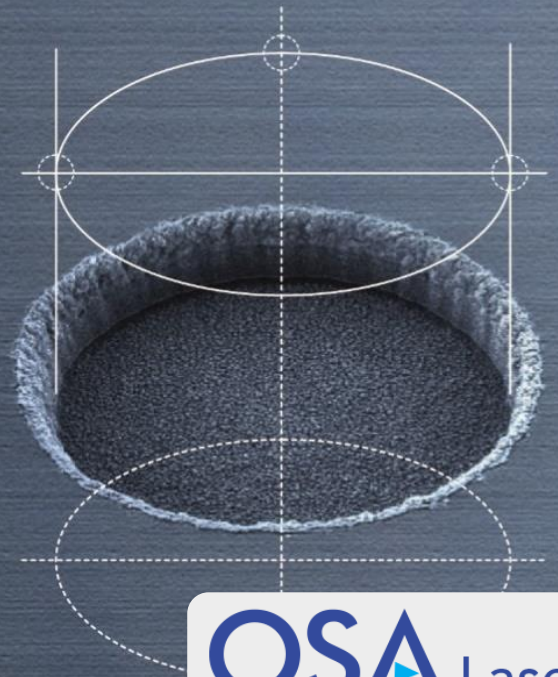
Laser based micro fabrication systems for electronics packaging



Dr. Haibin (Cliff) Zhang, zhangh@esi.com

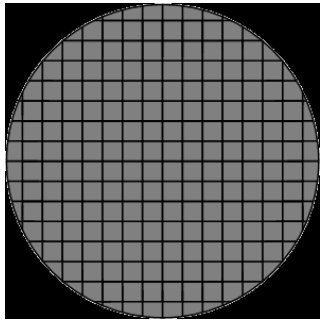
Electro Scientific Industries, Inc (esi), Portland OR, USA

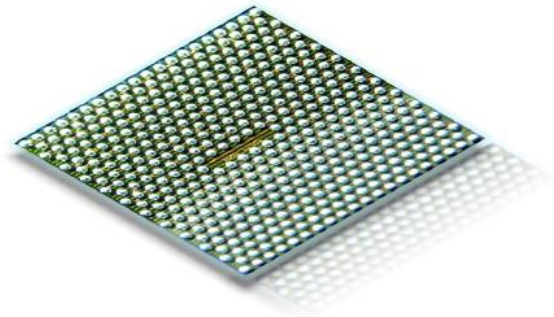
OSA Laser Congress
COLLOCATED MEETINGS
Advanced Solid State Lasers Conference
Laser Applications Conference
OIDA Executive Forum
4 - 8 November 2018

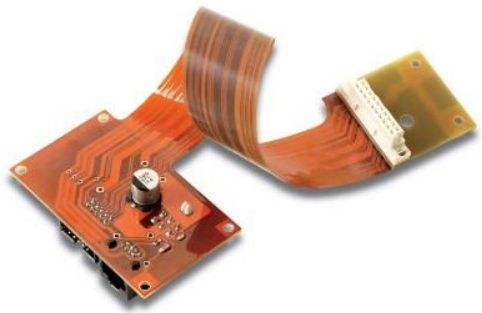
ESI: Electro-Scientific Industries

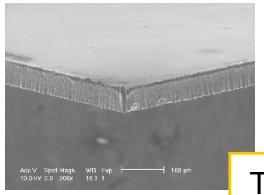
- Founded in 1944
- Technology: Laser-based microfabrication and inspection
- Markets: Consumer Electronics, Semiconductor, LED
- 700 employees worldwide
- IP Position: >800 patents
- ESI has over 1,100 customers in 50 different countries
- Installed base: > 6000 systems
- >90% of installed base is in Asia

Lasers in microelectronics, and challenges ahead

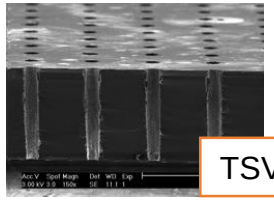




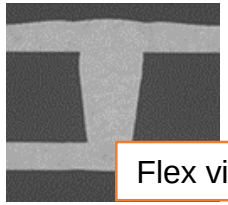




Thin wafer

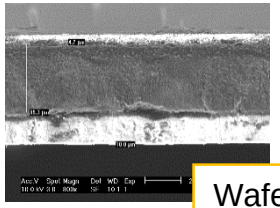


TSV

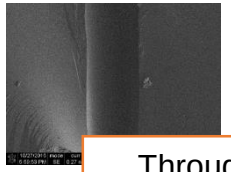


Flex via

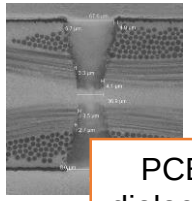
Package mark



Wafer + DAF

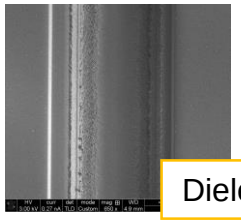


Through glass via

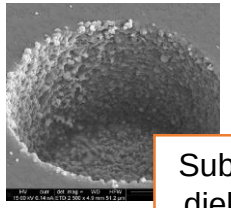


PCB dielectric

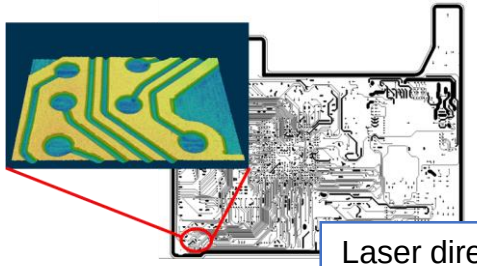
Wafer mark



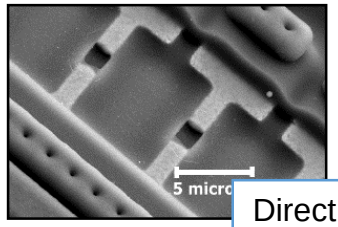
Dielectric scribing



Substrate dielectric

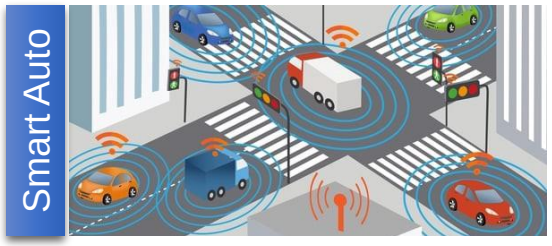


Laser direct patterning



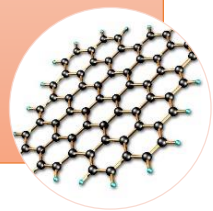
Direct ablation

New materials – rethink laser material interactions



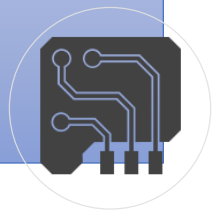
- New PCB materials to support high frequency (>10Ghz)
- Multi-stack

New materials



- Tighter pitch
- Higher density
- Thinner substrates

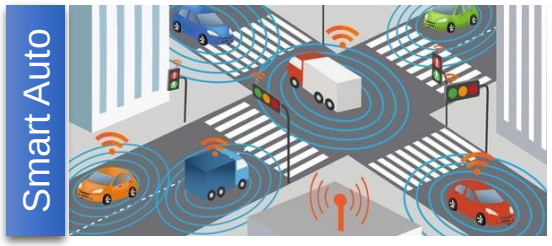
Tighter design rules



- Performance
- Yield
- Cost

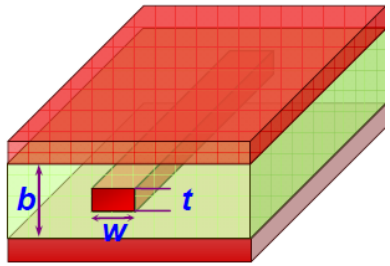
High volume low cost

New materials – rethink laser material interactions



	4G	5G
Latency	10 ms	Less than 1 ms
Peak data rates	1 Gbps	20 Gbps
Frequency band	600MHz to 5.925 GHz	600MHz–mmWave (28GHz, 39GHz, and onward to 80 GHz)

Stripline



b : Dielectric layer thickness
w : Conductor width
t : Conductor thickness

Low insertion loss

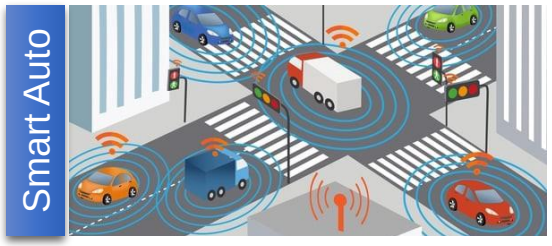
$$\alpha = \alpha_c + \alpha_d = A_1 \times \sqrt{f} + A_2 \times f \times \sqrt{D_k} \times D_f$$

Low signal delay

$$T_d = A_3 \frac{\sqrt{D_k}}{c}$$

Low Dk & low Df

New materials – rethink laser material interactions



FR4

- Baseline PCB material
- Resin and glass cloth
- CO2 laser widely used

PTFE

- "Teflon"
- Superior HF performance
- Enables microwave

PI (Polyimide)

- Baseline flex material
- Blind and through vias
- UV ns lasers

LCP

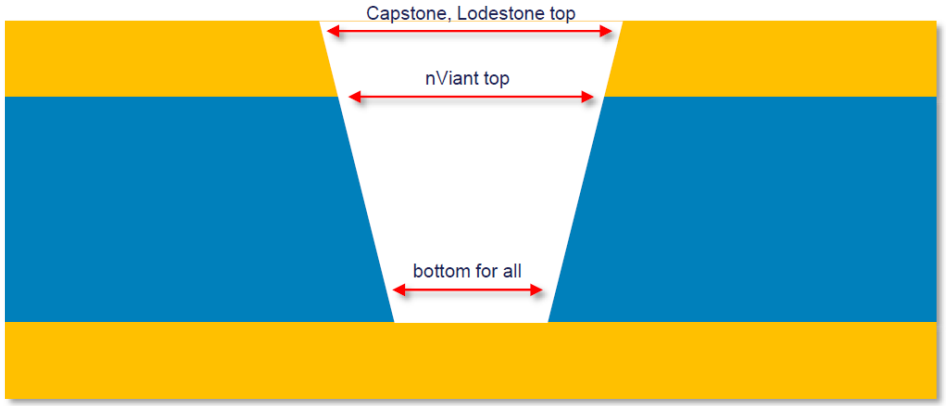
- Superior HF performance
- Thermal performance
- Moisture resistance (0.04%)

