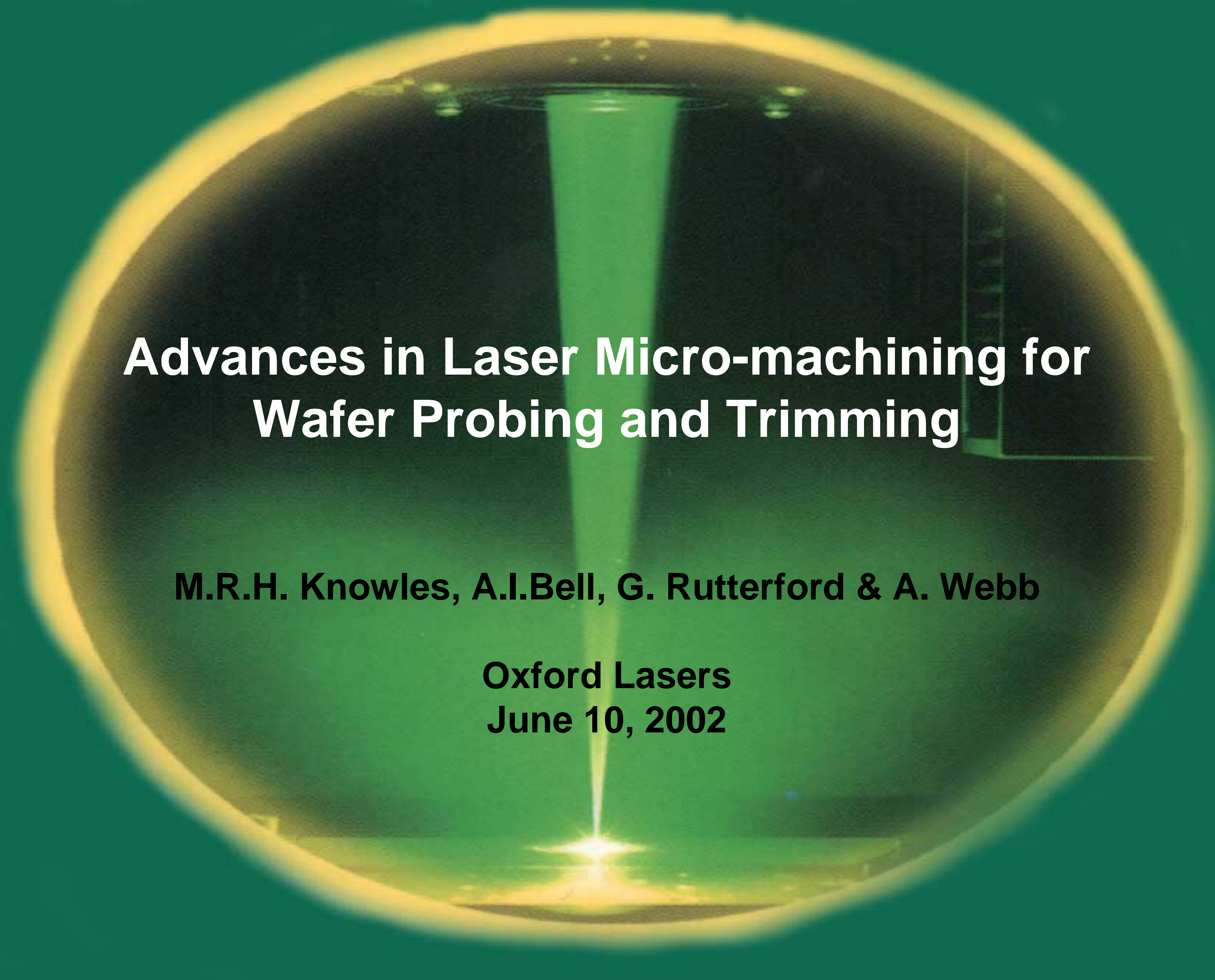
Advances in Laser Micro-machining for
Wafer Probing and Trimming
M.R.H. Knowles, A.I.Bell, G. Rutterford & A. Webb
Oxford Lasers
June 10, 2002

www.oxfordlasers.com

- Introduction to Laser Micro-machining
- Laser micro-hole drilling for probe cards
- Laser trimming of MEMS
- Conclusions

