Laser Micromachining: A flexible tool in Vertical Probe Card Manufacturing

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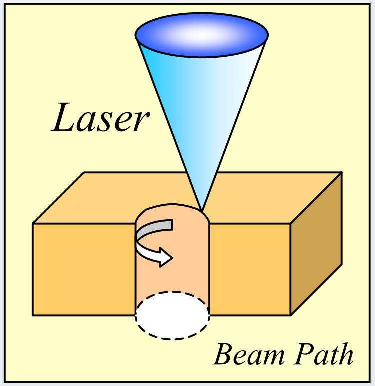
Outline

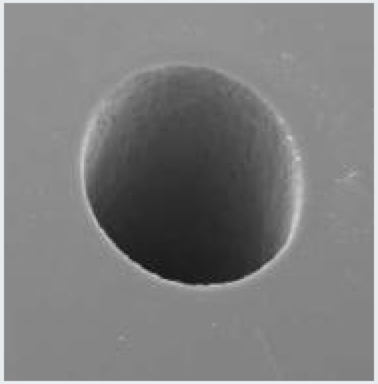
1. *Introduction to Laser Micromachining*

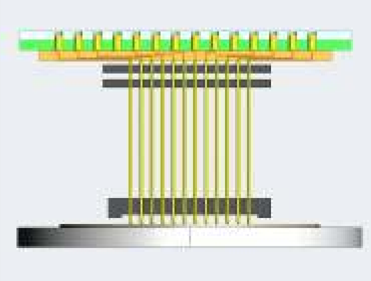
2. **Laser micro-Drilling capability**

3. **Laser Drilling for Vertical probe card manufacturing**

4. **Future Trends**







Oxford Lasers

Laser Manufacturer & Laser System Integrator

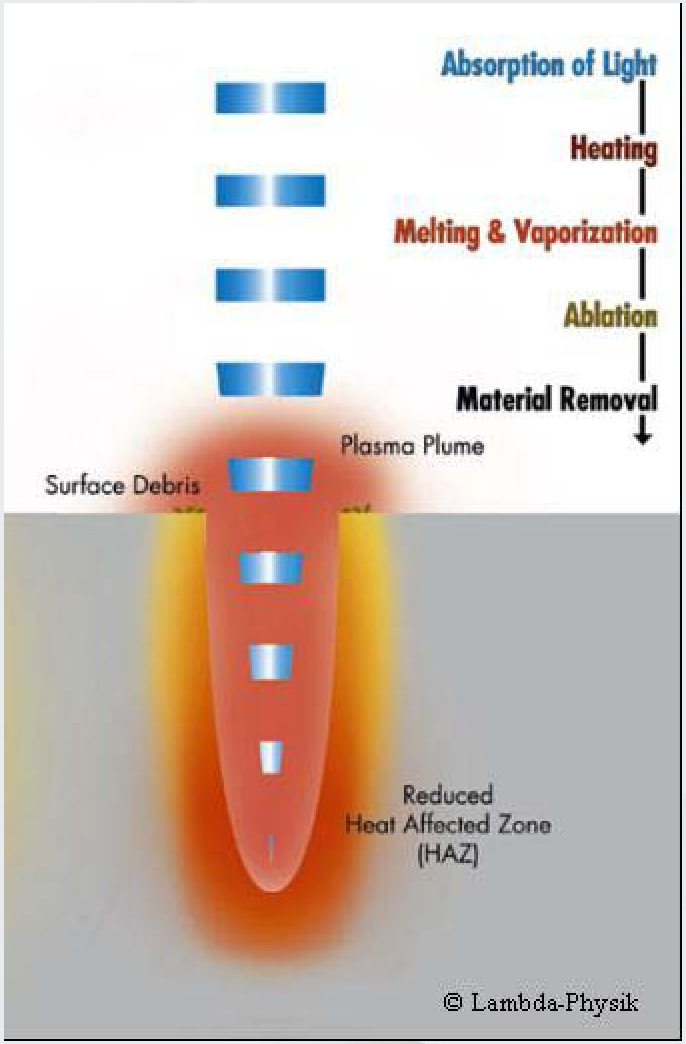
Founded 1977, spin-off Oxford University
Location: Oxford (UK), Boston (USA)

Main Areas of Activity:

- High-Speed Imaging
- Laser Micromachining

- Turn-key Laser Systems
- Proof-of-Concept Trials
- Contract R&D
- Sub-contract Manufacturing
- Collaborative Projects
- Lasers & Accessories

What is Laser Micromachining?



Laser Ablation - material removal by a combination of evaporation and melt expulsion.

Proportion of evaporation vs melt expulsion depends on laser parameters and material

Why Use Lasers?

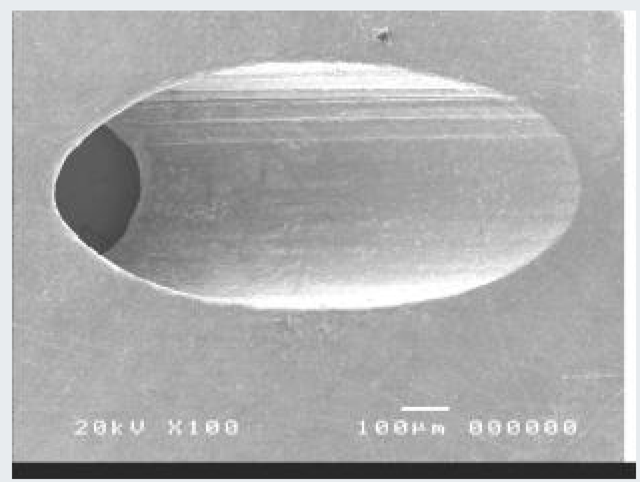
Conventional

Wire Electro-Discharge (EDM)
Mechanical
Chemical milling
Water Jet
Ion Milling
Electron Beam
Punching

Laser

Non-contact technique
Soft Tooling
Processing speed
High Resolution
Flexibility (hole size, shape)
Compactness (footprint)
Cost effectiveness

Low Drilling Speed = High Cost

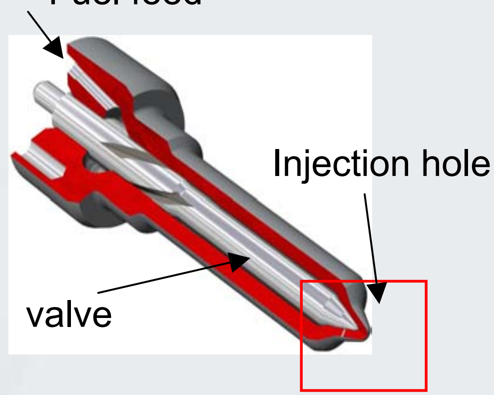


Benefits of Laser Drilling

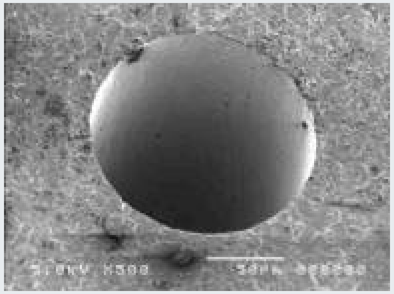
1. **Lasers can machine all industrial materials** (plastics, ceramics,silicon, metals, glasses)
2. **Small holes and high packing densities give end user more flexibility in design**
3. **Lasers can create any toolpath on a workpiece using a CAD/CAM interface (shaped holes possible)**
4. **Laser drilling systems are safe, easy to operate with minimal training and have minimal downtime**
5. **Future proof technology**
6. **Rapid turnaround due to soft tooling**