Material	Product (Cu/Dielectric/Cu)	Copper	Dielectric	DK @ 10GHz	Df @ 10GHz
HF FR4	Isola IS 300MD	12um treated	70um 1067 glass type	3.05	~0.003
PTFE	Dupont Pyralux TK187551R	12um treated	19um PTFE/38um PI/19um PTFE	2.5 – 2.8	~0.002
Polyimide	Dupont Pyralux TA	12um treated	50um	3.2	~0.003
LCP	Panasonic R-F705T	12um treated	50um	3.0	~0.002

Laser systems for the tests



	Capstone (UV)	nViant (CO2)	Lodestone (Green)
Pulse duration	Nanosecond	Microseconds	Femtosecond
Wavelength	355nm	9400nm	515nm
Heads	One	Two	One
Max. avg. power	~11W	~50W / head	~8W
Laser max rep. rate	300kHz	2.5kHz / head	1000kHz
Via beam steering	3rd dynamic™	Punch	Galvo + stage



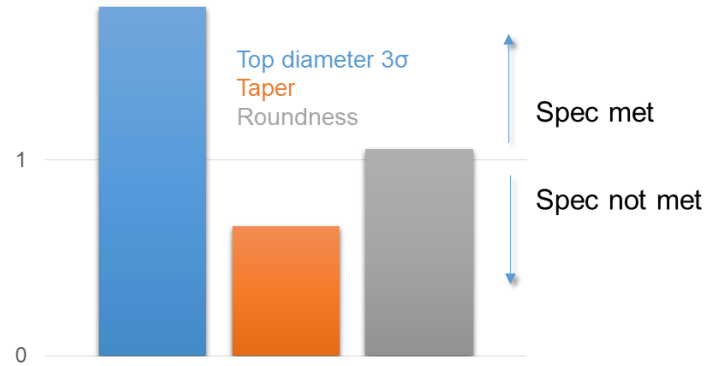
<u>Via specifications</u>

Top diameter: 75 ± 5μm (3σ)

Taper: >0.85 (|M| - 3σ)

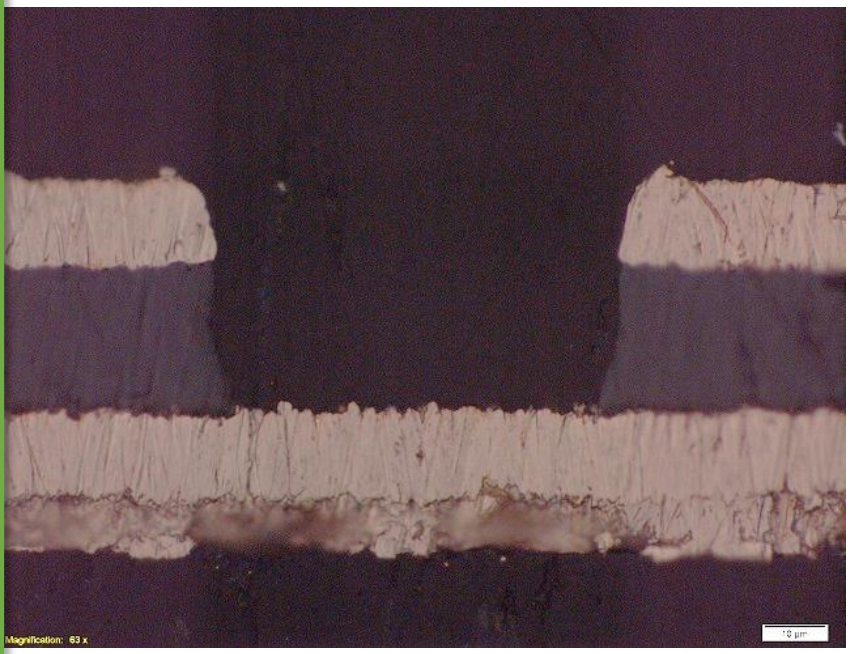
Top roundness: >0.90 (|M| - 3σ)

<u>Example data</u>



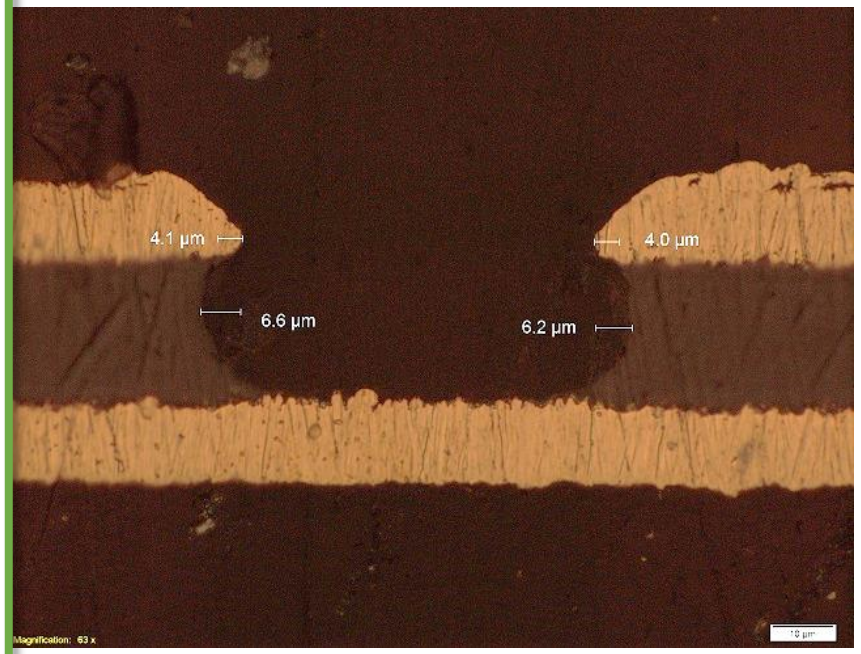
Results: PI – 12/25/12

Capstone



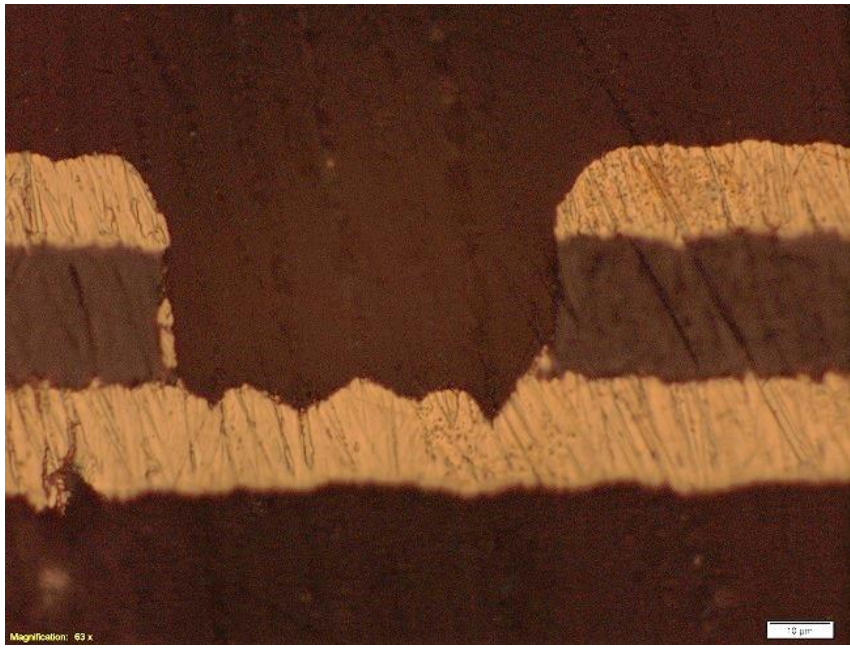
Throughput: 1430vps

nViant

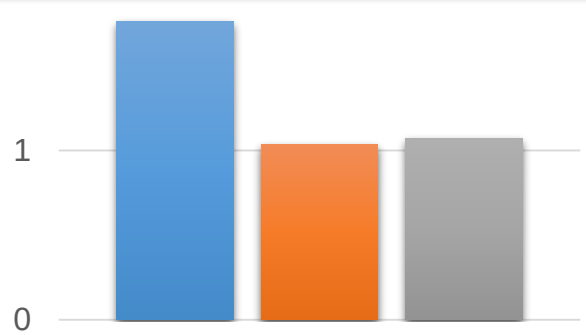


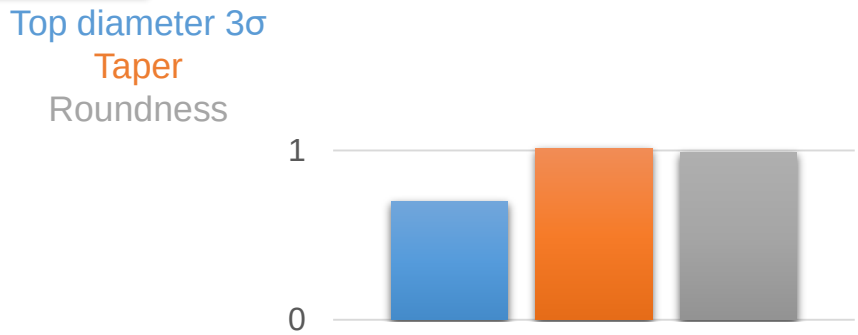
5000vps (dual panel)