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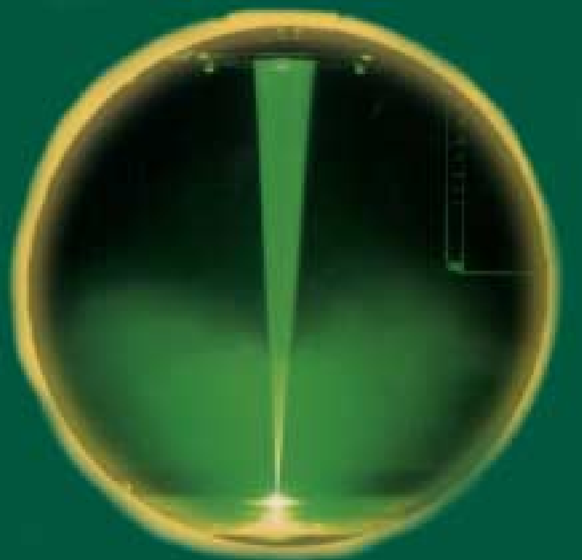
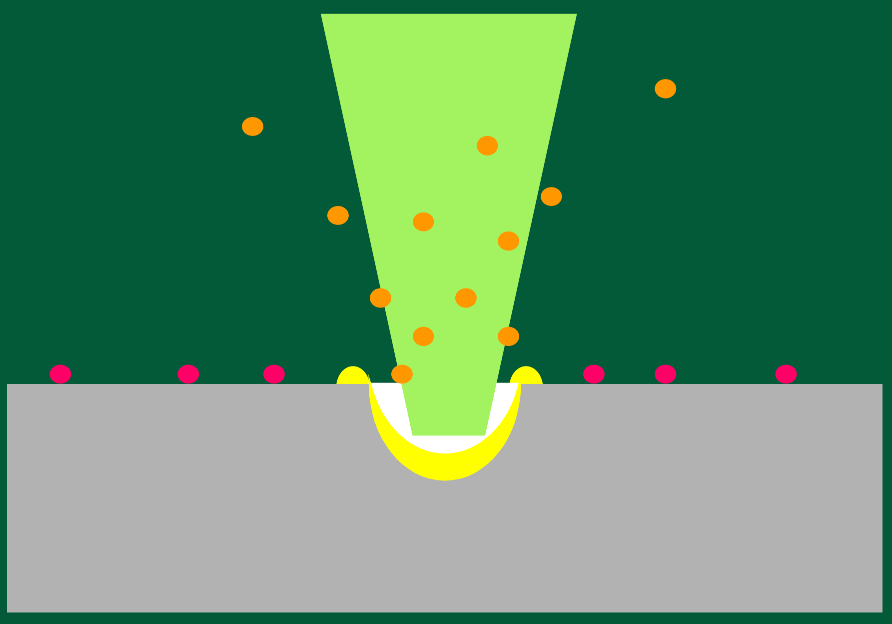
Introduction to Laser Micro-machining

Laser Micro-machining - Ablation



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

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

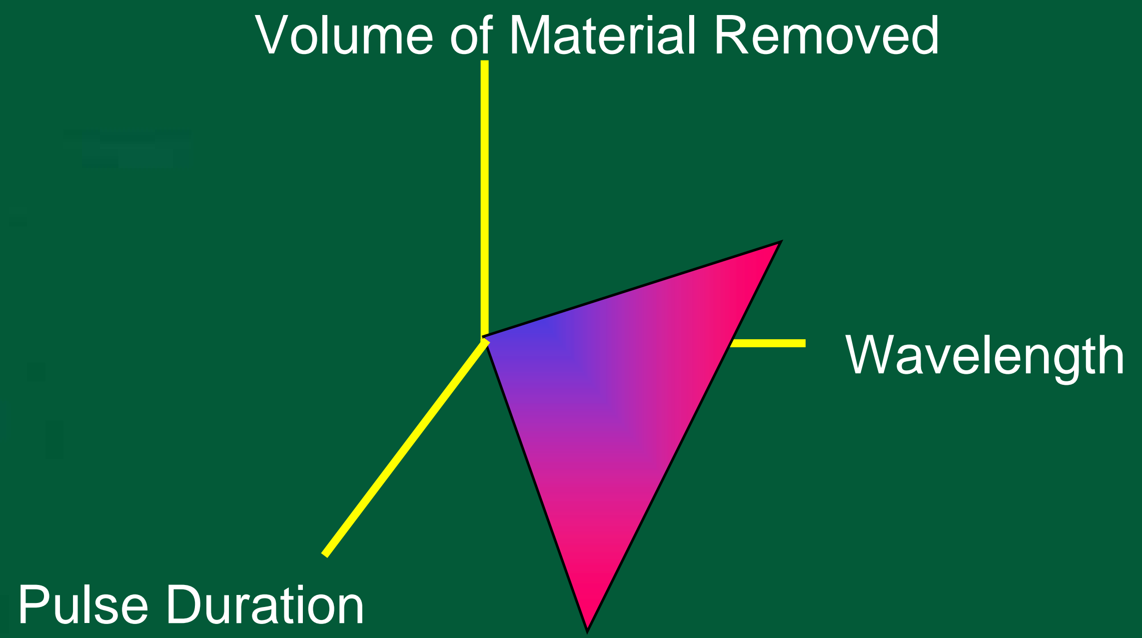


- Laser Beam
- Ejected material
- Deposited Ejected Material
- Recast material

Laser Micro-machining - Ablation

General Rule (with notable exceptions)