Applications of Laser Micromachining

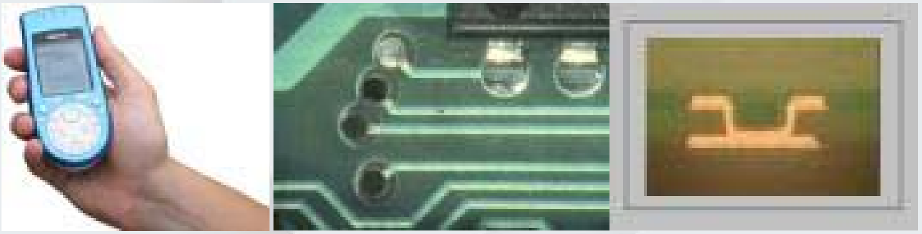
Diesel-injection nozzle drilling



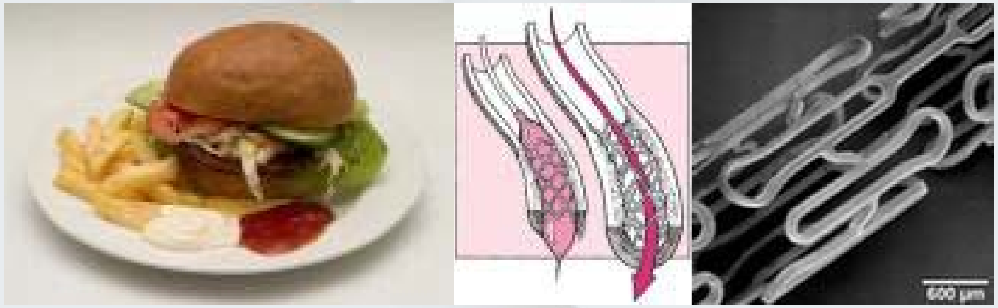
150µm Ø, 511nm,
1mm thick steel



Pcb via drilling



Cardiac stent manufacturing



Inkjet printer manufacturing

Industrial Laser Drilling Applications

Semi/Microelectronics
Inkjet Printer Nozzle
PCB via interconnects
Optical Switching
Heat management in PCB packaging
- **IC Test Vertical Probe Card**

Automotive
Fuel-Injection Nozzle
Fuel Filter
ABS Car brake sensors
Con-rod lubrication

Environment/Ren.Energy
Toxic Gas Sensors
Solar Cell Technology
Fuel Cell
Particulate Filters

Aerospace/Defence
Turbine component cooling
Engine Silencing
Missile guidance
Aerofoil laminar flow

BioMedical MEMS
Catheter Sensors
Aerosol Spray Atomisers
DNA Sampling
Vaccine production
Lab-on-a-Chip
Cardiac Stent Manufacturing

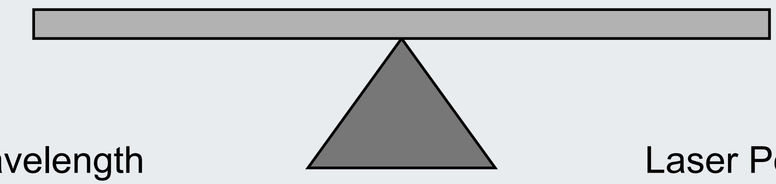
Other
Food Packaging
Gem Stone drilling
Digital Fingerprinting

Which Laser to use?

Important Parameters

(hole size)
(hole aspect ratio)
(feature quality)
(processing speed)
(cost per hole)

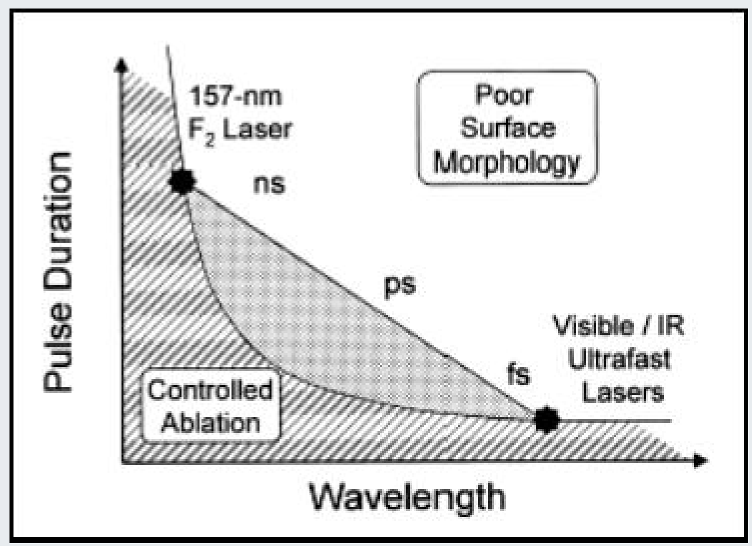
(Quality) (Proc.Speed)



Laser Wavelength
Laser Pulse Width
Laser Beam Profile
Pulse-to-pulse stability

Laser Power
Laser Rep.Rate
Laser Focussability

LASER	λ (nm)	Pulse width	PRF
DPSS	213-1064	ns-μs	1Hz-200kHz
Copper	255,511	ns	kHz
Excimer	157-351	ns	1Hz-1kHz
Ultrafast	390-1048	Fs-ps	1-5kHz



From *P.R. Herman et al., Applied Surface Science 154–155 (2000) 577–586*

Important Parameters

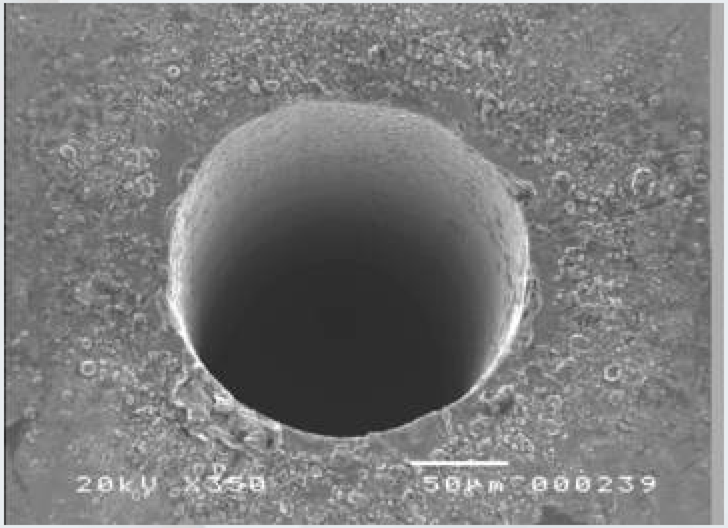
- **Laser**
  - Type
  - Wavelength
  - Output Power
  - Pulse Energy
  - Rep.Rate
  - Pulse Length
  - Beam Diameter
  - Beam Polarisation
  - Beam Divergence
  - Beam Intensity Profile
    - Spatial
    - Temporal
- **Material**
  - OPTICAL
    - Absorptivity
    - Reflectivity
    - Refractive Index
    - Surface Roughness
  - THERMOPHYSICAL
    - Thermal Conductivity
    - Specific Heat
    - Melting Point
    - Boiling Point
    - Evaporation Enthalpy
    - Surface Tension
    - Vapour Pressure
  - MECHANICAL
    - Density
    - Hardness
    - Poisson Ratio
    - Young's Modulus
- **Processing**
  - Lens NA
  - Spot Size
  - Shot Overlap
  - Gas Assist
  - Focal Plane
  - Processing Speed
  - Drilling Technique