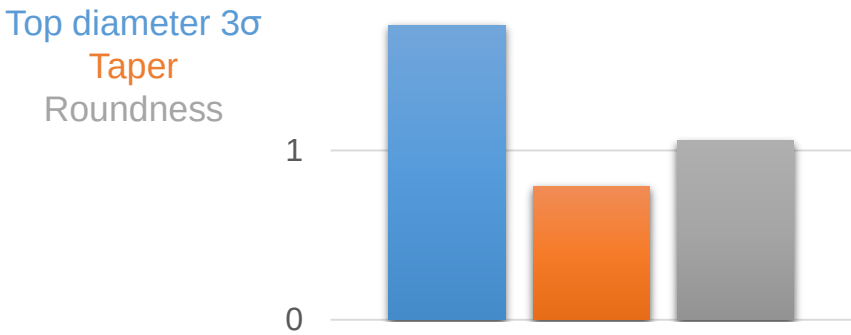
Lodestone



74vps

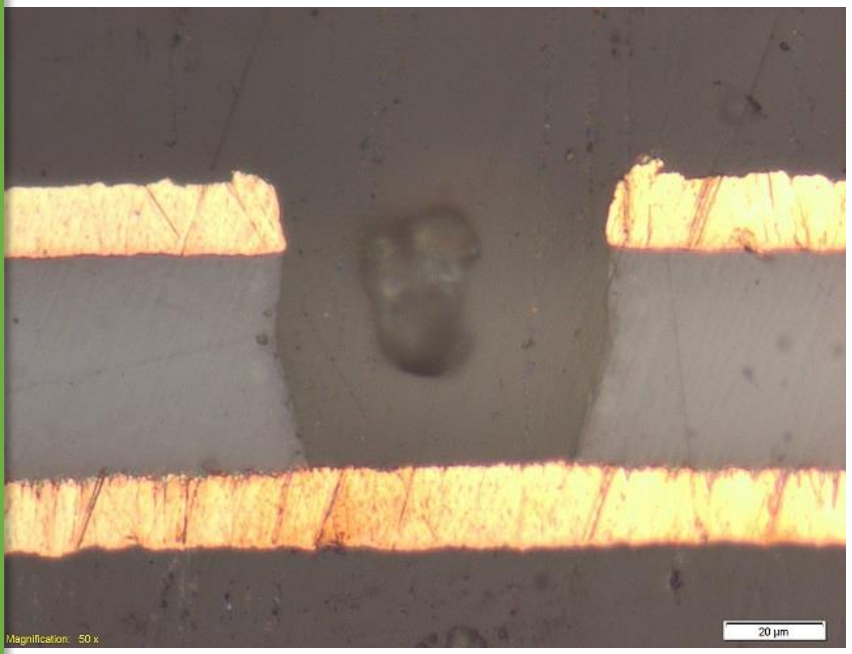






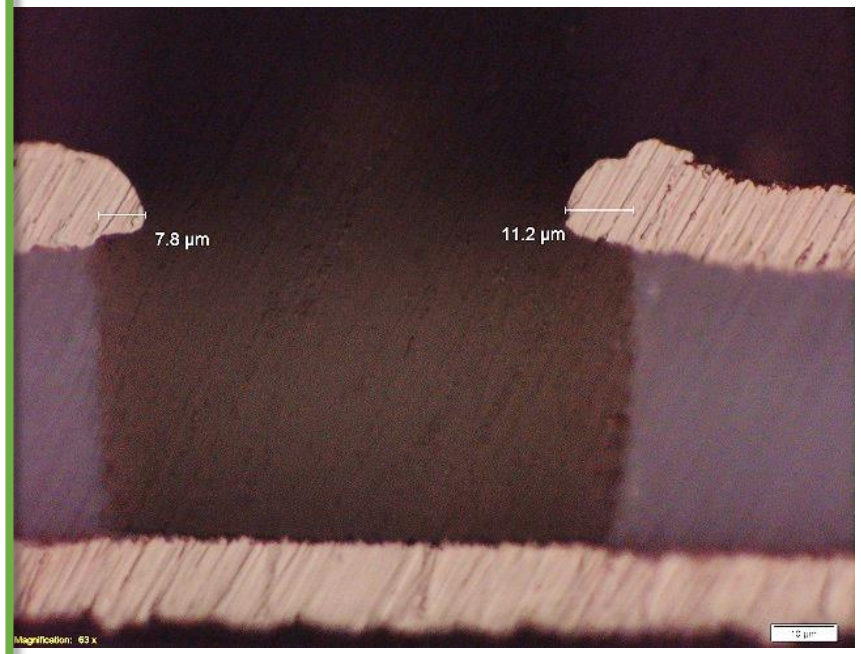
Results: LCP – 12/50/12

Capstone



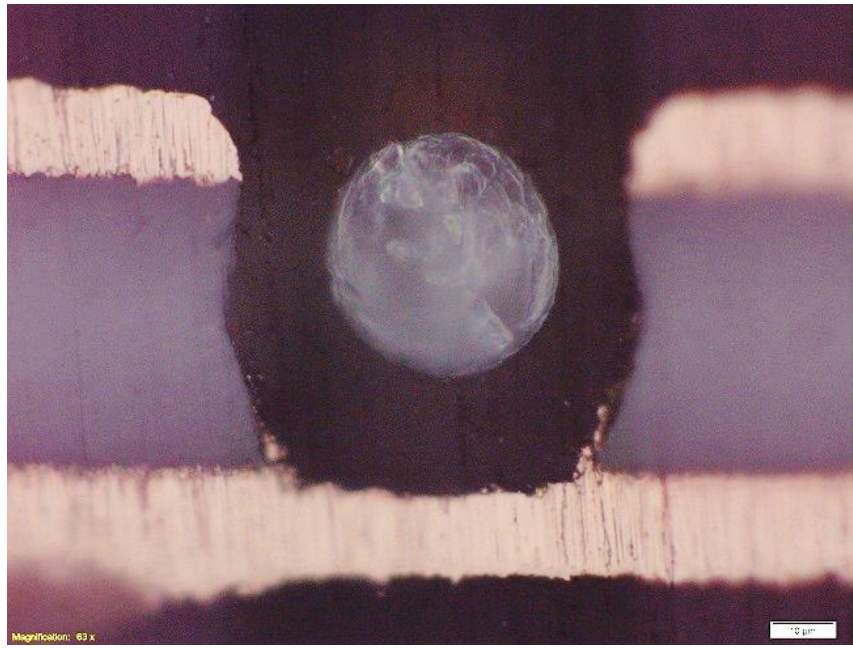
Throughput: 1000vps

nViant

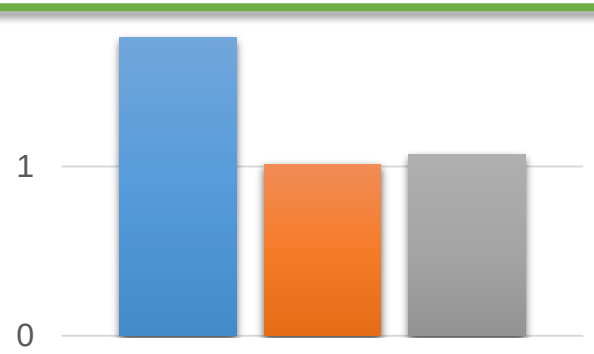


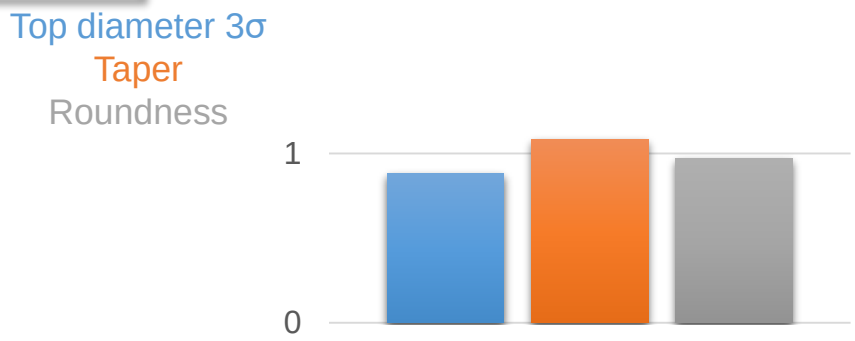
2500vps (dual panel)