- Shorter wavelength removes less material
- Shorter pulse removes less material
- Less Material removed = higher precision
- Less material removed - benefits from higher pulse rate



Laser Micro-machining

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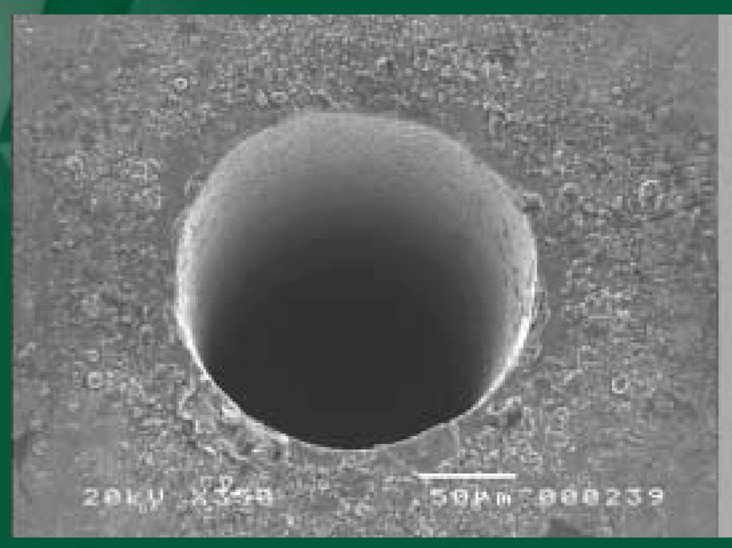
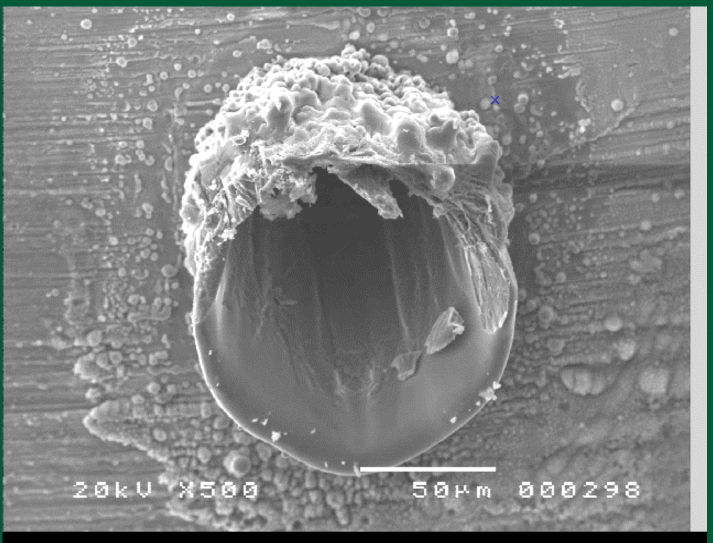
Importance of correct choice of laser & process

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

CVL & UV CVL Characteristics

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Copper Vapour Laser
Laser type used in this presentation

Laser	*CVL*	*UV-CVL*
Wavelength (nm)	511& 578	255, 271 or 289
Power (W)	10 - 50	1
Pulse Freq (kHz)	1 - 50	4 - 10
Pulse duration (ns)	10 - 50	10 - 50
Beam quality (xDL)	1 - 2	1 - 2

Integrate CVLs and solid state lasers into turn-key systems depending upon the application

