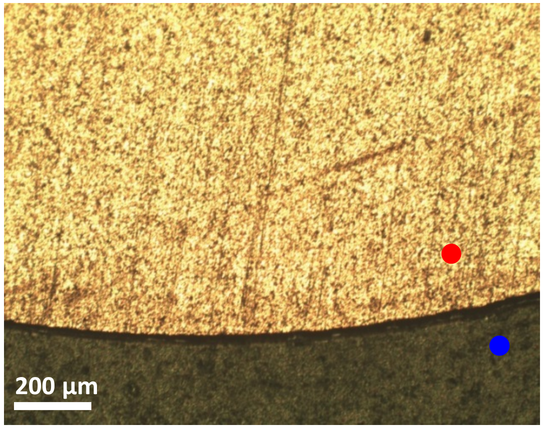
- Linear array of 'V' grooves with period 20 µm, and depth 24 µm

- Array of 'Cone' features with period 20 µm, and height 18 µm

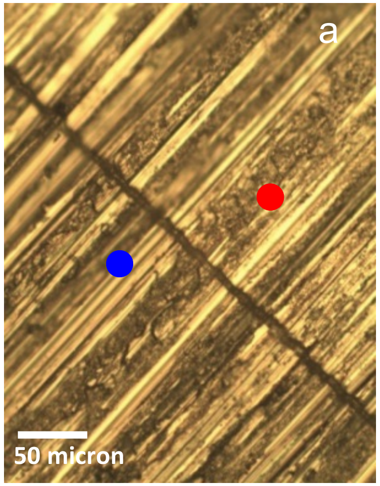
- Top View, Metal Alloy

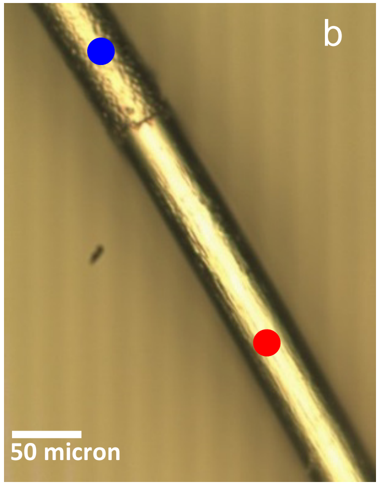
Ablation of Conformal Coatings

- Parylene selective ablation
- Good edge definition
- Minimal impact on the substrate
- High speed area scanning for high throughputs
- CAD conversion for shape definition
- Flexible hatching techniques for precision removal