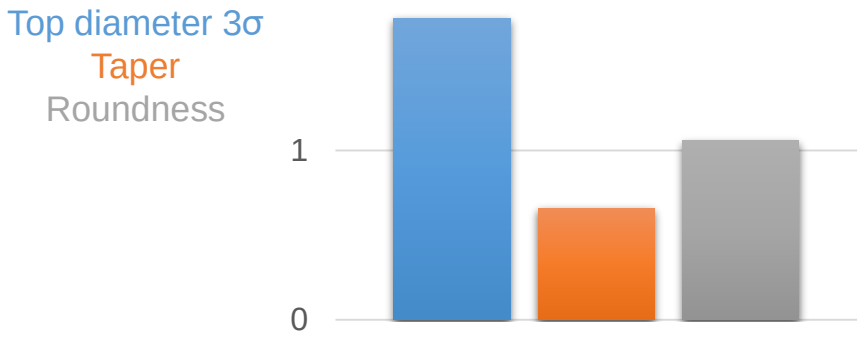
Lodestone



82vps

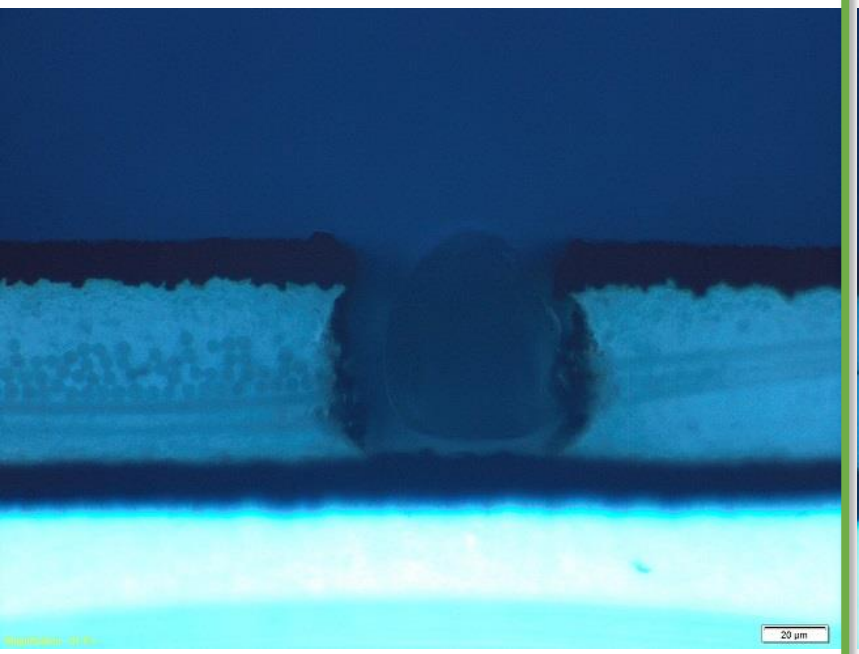






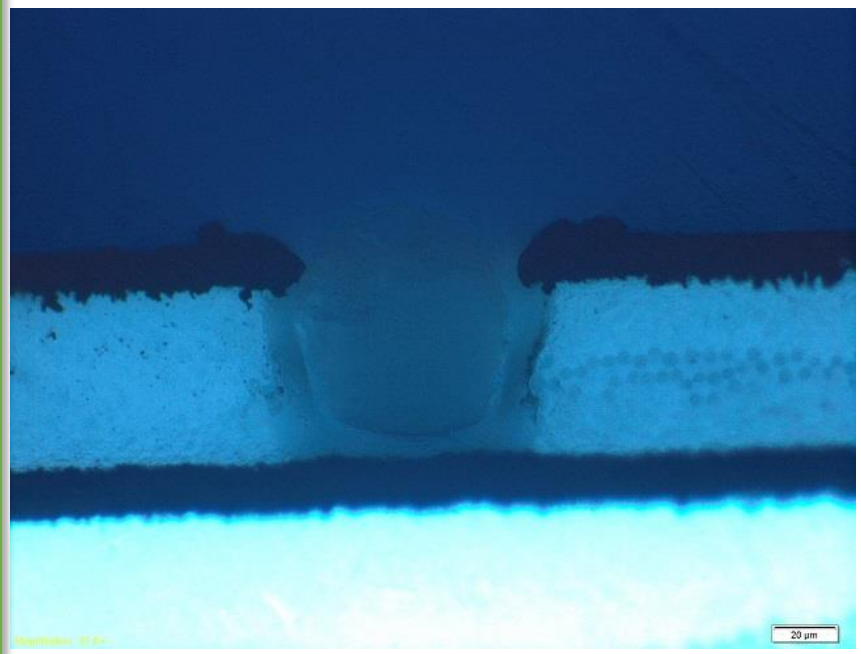
Results: FR4 – 12/60/12

Capstone (UVns)



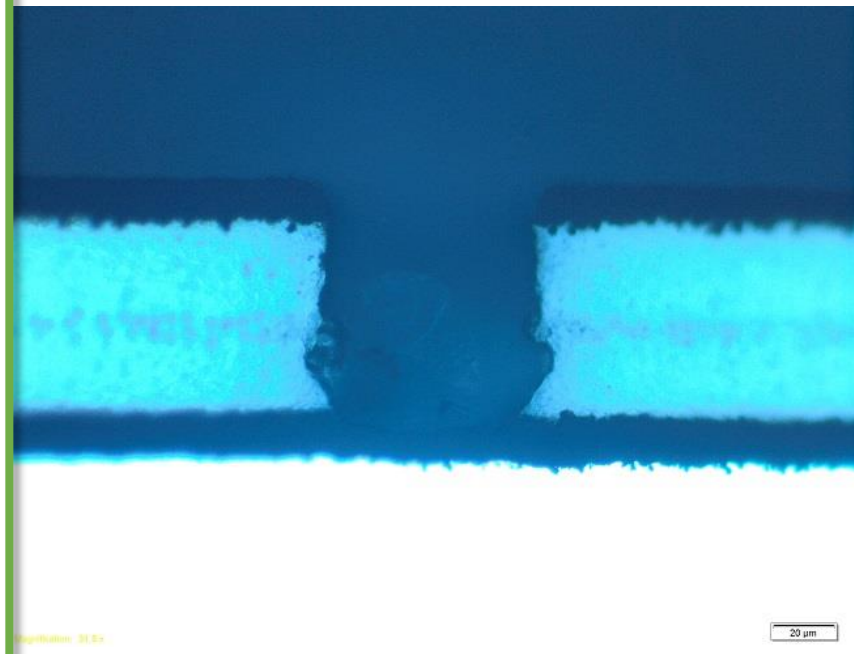
Throughput: 645vps

nViant (CO2µs)

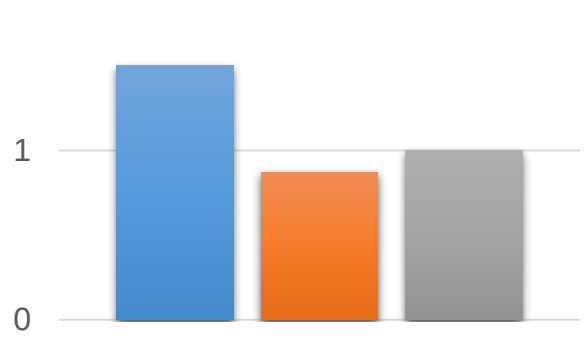


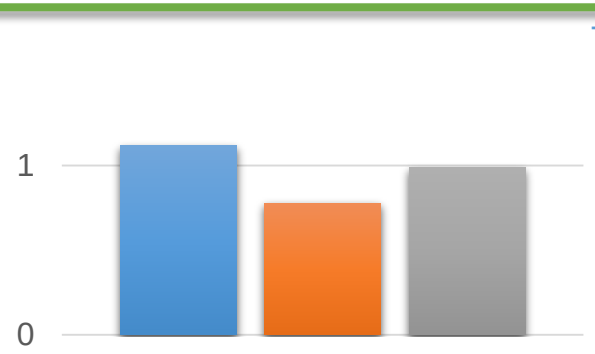
1667vps (dual panel)

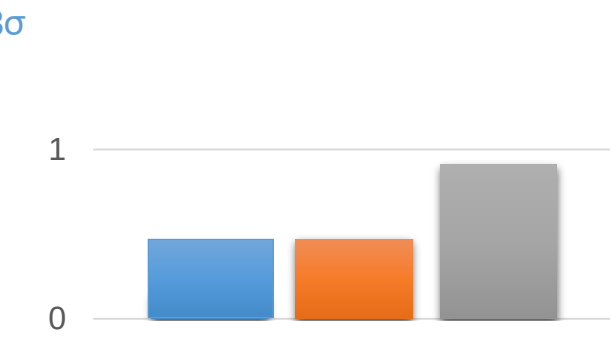
Lodestone (Green fs)