Laser Micro-machining - Cutting

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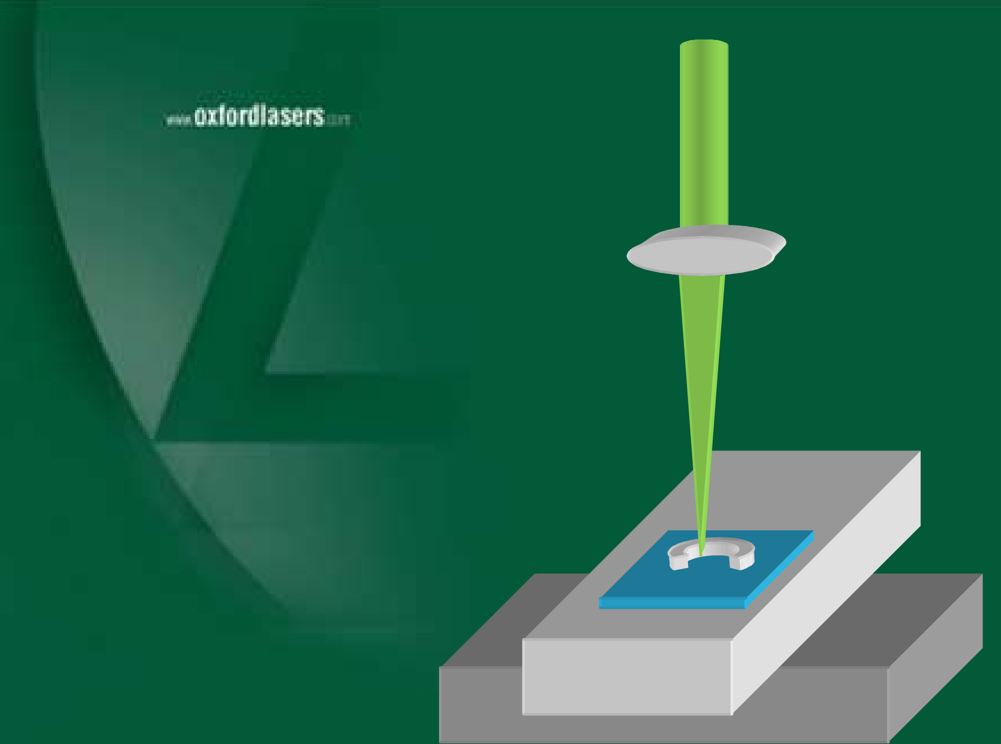

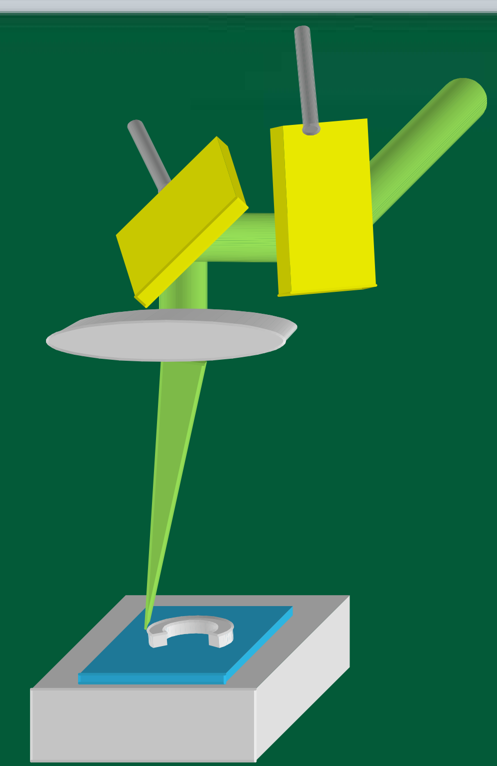

Fixed Beam	Moving Beam
XY Linear Axes	XY Galvo Mirrors & Flat-field lens
Very High Accuracy	Moderate Accuracy
Large Area	Moderate Area
Moderate velocity & acceleration	Very high velocity & acceleration