Ablation of 6 µm thick Parylene on copper





Ablation of 3.5 µm thick Parylene
a) flat surface; b) probe card pin

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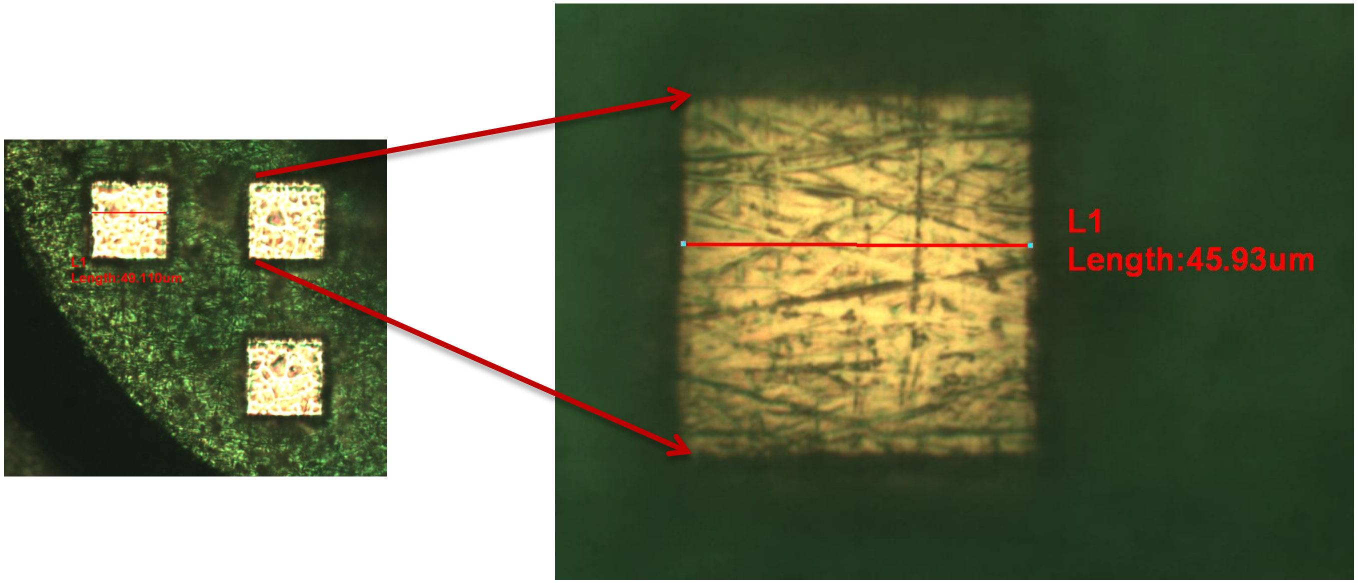
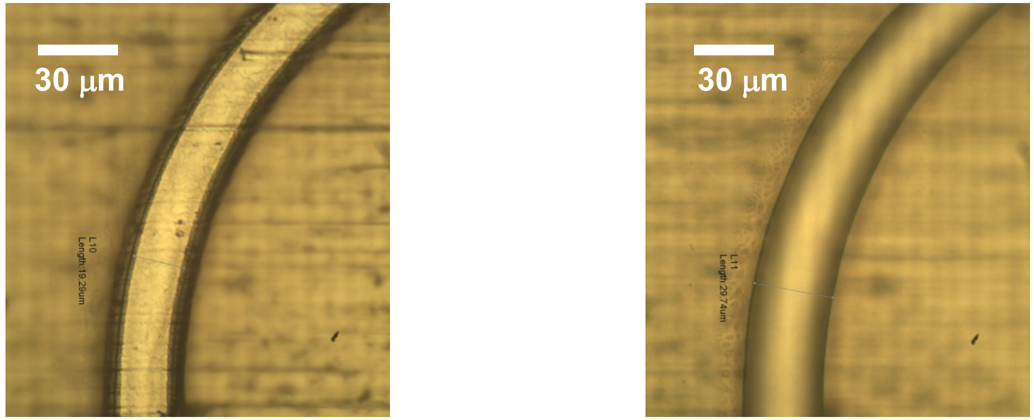
Ablation of Solder Mask



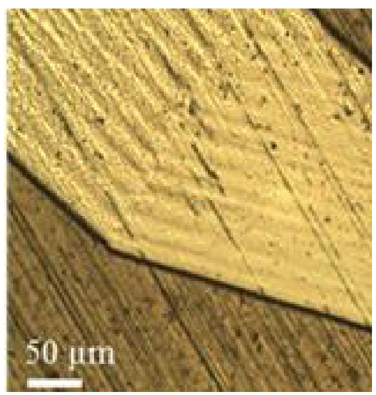
- Ablation of Solder Mask ~ 50 μm deep to Copper Layer in PCB

PHOTONICS

Ablation of Photo Resist



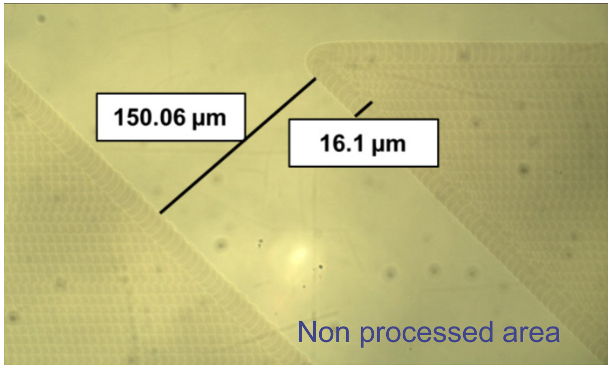
Patterning micro channels in 10 microns thick photoresist (epoxy) on metallic substrate