65vps

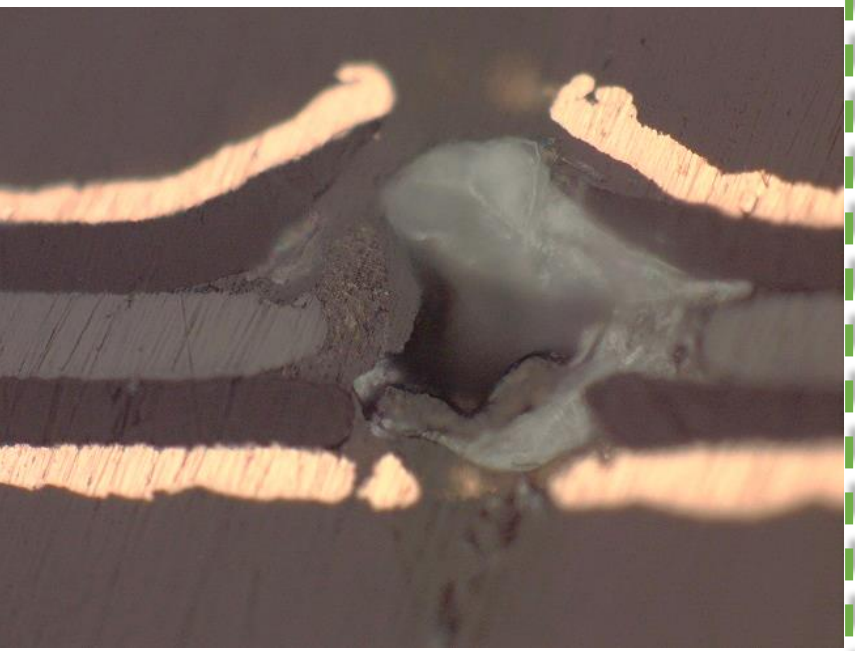






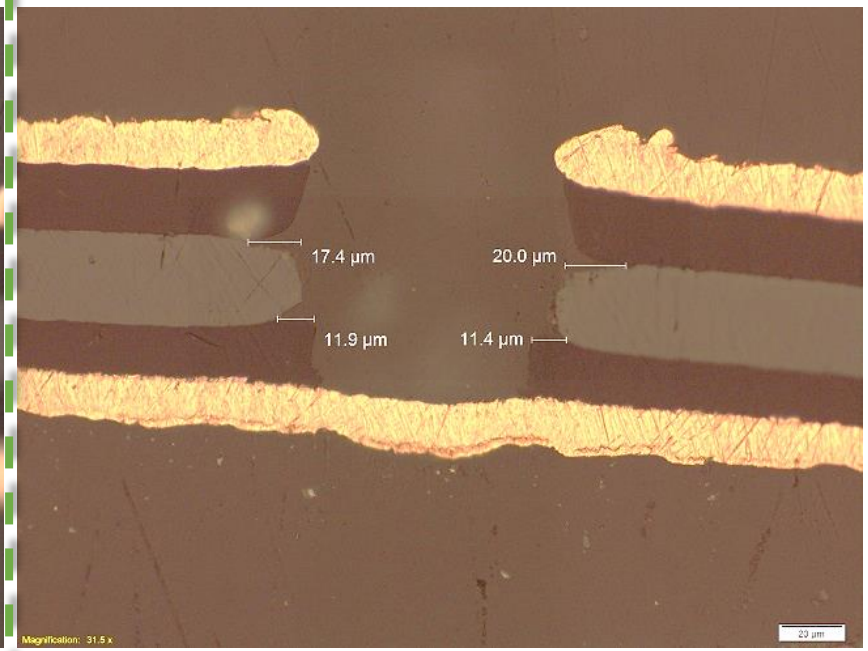
Results: PTFE Comp. – 12/75/12

Capstone



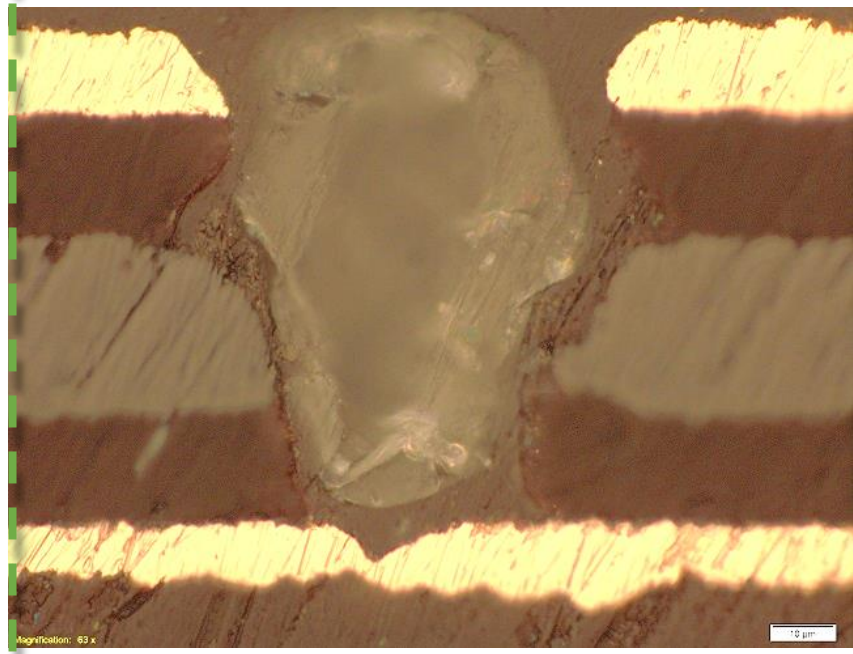
Throughput: n/a

nViant

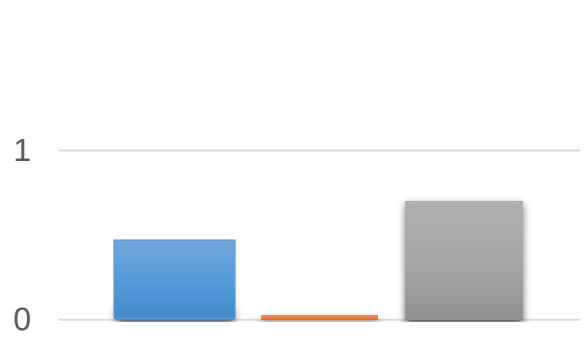


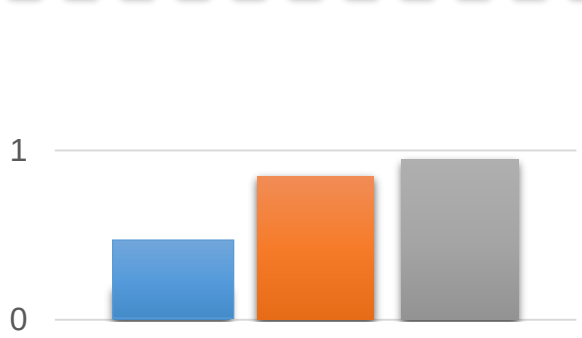
1667vps (dual panel)

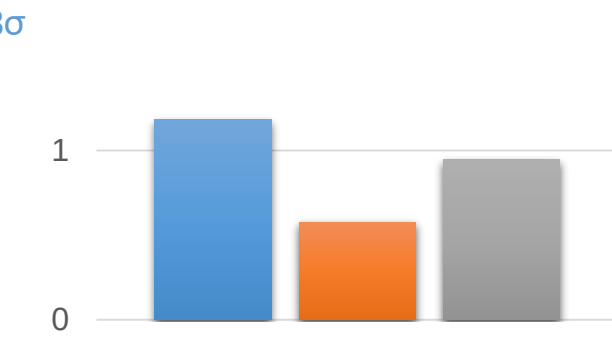
Lodestone



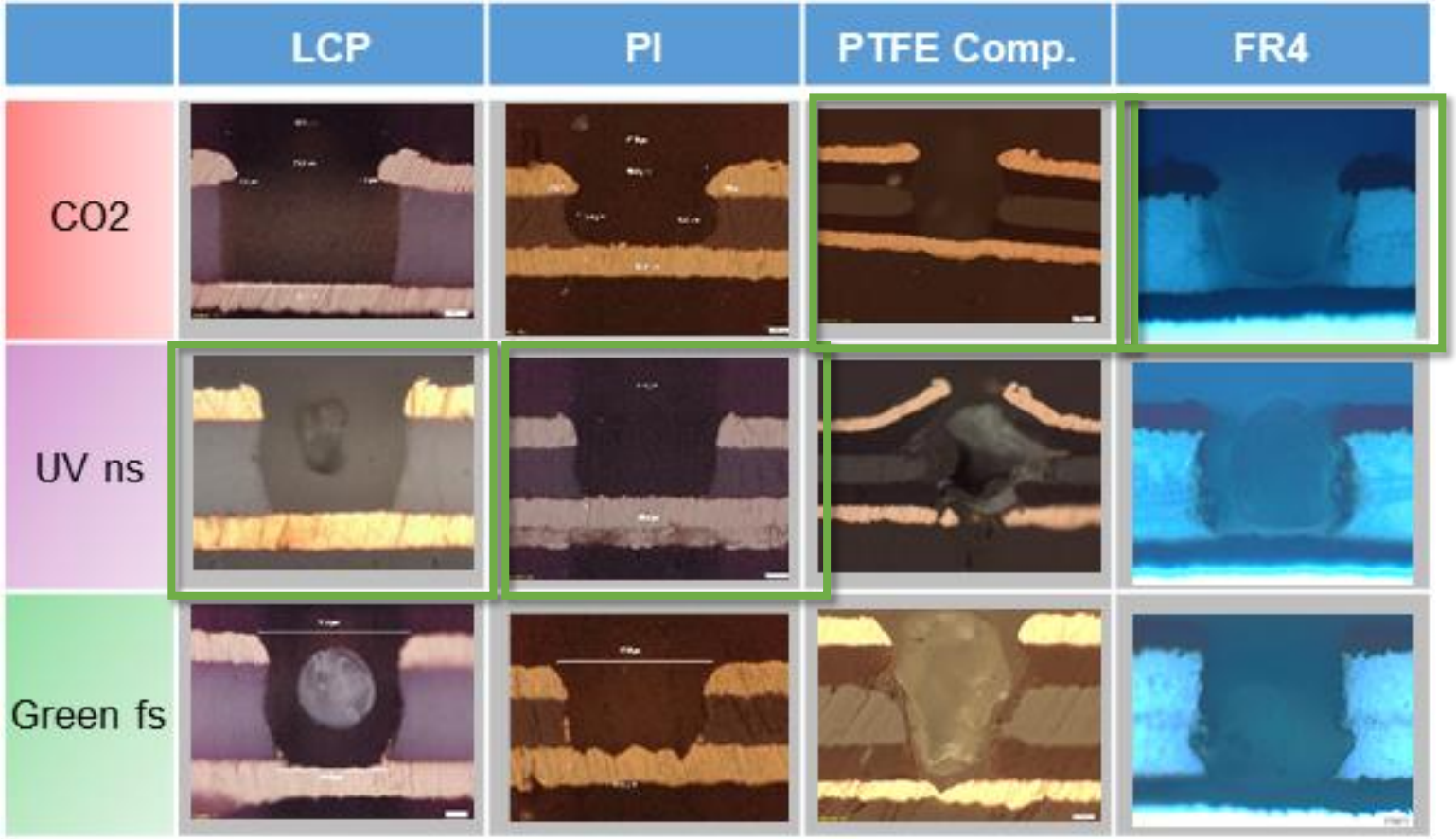
69vps







Summary of high frequency materials



LCP:

- UV ns solution, all metrics met.

PI:

- Best quality with UV ns solution.

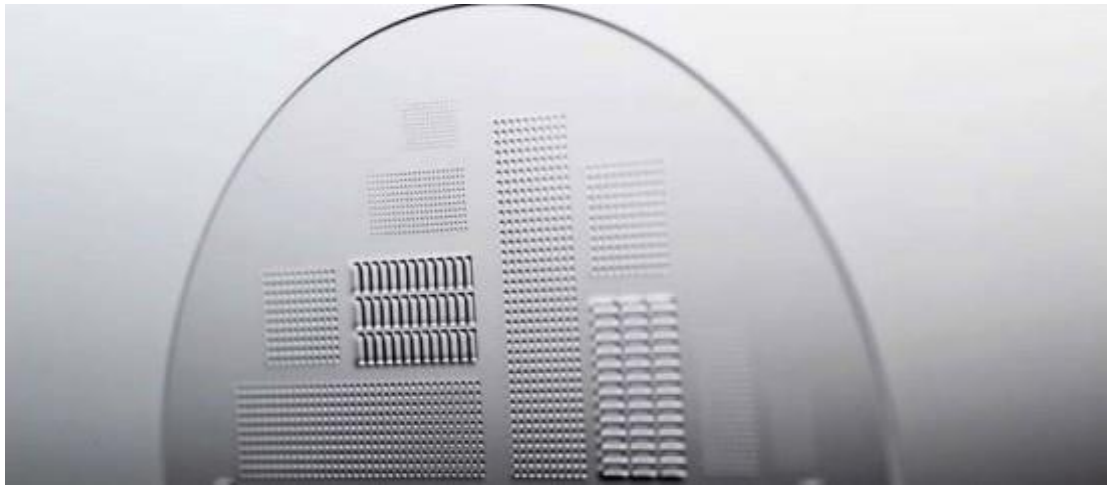
PTFE Composite:

- Closest is CO2 with delamination

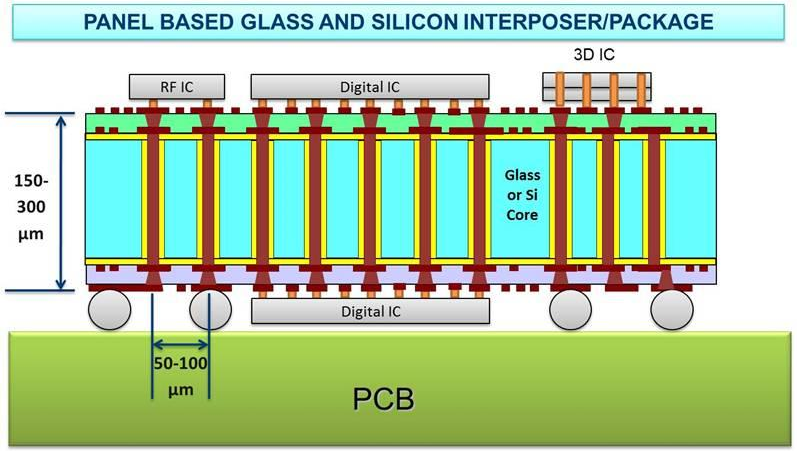
FR4:

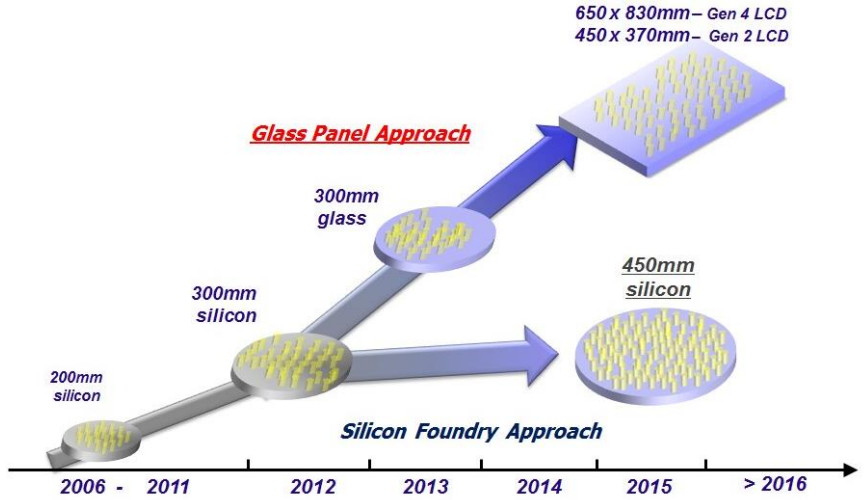
- CO2 best quality/throughput compromise

Glass as emerging material for interposer and other applications



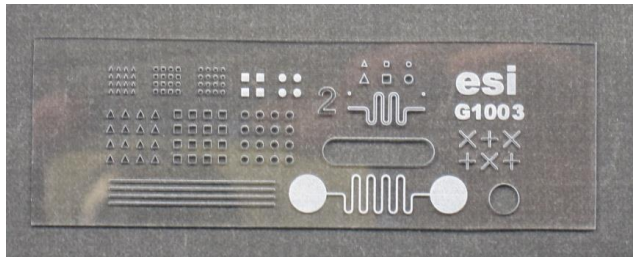
- Electrical property
- Multiple CTEs – matching silicon and other
- Superior surface quality
- Stiffness lead to better flatness
- Scalable form factor
- Lower cost/mm2, tighter I/O pitch





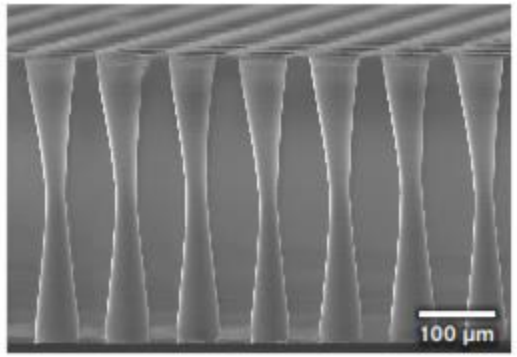
Wafer → Panel

Current Glass Processes

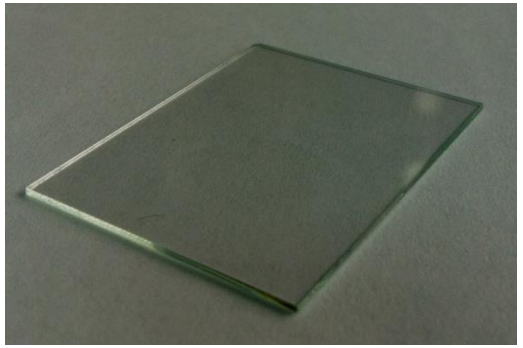


Marking

Small Features



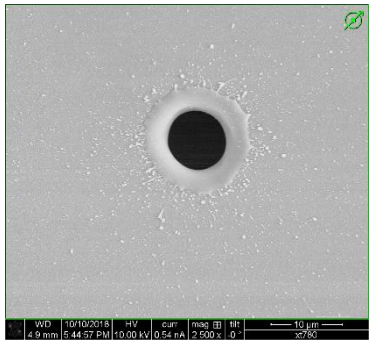
Expose and etch (LPKF)