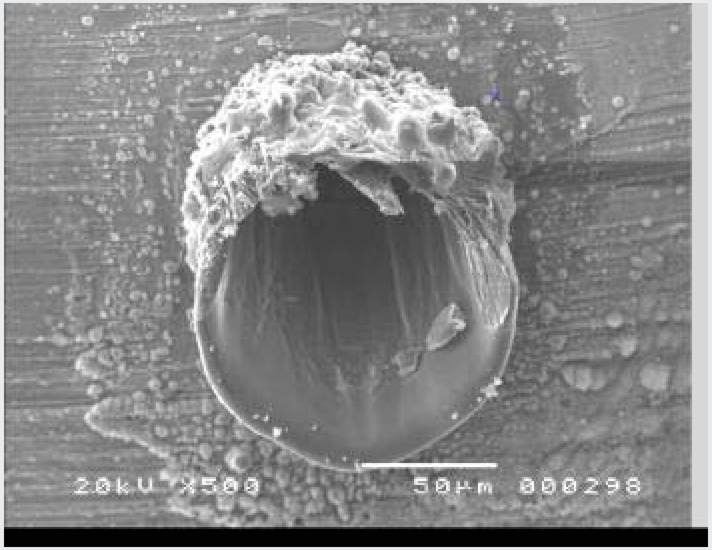
! IMPORTANT:
Most parameters are interrelated and/or depend on temperature, pressure, etc.

Laser Micro-machining

Importance of correct choice of laser & process

Holes in 1mm thick Steel





Optimum Laser Parameters
Clean hole with no recast
almost no debris

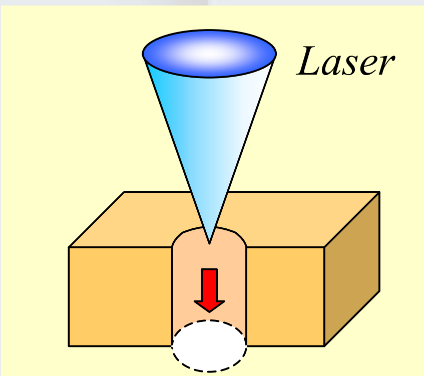
Non-Optimum Laser Parameters
Significant recast, crown and debris

Laser Drilling Techniques

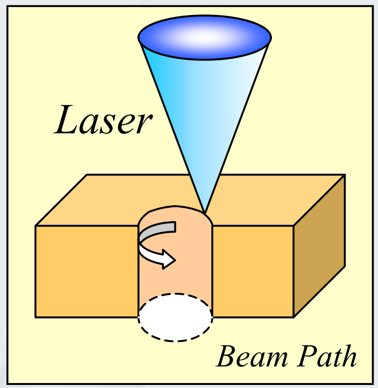
PERCUSSION DRILLING

TREPANNING DRILLING

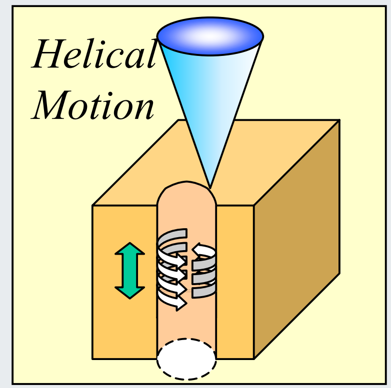
Direct Writing



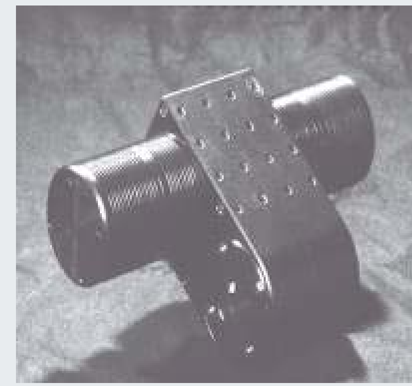
Laser Trepanning



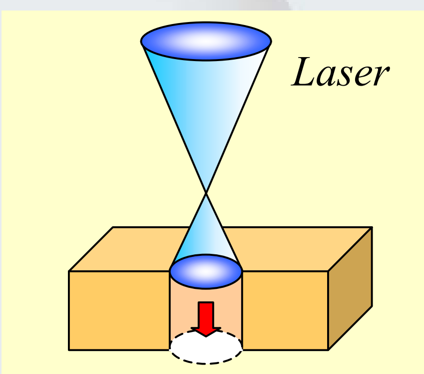
Helical Trepanning



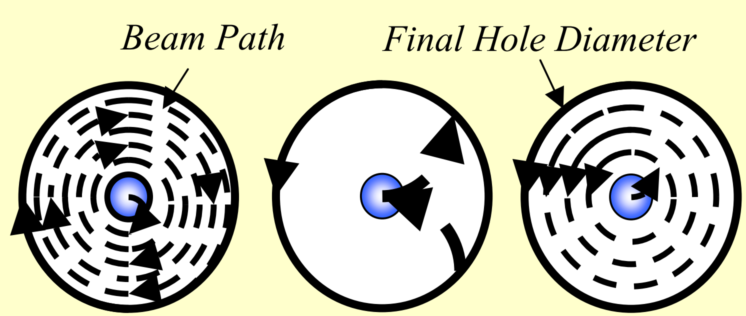
Auto-Trepanning Head



Mask Imaging



1. Start at hole centre
2. Trepan outwards (spiraling, con.circles)



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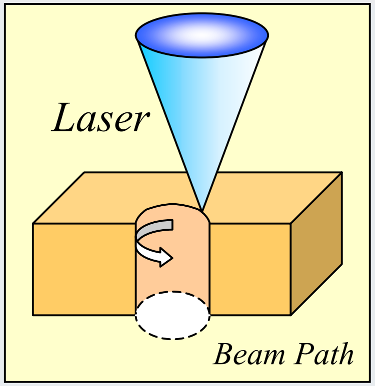
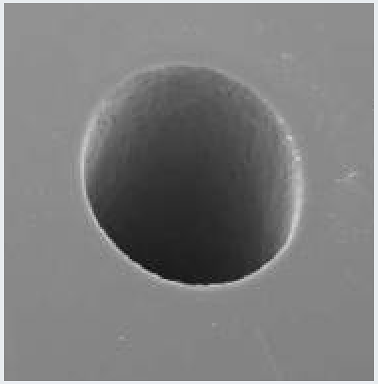
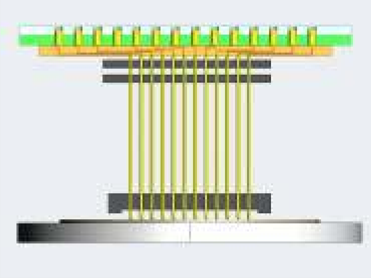
4. Future Trends