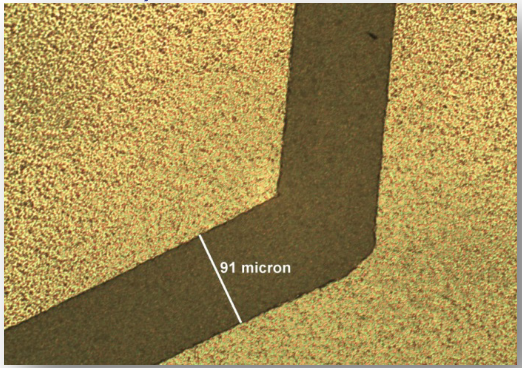
Patterning large features in 10 microns thick photoresist (epoxy) on metallic substrate

Patterning of Sub Micron Thin Films

ITO patterning from glass substrate (transparent to NIR)



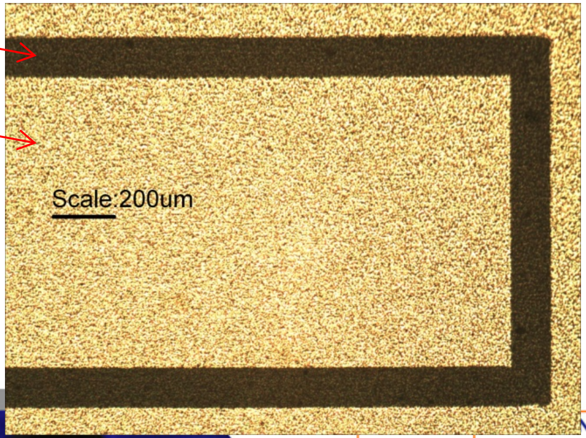
Thin Metal ablation from PET (1 meter/sec)