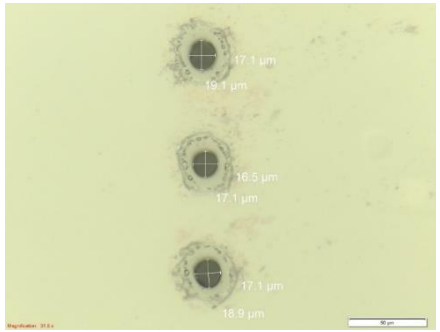


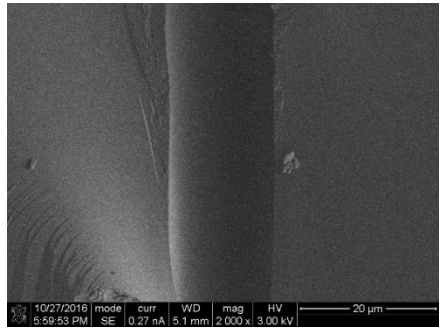
Singulation

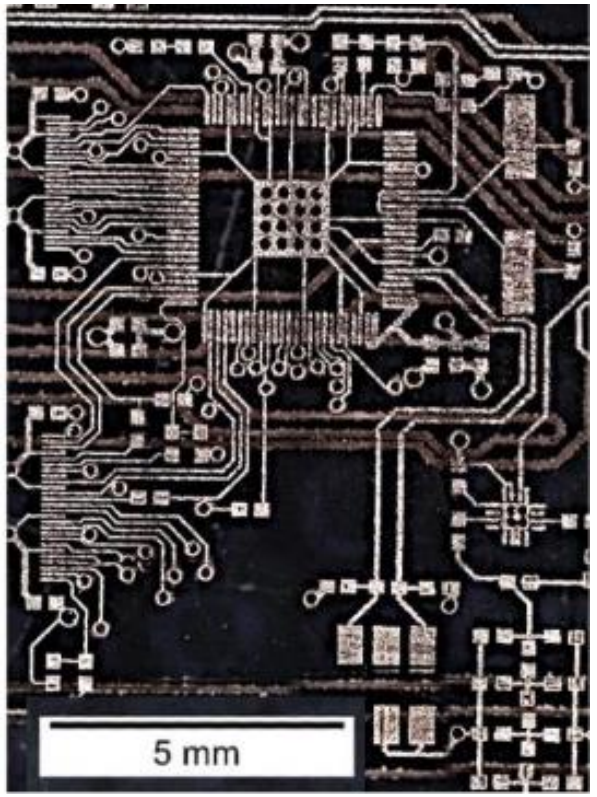
Multi-layer Glass PCB

10um ~ 20um vias in ~100um thick glasses









High speed glass via

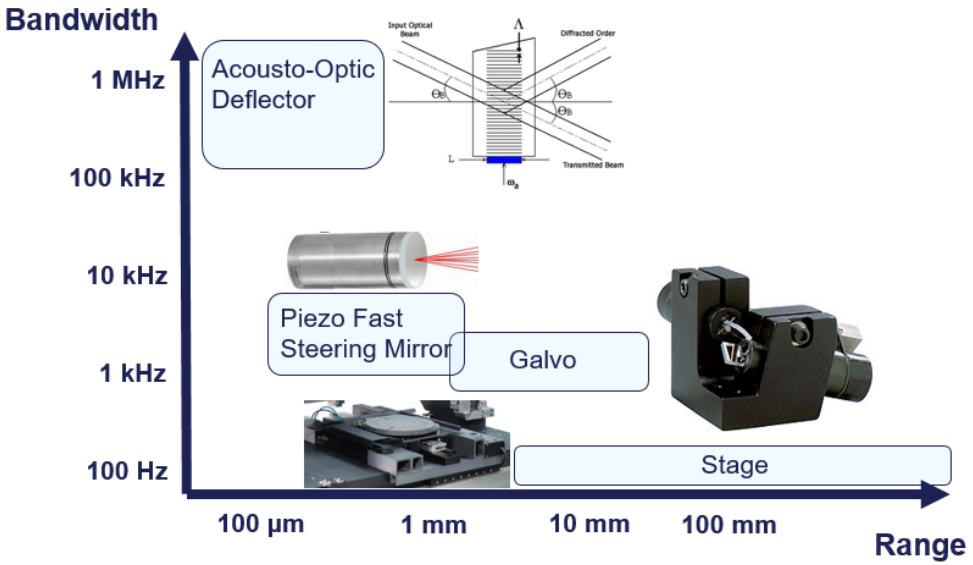
High speed direct circuit on glass

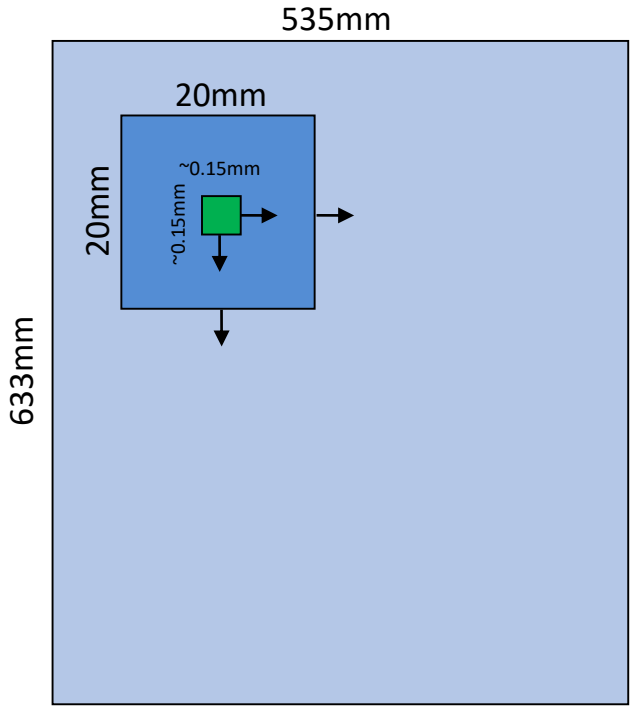
>10,000 via/s/head

~10 to 20 seconds

3rd Dynamic™ – extreme high speed scanning on large areas

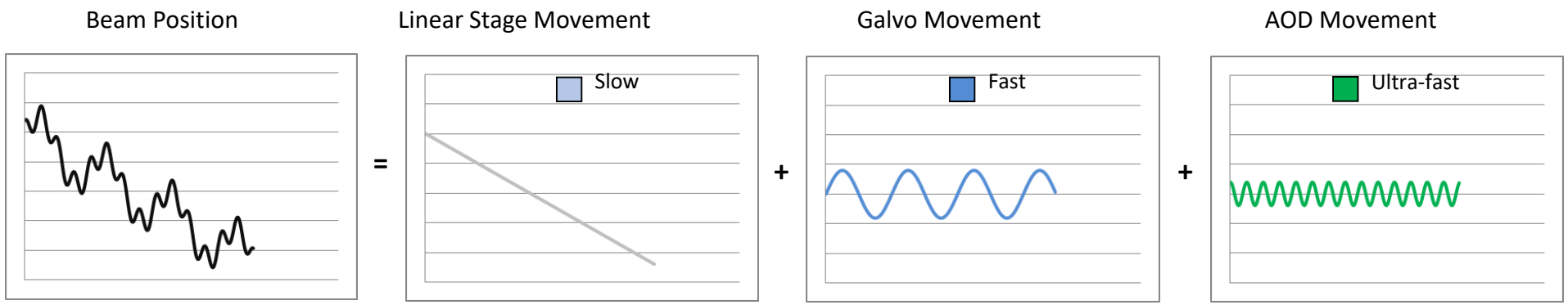
Third dynamic technology provides ultimate efficiency: speed + range



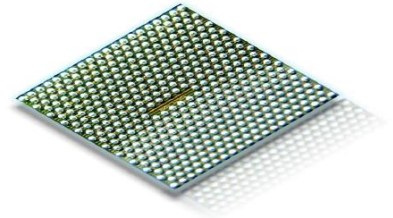


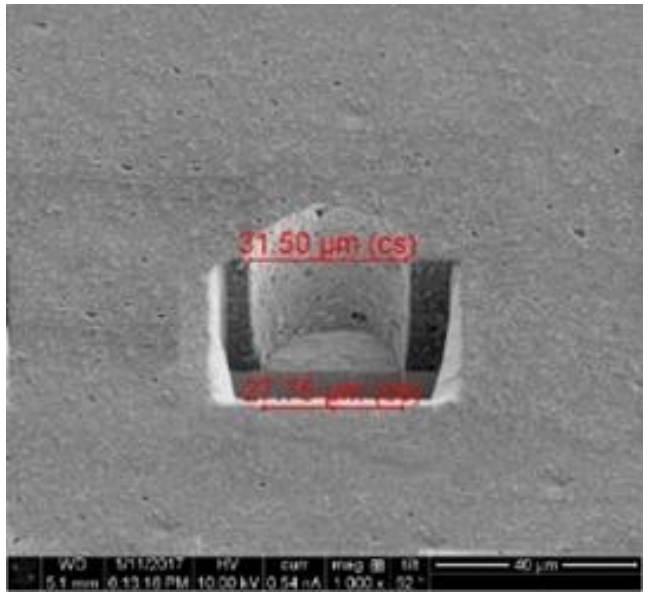
Example: ESI tertiary beam positioning system (Third Dynamic®)

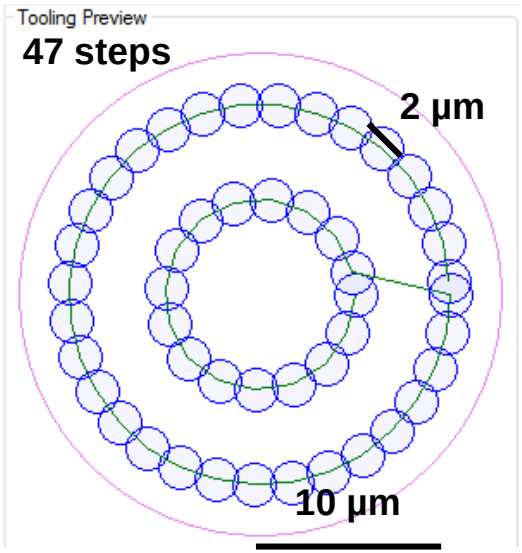
- Linear Stages provide the overall range of motion for the target panel dimension
- Galvos provide fast intra-via beam positioning
- AODs provide ultra-fast beam positioning for rapid and precise tooling actions



Application Example – Via Drilling







Effective Speed = 2 m/s

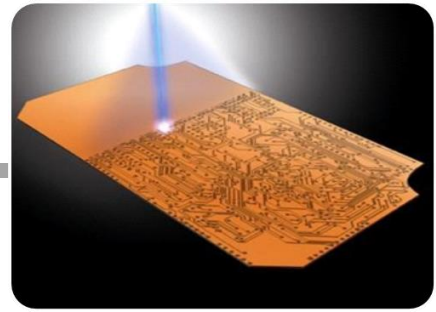
Effective Acceleration (outer circle) = $400{,}000\ m/s^2$

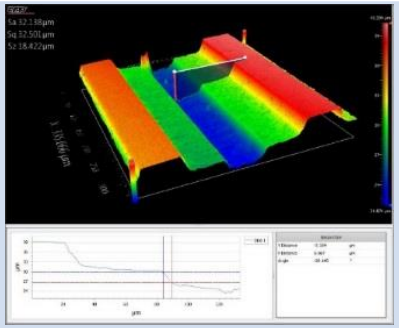
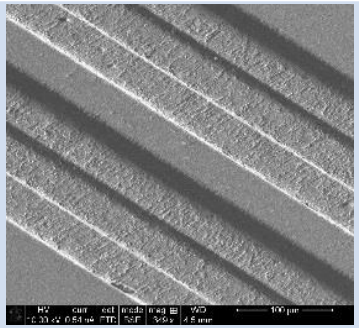
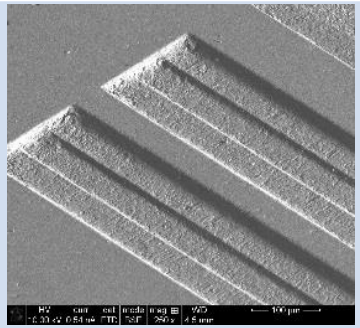
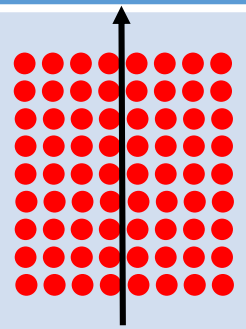
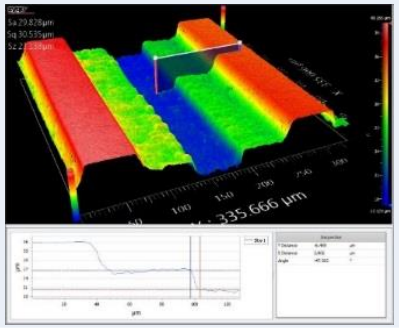
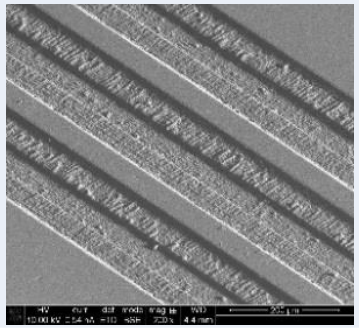
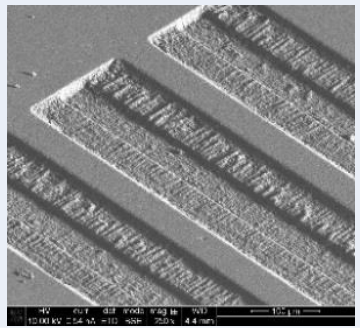
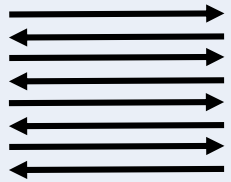
Effective Acceleration (inner circle) = $800{,}000\ m/s^2$

Galvo Routing Max Speed ~ 0.4 - 0.5 m/s

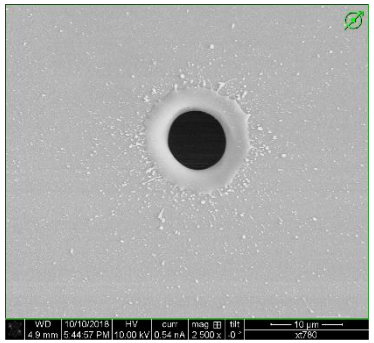
	Drill Time	Reprate	Effective Speed (m/s)	Acceleration (x 1000 g)
AOD Raster	47 us	1MHz	2	40 - 80
Galvo Rout	>500 us	<100 kHz	<0.2	3

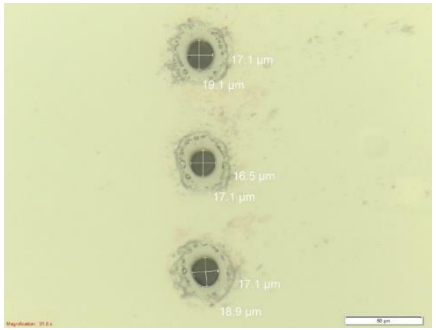
Application Example – Trenching and Skiving