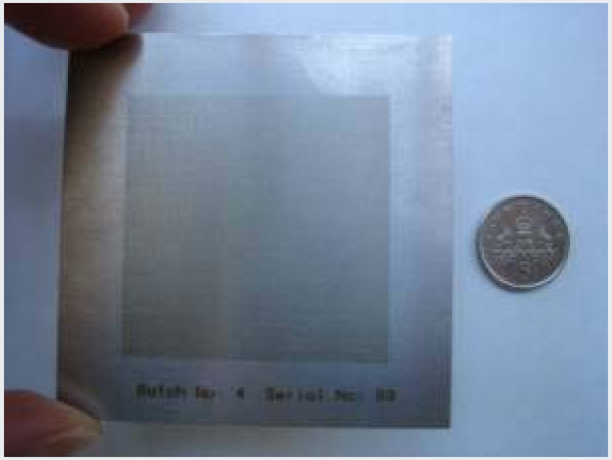






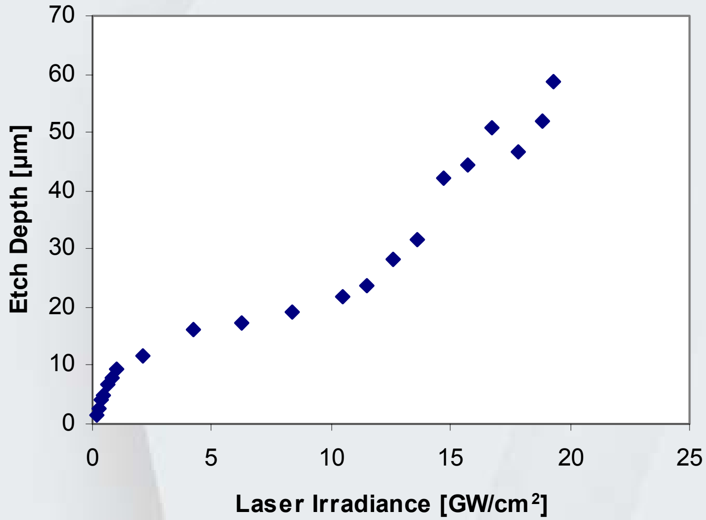
Example of high-speed drilling

Fuel cell mesh

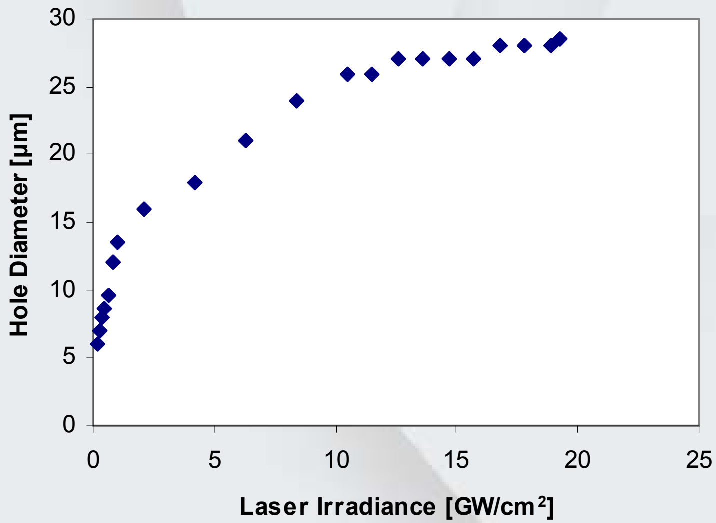


Total: 46,000 holes
Drill speed:up to 250 holes/sec

DPSS ns Laser Ablation of Silicon



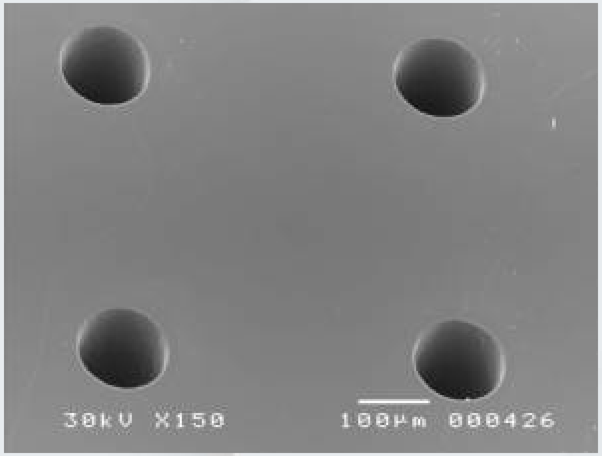
Single-shot Laser Ablation
355nm UV DPSS
Max.Pulse Energy: 0.5mJ
Spot size: 9μm
Pulse Duration: 45ns
M^2 <1.2



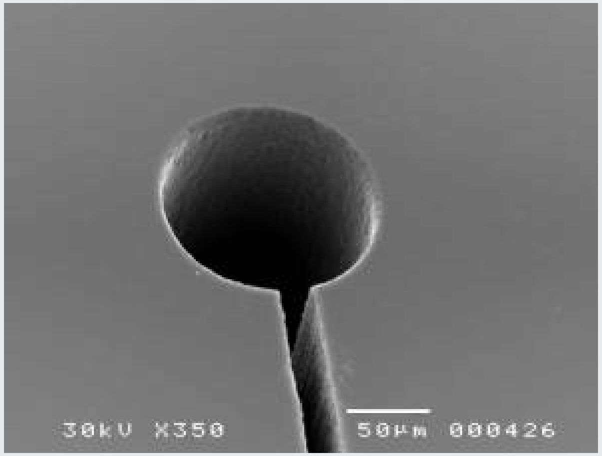
- UV ns DPSS lasers can provide high peak power due to diffraction limited small spot sizes on target
- Very high peak power helps drill silicon fast.
- Small holes down to 5μm can be achieved varying peak power with high aspect ratios >100:1

Silicon

UV ns Laser Trepanning Drilling

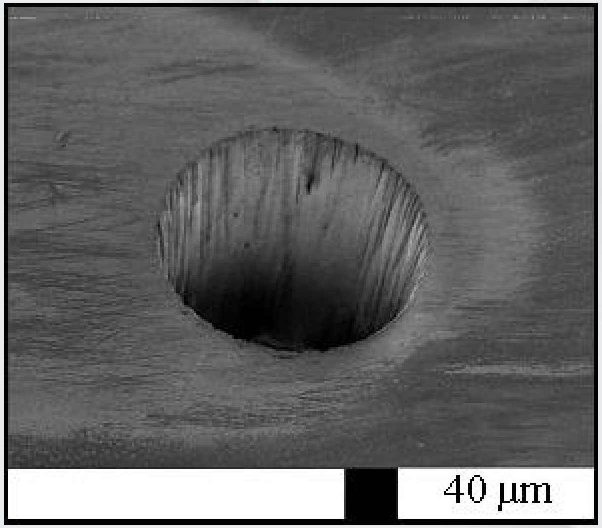


Example of laser machined channel and hole for micro-fluidic application



125µm Ø, 355nm, c-Si 350 µm thick

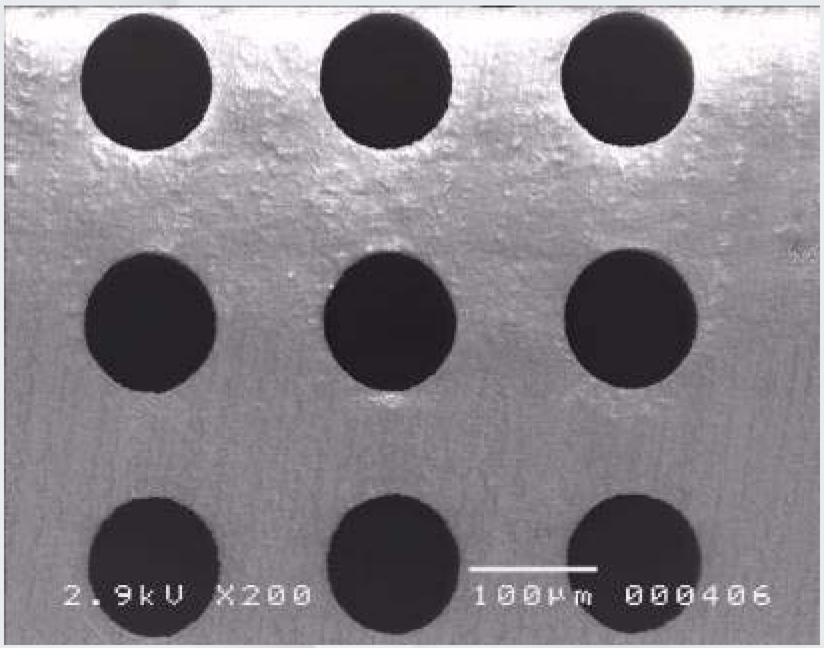
Femtosecond laser drilling



- Short (λ) or short (τ) lasers show superb result
- No laser-induced thermal damage
- No Particulate contamination