Laser Micro-machining - Drilling

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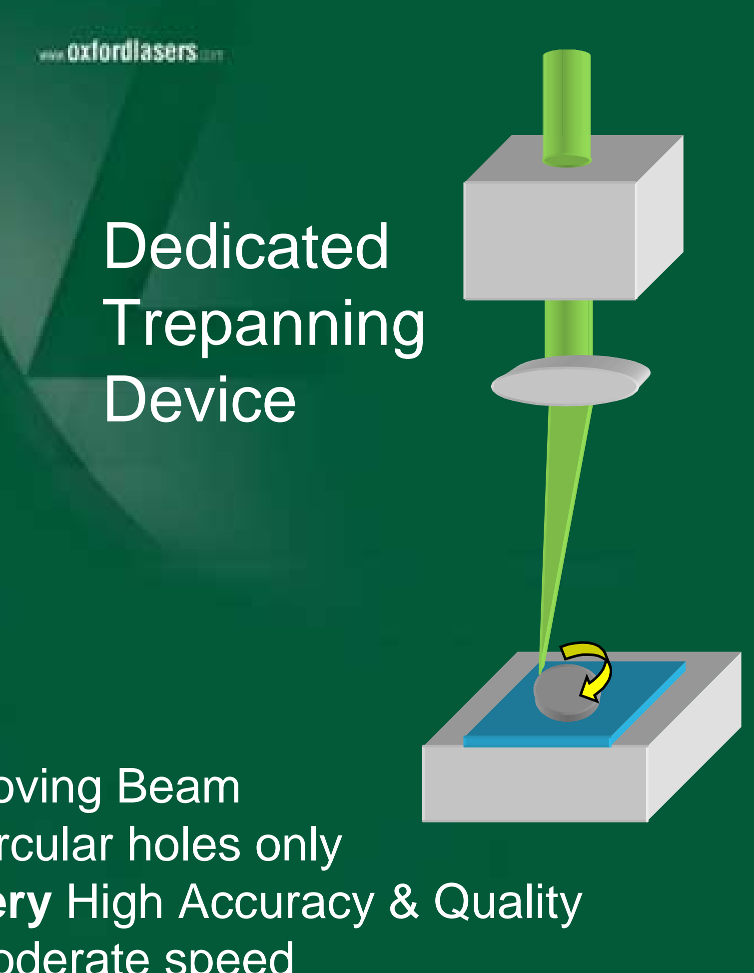
Percussion

Fixed Beam
Hole size & Shape determined by beam
Low Accuracy & Quality
High speed

Mask Imaging

Fixed Beam
Hole size & Shape determined by Mask
High Accuracy & Quality
Moderate speed