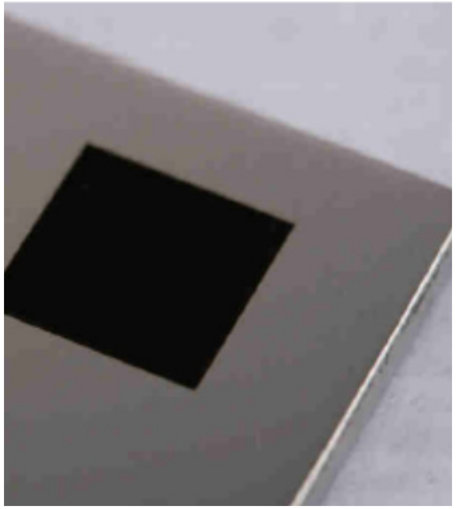
Gold layer removed

Untouched

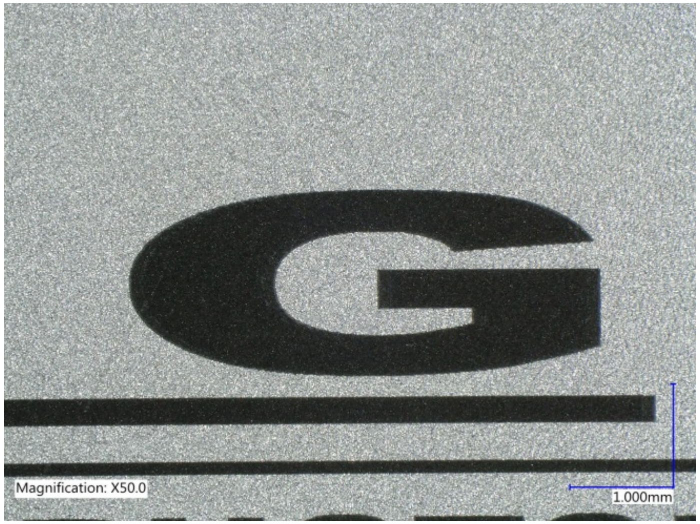
- Gold on PET



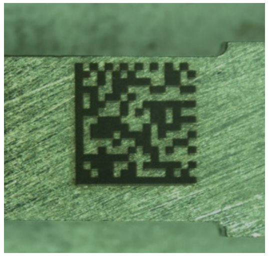
Marking of Metals



Dark Marking on Stainless



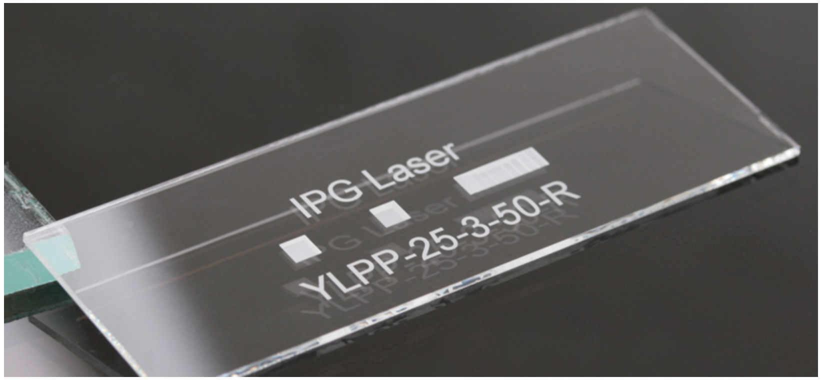
Dark Marking on Anodized Aluminum



Aluminum
marking

Ablation of surface
coating layer

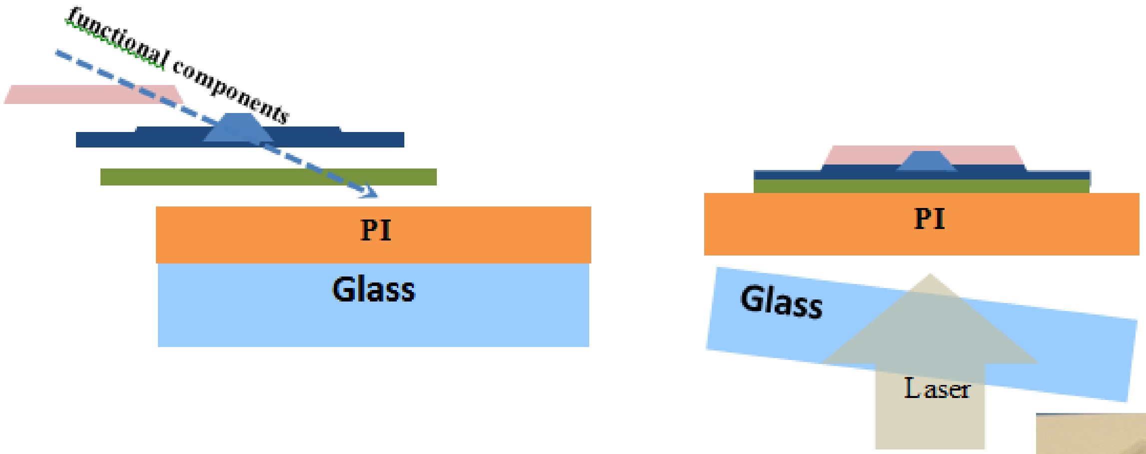
Marking of Glass and Polymers



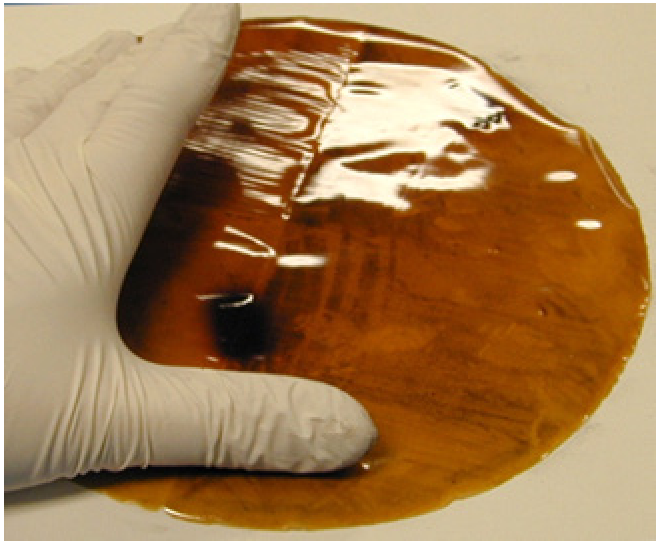
High contrast glass marking

Polymer marking

Laser Lift Off of PI film



Schematic of Laser Lift Off step in the manufacturing of flexible electronics with 355 nm UV fiber laser.



PI LLO from glass wafer

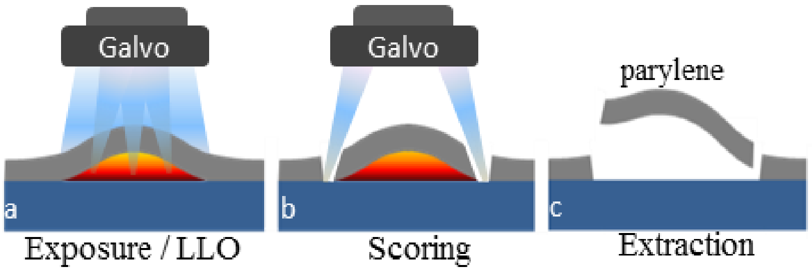
Flexible Electronics

Debonding/Lift Off of polymer film stack from transparent substrates

Flexible Displays

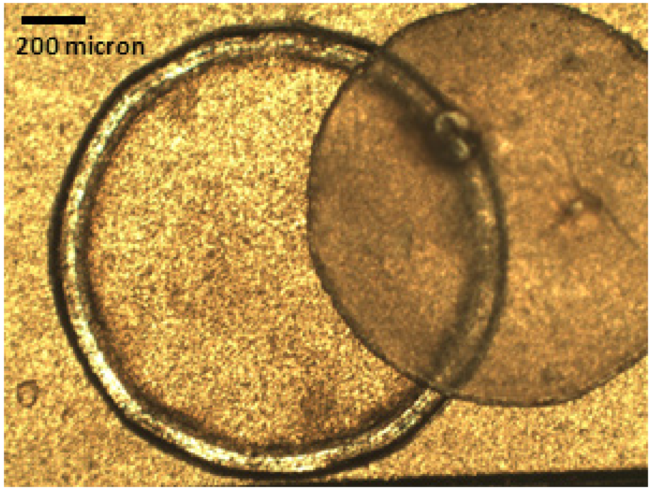
Transfer of flexible polymer and circuitry backplane situated on it from glass substrates, as used in flexible displays for smartphones, tablets, and other devices

Laser Lift off and Scoring of Parylene



Laser lift off and scoring of Parylene using 355 nm

- Used for Parylene removal from thin metalized substrates
- No affectation to the substrate
- Laser scoring for material extraction



Large circular Parylene disk lifted off

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Summary

- Fiber lasers cover a wide range of power levels, pulse energies, pulse durations and wavelengths, also supporting a variety of beam profile characteristics.

- Pick the right laser for each application.

- Laser processing can be used for multiple applications in packaging including cutting, scribing, drilling, welding, milling, selective ablation, patterning, marking, and laser lift off.

- On going developments of laser technology, beam delivery and workstations will continue to further expand the range of applications possible while driving packaging breakthroughs.

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