Special Ceramics

High aspect ratio microholes



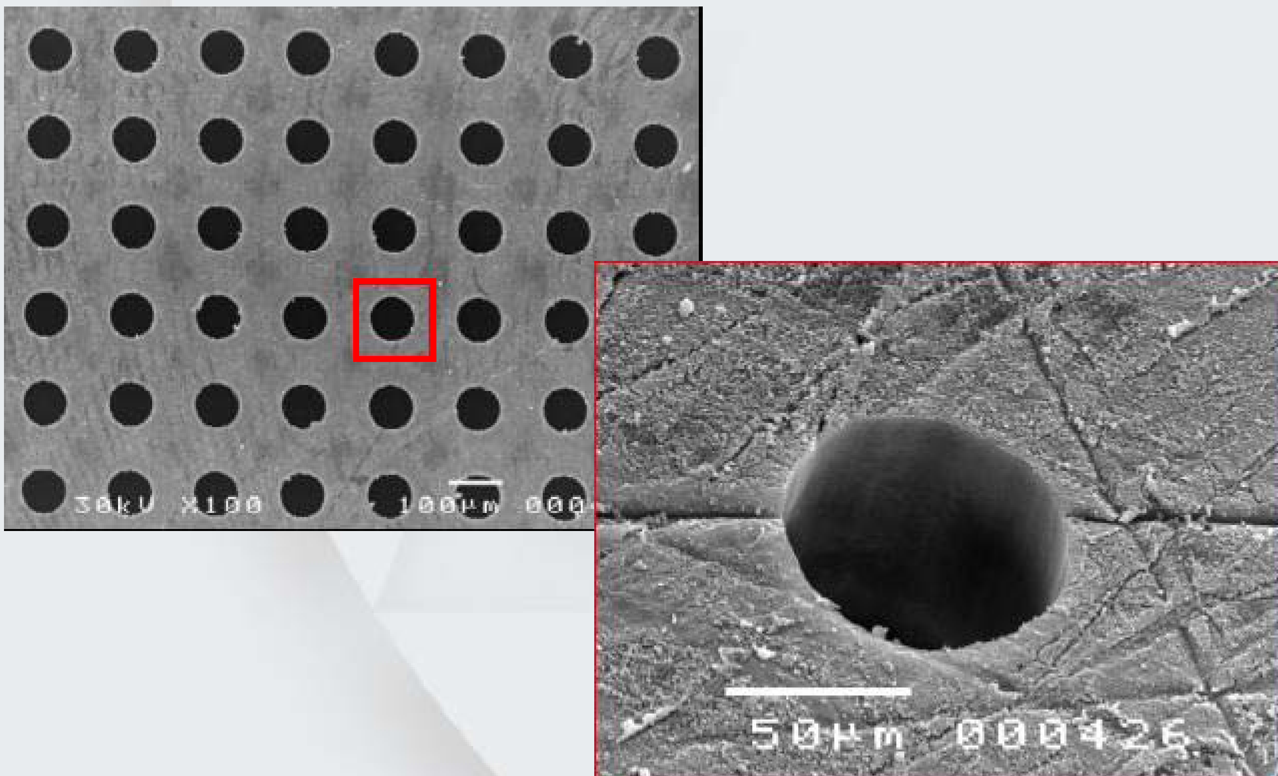
Low thermal expansion ceramics

Difficult to process with conventional drilling

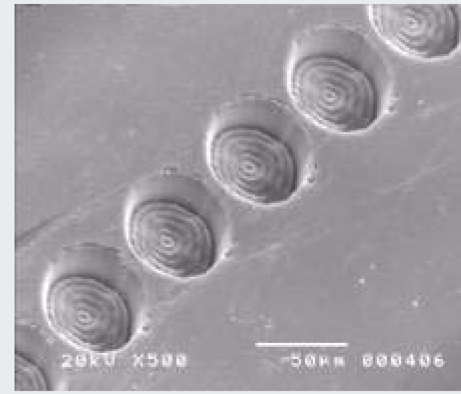
Polymers

Laser Optical Trepanning

355nm UV DPSS
High quality,minimal HAZ



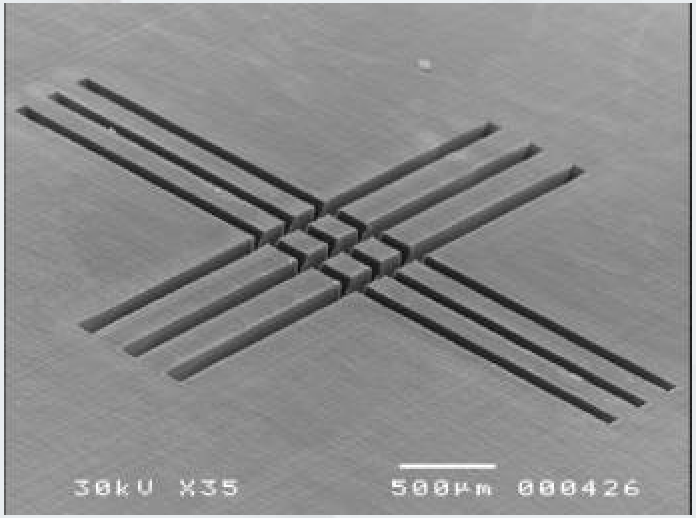
Blind-holes

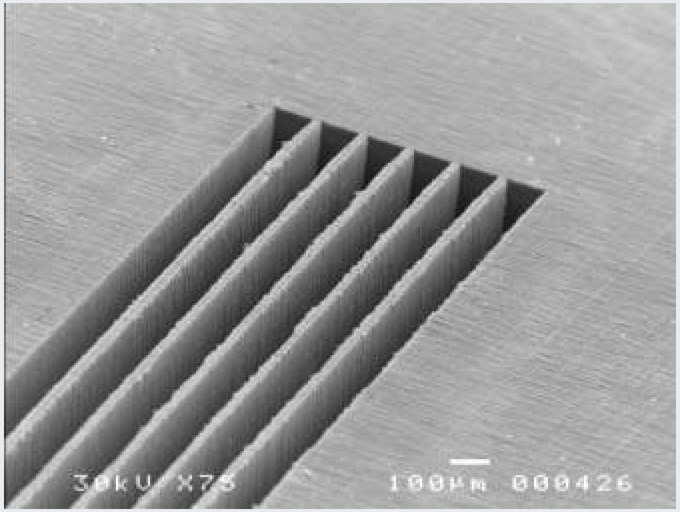


Polymers

Laser Cutting

355nm UV DPSS
High quality,minimal HAZ, sharp features





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3. ***Laser Drilling for Vertical probe card manufacturing***