Laser Micro-machining - Drilling



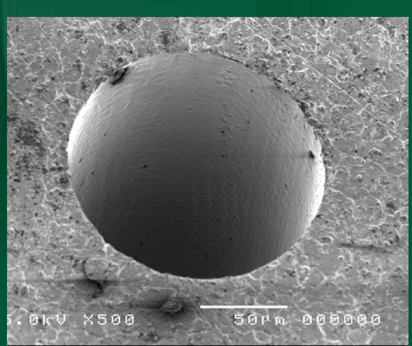
XY Galvo
Mirrors

Moving Beam
Circular holes only
Very High Accuracy & Quality
Moderate speed

Moving Beam
Any hole shape
High Accuracy
Moderate Speed

CVL Micro-hole Drilling

Holes from 1 μm diameter upwards



Ø 100 μm in 1mm steel

Ø 50 μm in 0.1mm stainless steel

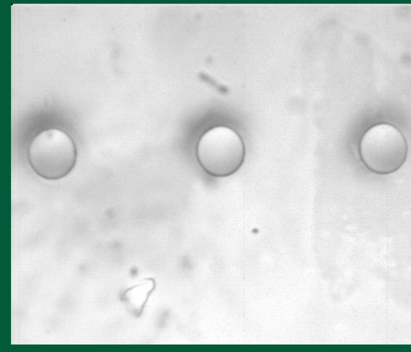
Ø 5 μm in 0.05 mm stainless steel

Ø 1 μm in 0.05 mm gold

Micro-hole Drilling

Through-holes

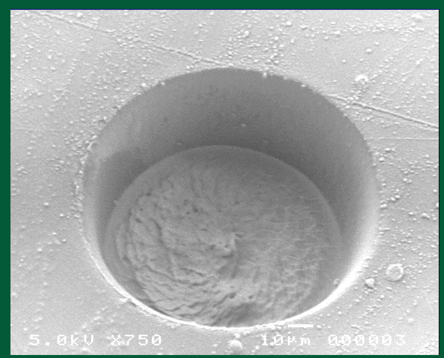
Polyimide



Polyimide

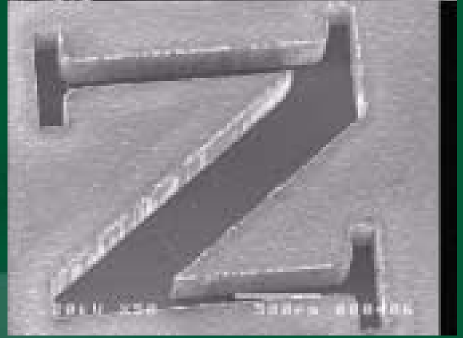
Blind-holes

Polyimide



Kapton on copper

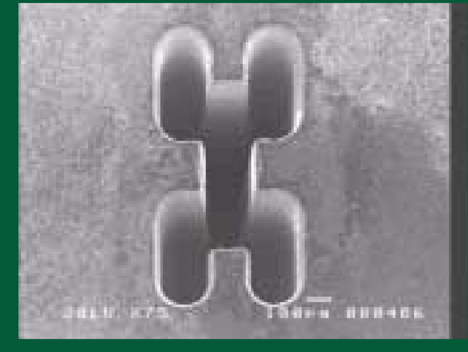
Micro-hole Drilling/Micro-Cutting



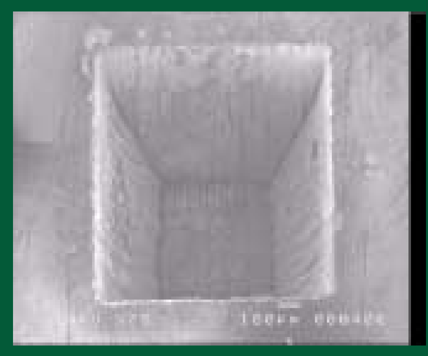
Silicon

Steel

Polyimide



Diamond



Ceramic

Micro-machining

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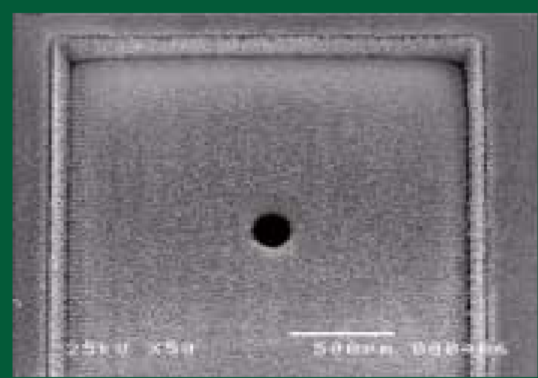
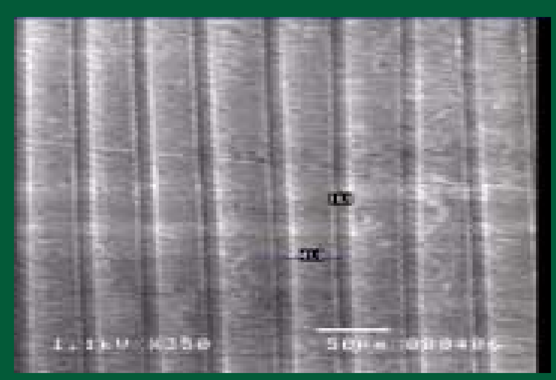
Micro-Milling