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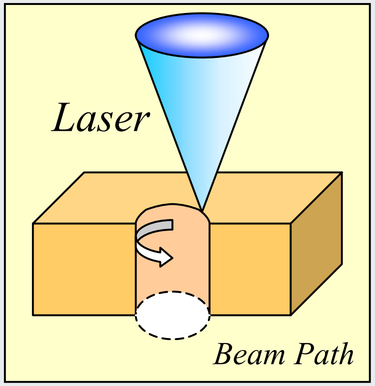
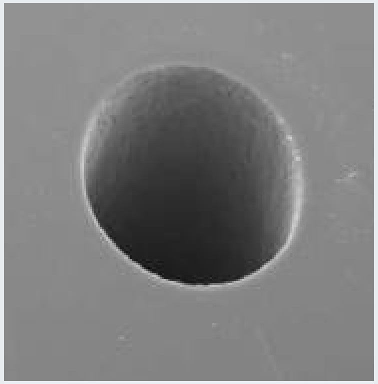
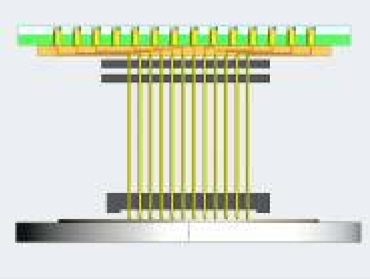
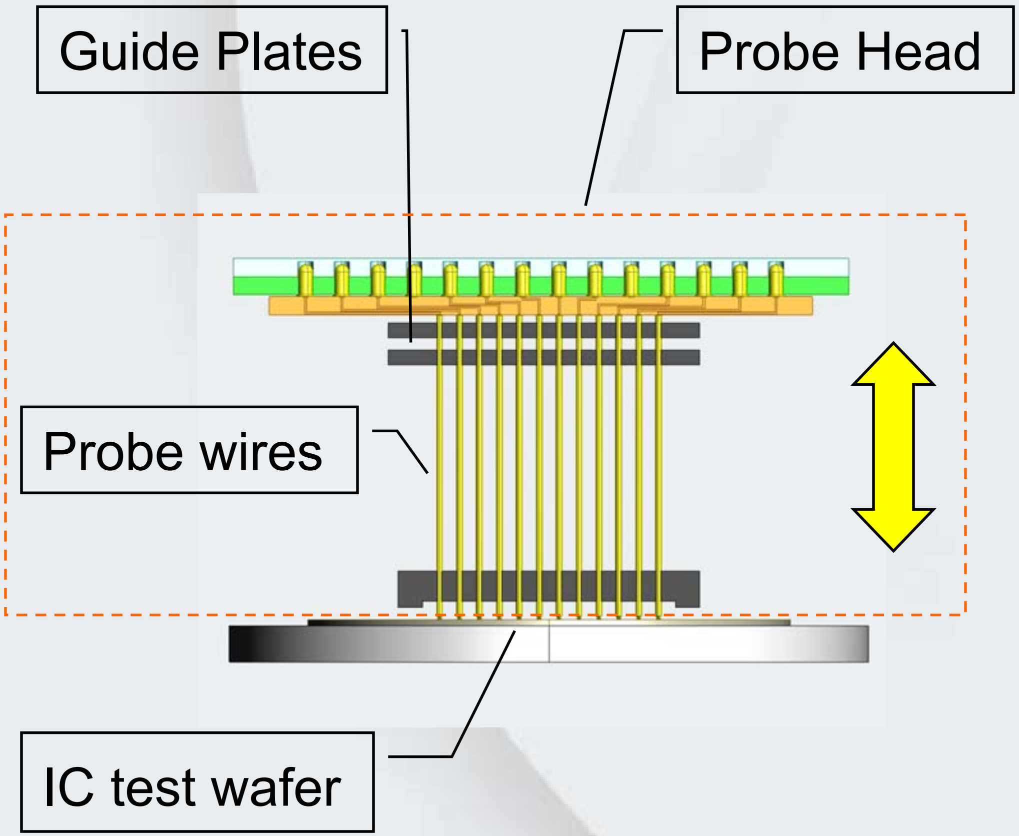






IC Vertical Test Probe Card

Vertical probe heads used for IC electrical testing prior to packaging.
They require microholes to guide the contacting wires.
Laser drilling of the guide plates allows high packing density with smaller hole sizes and provides flexibility, high processing speed



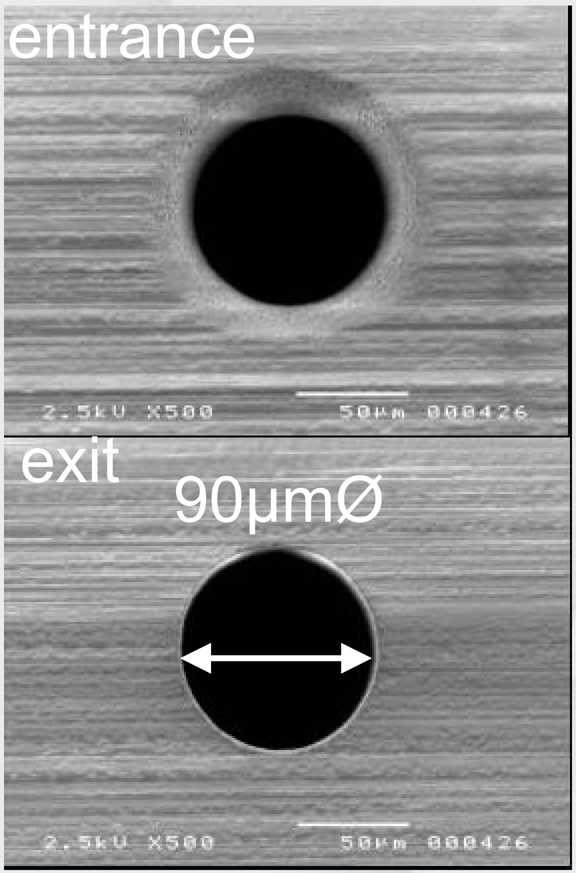
Materials
Silicon
ceramics
plastics

Hole Geometry
Hole size : 40 - 100 μm diameter
Hole shape : square, circular, elliptical
Hole Cylindricity : parallel or tapered
Wafer thickness : 300-700 μm

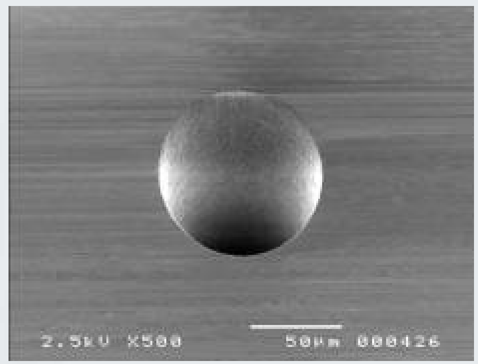
Technology challenges
Hole position accuracy
Speed of drilling
Taper angle control tolerance
Toolpath flexibility, any hole shape

Ceramic MicroDrilling

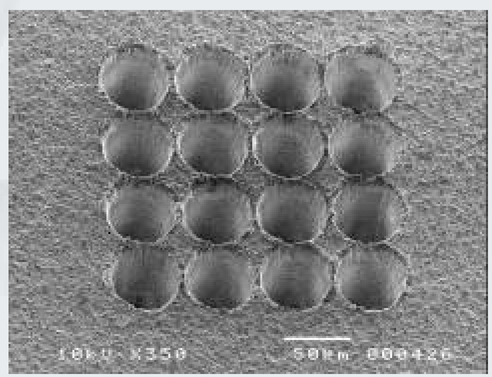
500µm thick, 511nm



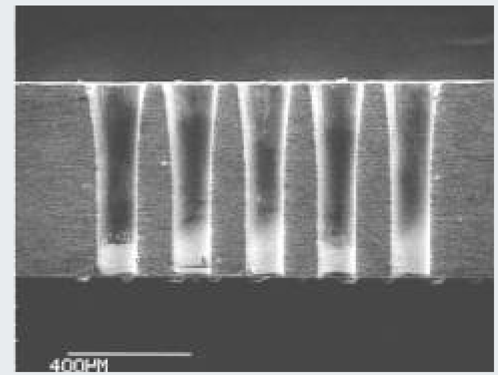
Si_3N_4



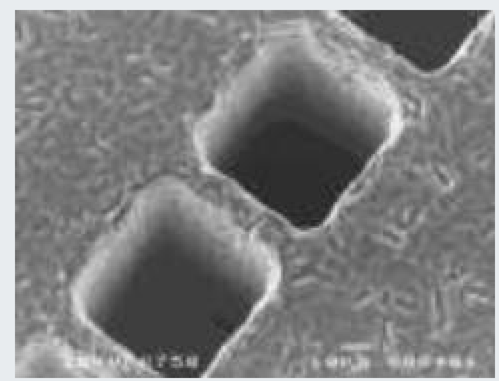
50µm Ø, 60µm pitch



Alumina 650µm thick

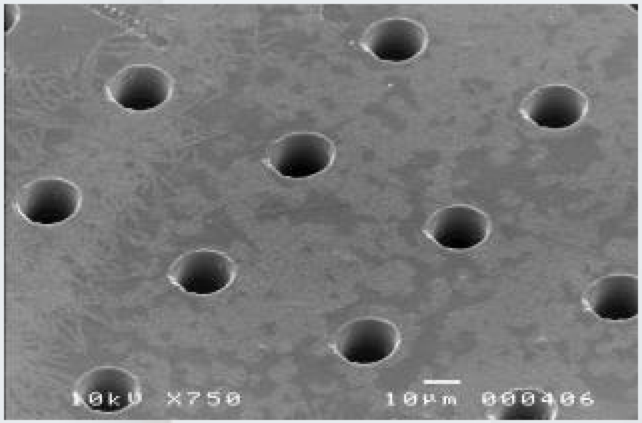


50µm square holes

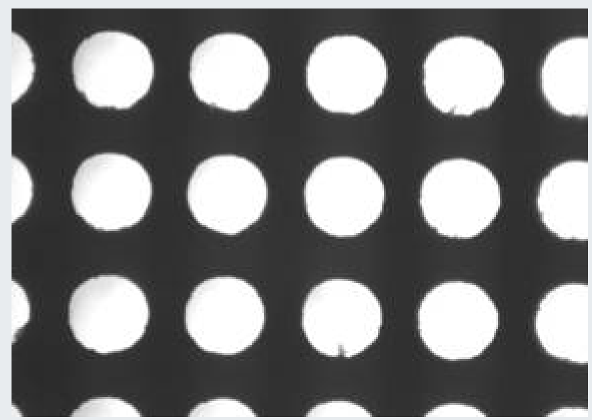


Plastic MicroDrilling

15um hole, pitch 40um, 50um thick

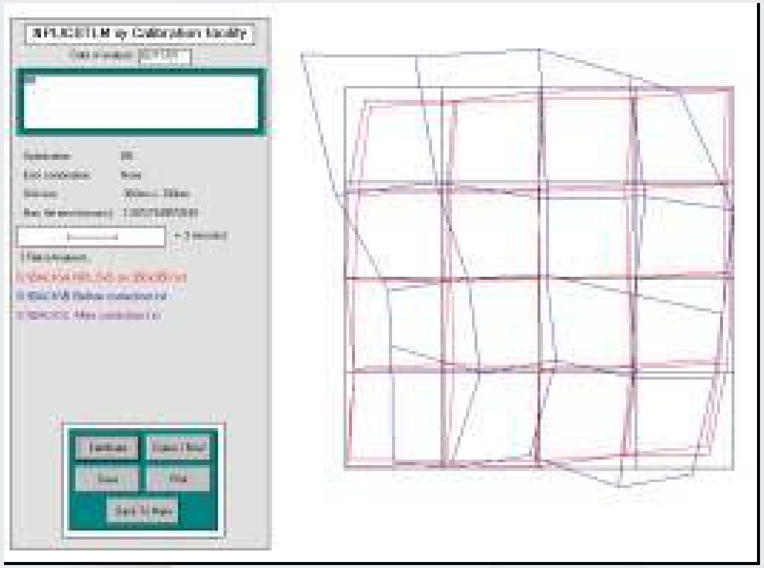


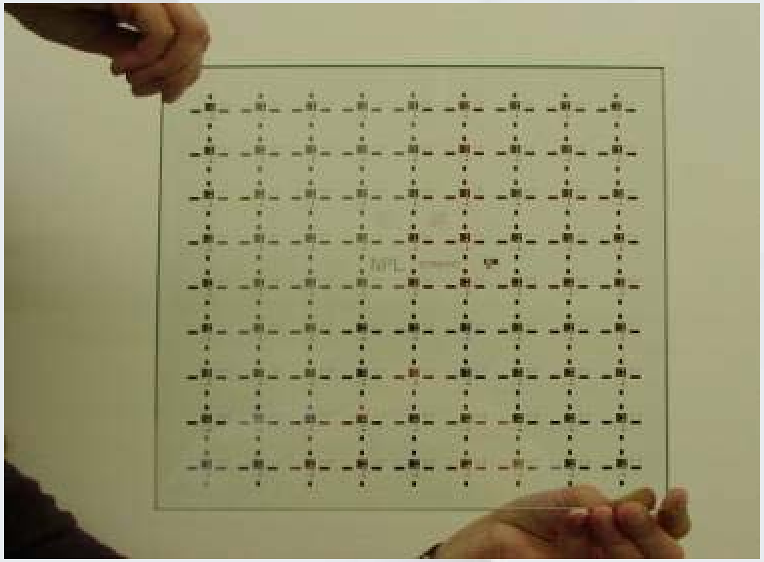
Polyimide 500µm thick



135µm Ø

2-D Error Mapping Stage Calibration





HOLE POSITION ACCURACY IS PARAMOUNT.

<u>We use</u>:

- High resolution, high position accuracy x-y stages
- Temperature controlled workstation
- Wafer leveling and alignment equipment.