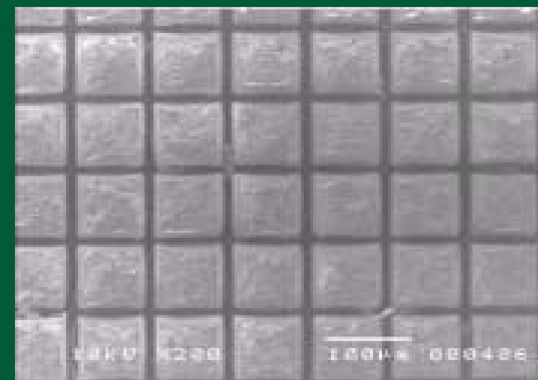
Etching



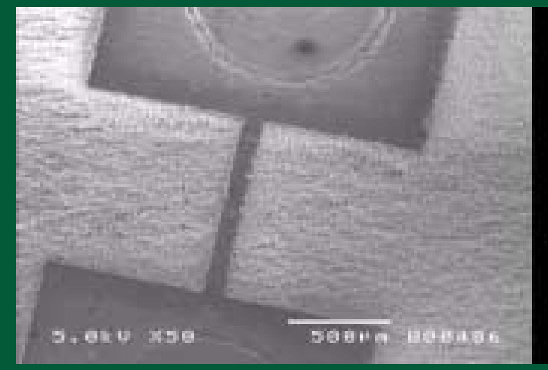
Copper



Copper on Kapton

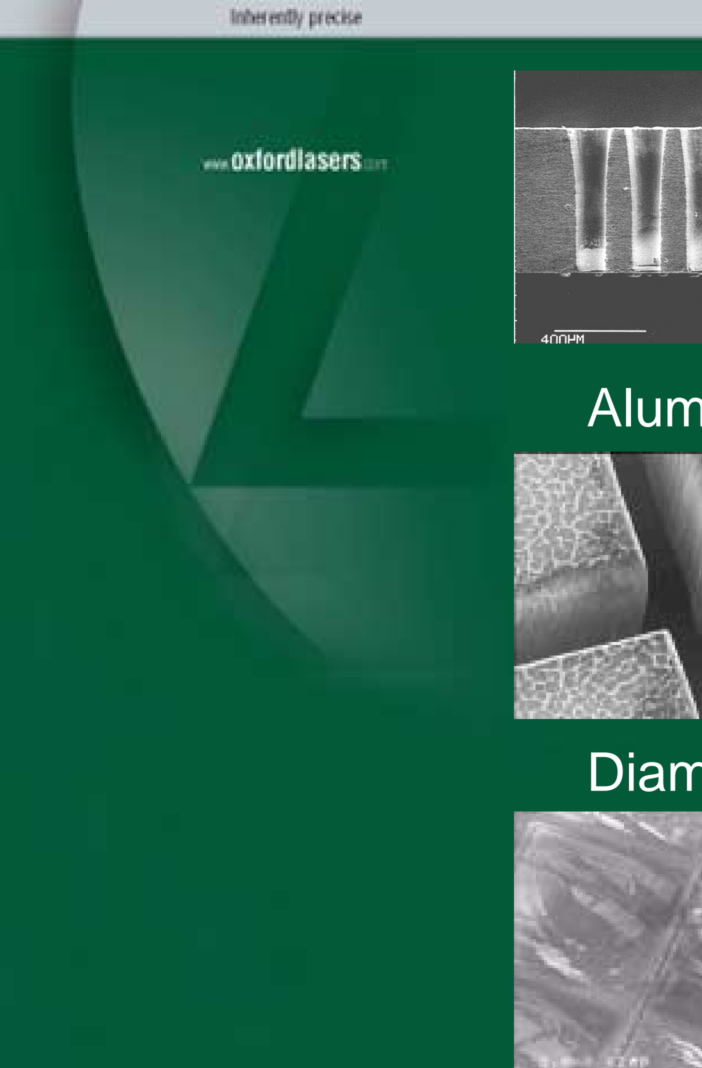


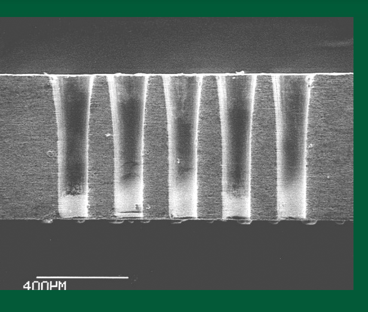
PZT



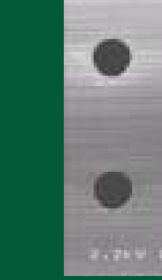
Aluminium on Polymer

Laser Micro-machining - Materials

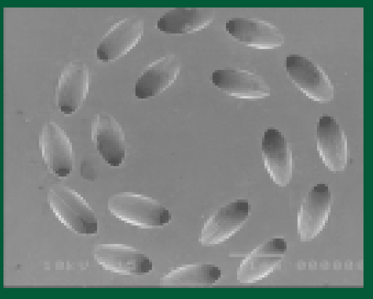




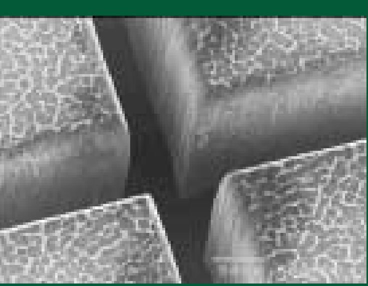
Alumina



Silicon Nitride

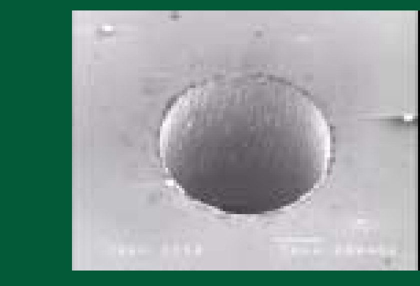


Steel



Diamond

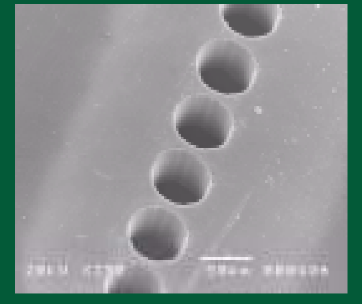
Silicon



Silicon

Sapphire

Metal on ceramic



Polyimide

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Laser Micro-hole Drilling for Probe Cards

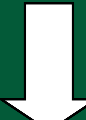
Laser Micro-hole Drilling for Probe Cards

Vertical probe cards require micro-holes to locate the probe wires.

Larger wafers & more complex ICs

Higher density probe cards,
match coefficient of thermal expansion

New materials, smaller holes, shaped holes, high accuracy



Laser micro-hole drilling

Laser Micro-hole Drilling for Probe Cards

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Materials: silicon, alumina, silicon nitride, silicon carbide, Vespal

Choose high prf, pulsed visible laser for all except Vespal.
For Vespal choose pulsed, high prf, deep-UV laser

Hole sizes : 20 - 100 µm diameter

Hole shapes : circular or elliptical, parallel or tapered

For circular holes choose dedicated trepanning head
For elliptical holes choose air-bearing XY axes or galvo mirror system
Parallel/taper depends upon laser power and focussing geometry

Laser Micro-hole Drilling for Probe Cards

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Typical examples:

Material	Thickness (mm)	Hole Dia (mm)	Drill time (s)
Alumina	0.64	0.120	15
Alumina	0.60	0.090	9
SiN	0.50	0.075	9
SiC	1.00	0.120	45
SiC	1.50	0.200	120
Vespal	0.50	0.025	0.05

Laser Micro-hole Drilling for Probe Cards

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Alumina

Cut speed
vs
Thickness
vs
Laser Power

Cut Speed (mm/s)
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
Laser Power (W)
0.25mm
0.38mm
0.60mm
1.00mm

All holes are trepanned so cutting speed is most relevant to estimate process speed scaling

Laser Micro-hole Drilling for Probe Cards

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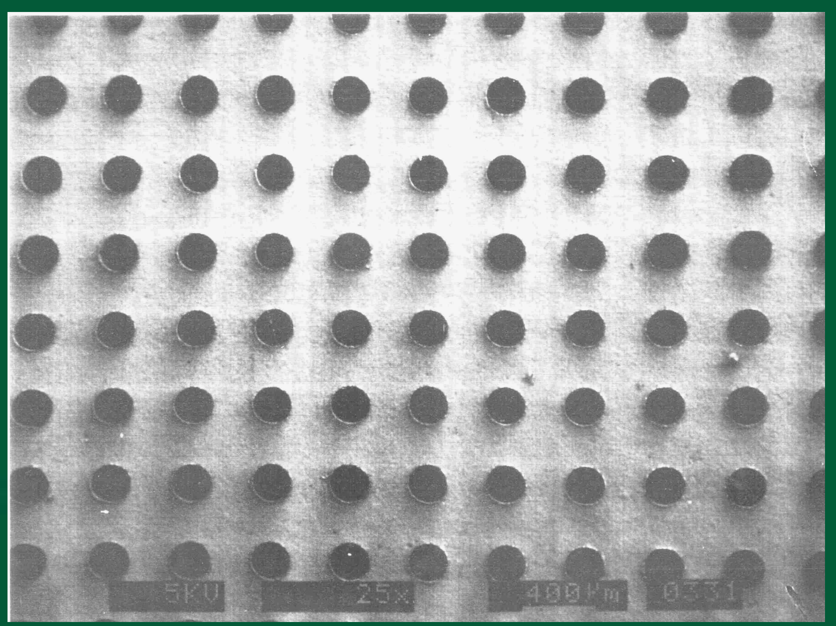
Close Packed Arrays



Alumina

200 μm dia on
500 μm pitch
through 640 μm thickness

Laser Micro-hole Drilling for Probe Cards

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System Requirements

Very High Accuracy Placement of Holes
Typically +/- 1.5 µm over 12 inch wafer

Air bearing axes with linear motors and linear encoders
True XY calibration using glass calibration plate
CAD file conversion software

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Laser Trimming of MEMS

Laser Trimming of MEMS

Improve Yield by Laser Trimming

- MEMS
- MEOMS (Photonics)

Probe first device

PASS

FAIL

Algorithm to determine laser trimming

Laser trim

Probe device

PASS

Probe next device

Laser Trimming of MEMS

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Precision Mass Removal by cutting, etching or drilling

Trimming of MEMS such as accelerometers & angular rate sensors to “balance” device

Ablated volumes in the range of 1 - 1000 μm^3 per pulse

For silicon 1 μm^3 = 2.3 $\times 10^{-15}$ Kg = 2.3 fg

But at pulse frequency of of 20kHz,
removal rate in the range 46 pg - 46 ng per second

Laser Trimming of Other Devices

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Photonic Devices - trimming of transmissive properties
- adding Bragg gratings

Electronic - trimming of resistive or capacitive properties

Wafer Processing Systems

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- Active wafer-level test, repair and optimization
- Wafer dicing and micromachining

- Device trimming/balancing
- Automatic probing
- IC & MEMS devices
- Micro-hole drilling
- Micro-cutting & dicing

- High throughput
- Full wafer test capability

Conclusions

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Laser micro-machining enables probe card designers greater choice in materials and flexibility in hole geometry to pursue advanced devices

Combined wafer probing and laser trimming enables higher yield in MEMS and other devices