We calibrate all our stages against known National Physical Laboratory standards

Performance Evaluation Data

Example of 1000 laser drilled holes

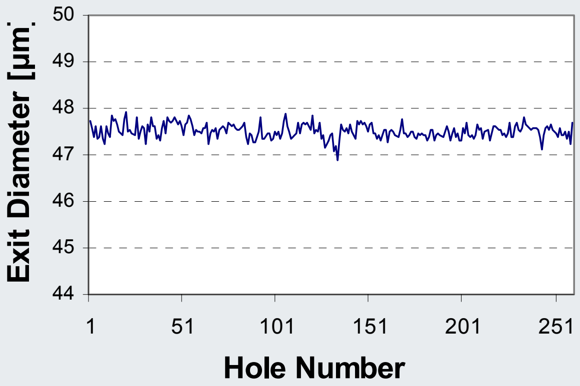
Important!!
The hole size repeatability depends on:

- *Laser pulse-to-pulse stability*
- *Sample uniformity and surface texture*
- *Sample levelling*

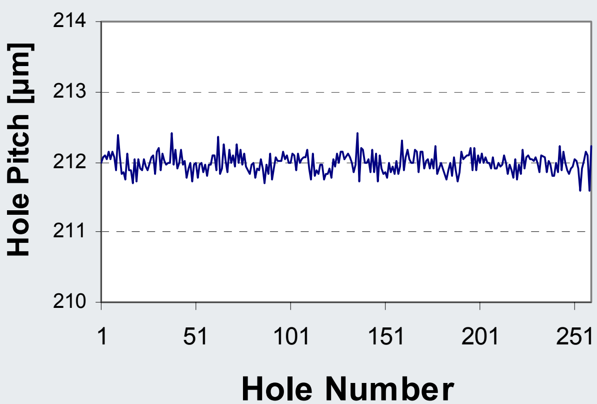
The hole positioning accuracy depends on:

- *X-Y table accuracy*
- *Laser beam pointing*

Hole Size Repeatability



Hole Pitch Accuracy



X-Y Table Positional Accuracy

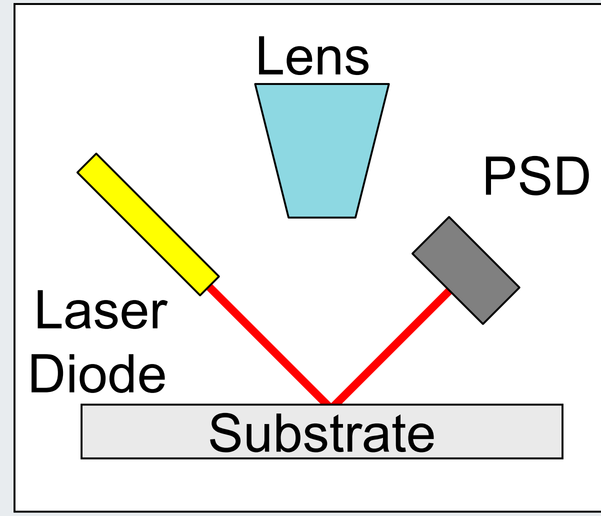
	X-AXIS	Y-AXIS
std.dev	0.56	1.05
Cp	4.8	2.5
Cpk	1.65	1.4

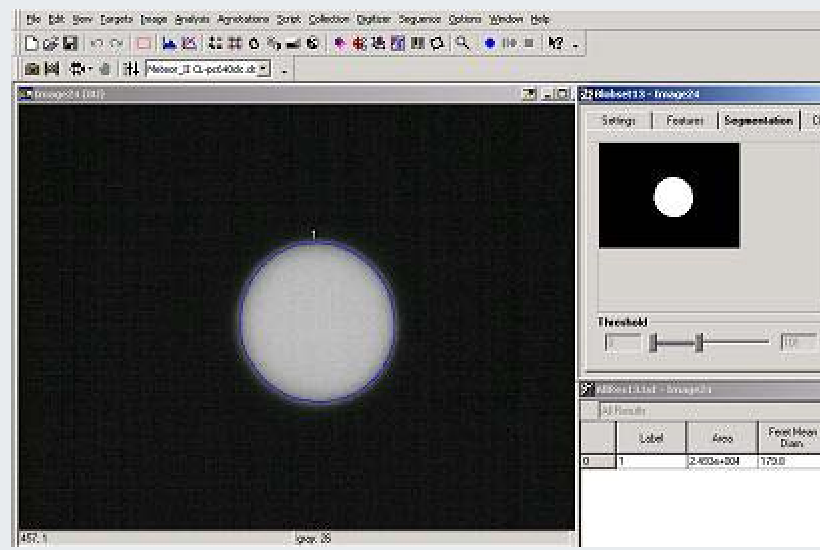
Machine Vision & Alignment

Wafer levelling and alignment is critical for –µm level position accuracy in laser hole drilling.

•High resolution cameras and on-axis position sensitive detectors are used to align the wafers.

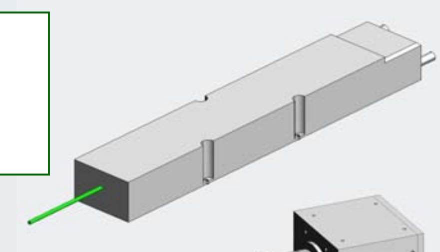
Laser-drilled hole size measurement and inspection can be performed in-situ with user-friendly digital imaging analysis software with custom recipes.



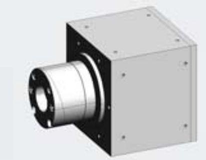


ProbeDrill™

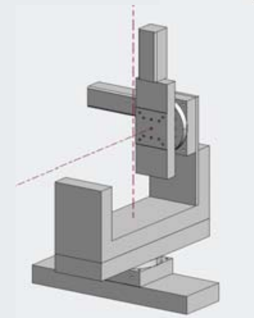
Fully automated turn-key laser drilling system for vertical probe card manufacturing



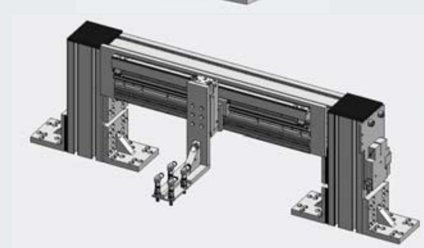
Laser



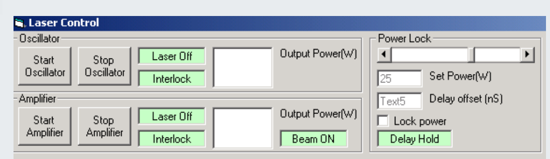
Proprietary Optical Trepanning System



5-axis part positioning



Material handling systems (options)



User-friendly pc interface

Future Trends in Laser Hole Drilling

- **Better Resolution**

  (shorter wavelength, 2nd, 3rd, 4th harm DPSS)

- **Lower Production Cost**

  (proc.speed, high rep.rate, high power)

- **Better Quality**

  (shorter pulses, motion control speed)

- **More Complex Materials**

  (multi-wavelength laser systems)

- **Industrial Robustness**

  (compact, fully diode-pumped laser systems)

Summary

•Laser micromachining is a well established industrial processing method

•Lasers can process all commonly used materials in the wafer test arena

•Laser microdrilling is a flexible tooling technique

•Lasers coupled with ultra accurate motion tables offer competitive advantages for vertical probe card manufacturing

•Lasers are an enabling technology – Smaller features in difficult to process materials

Thank You

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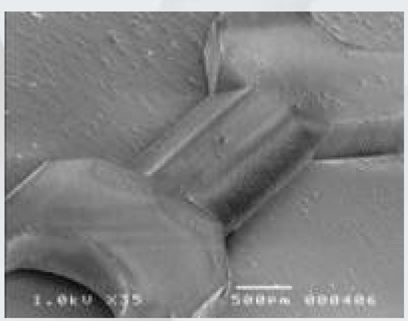

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