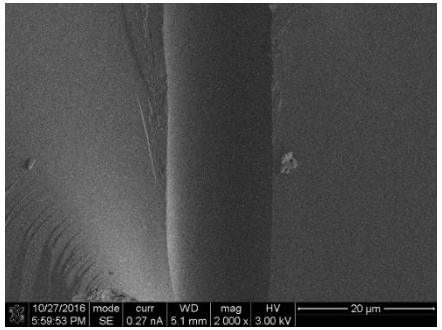


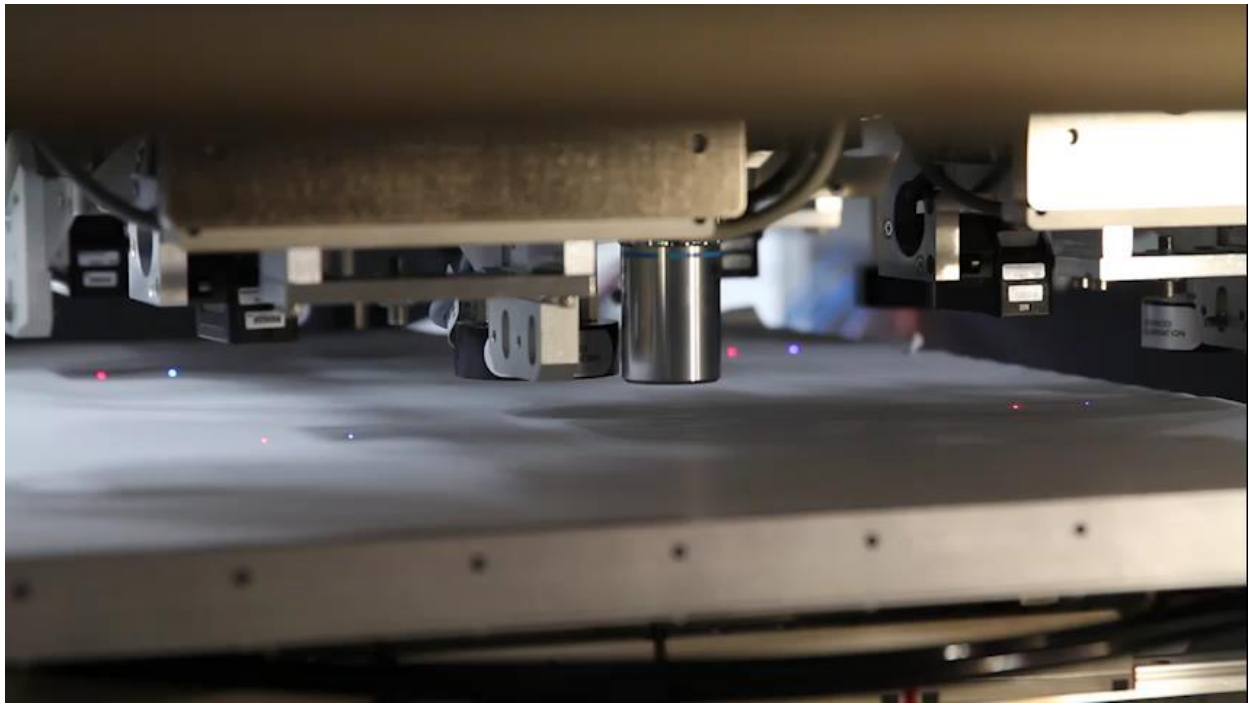
Approach				Method	Effective Speed
Serpentine AOD Raster					> 20 mm/s
Galvo Rout Y Direction					~ 4 mm/s

CornerStone ICP – 4 Beam Drilling







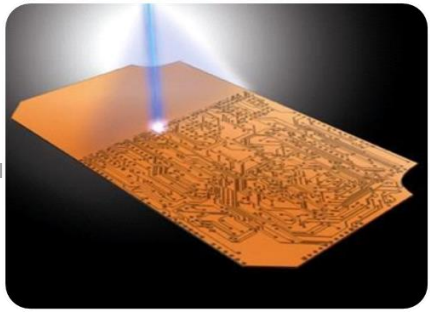


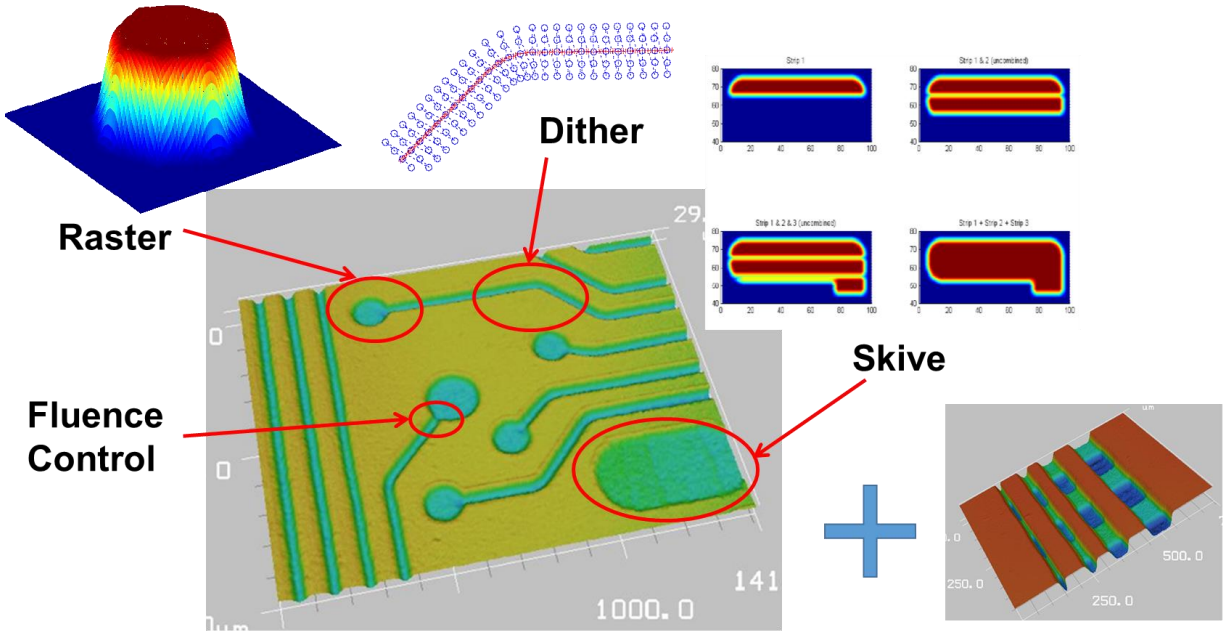
10um via

20um via

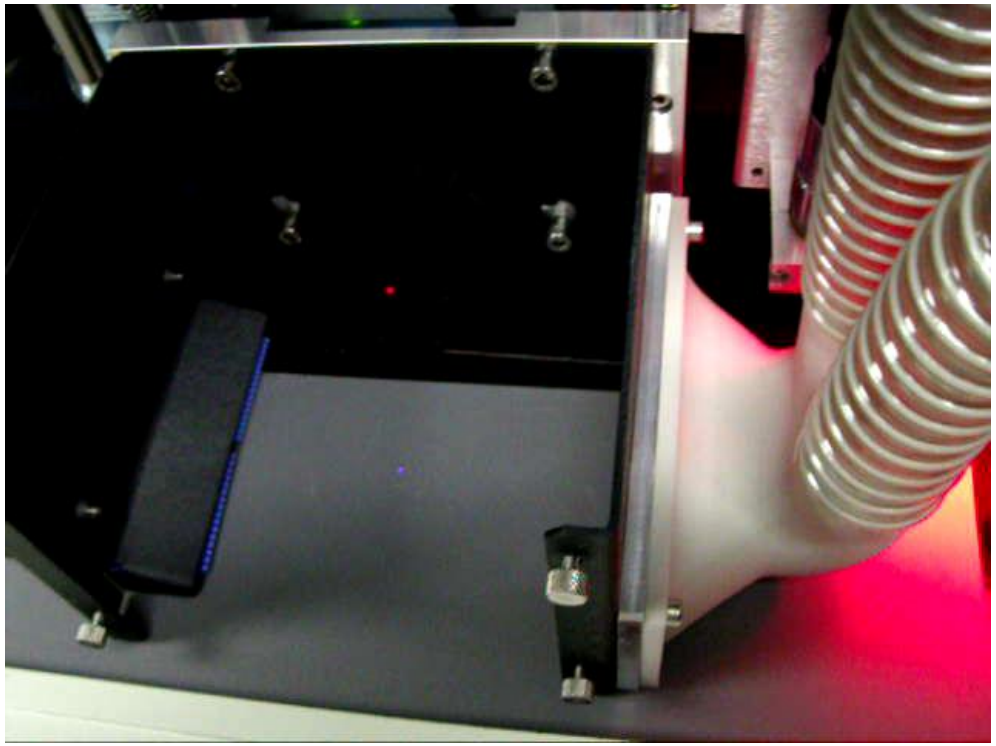
>10,000 via/s/head

Laser direct ablation patterning in action

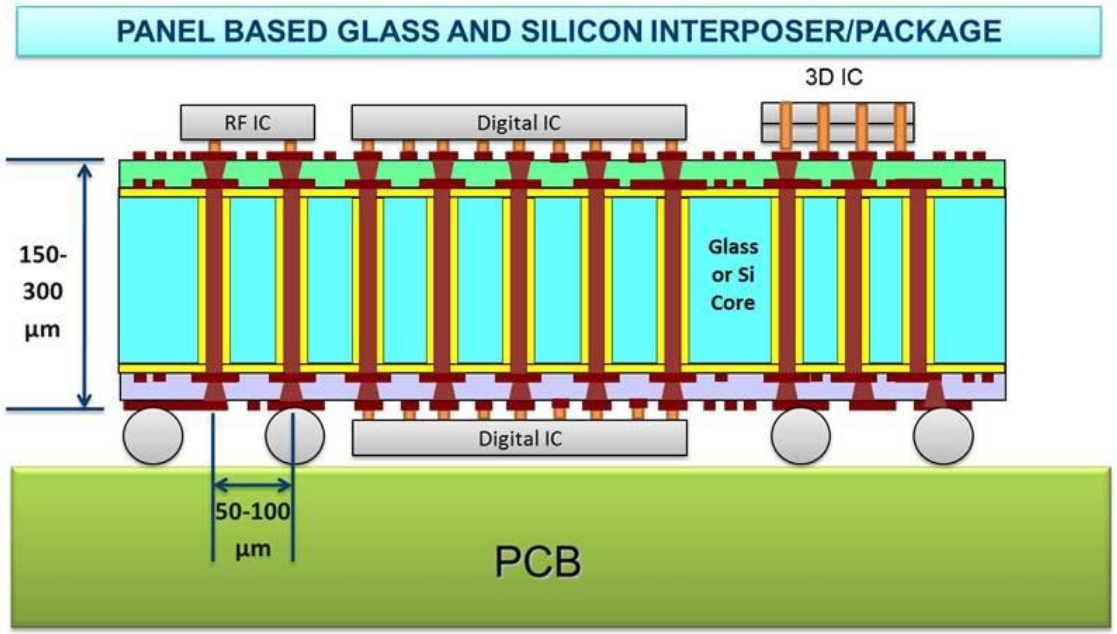


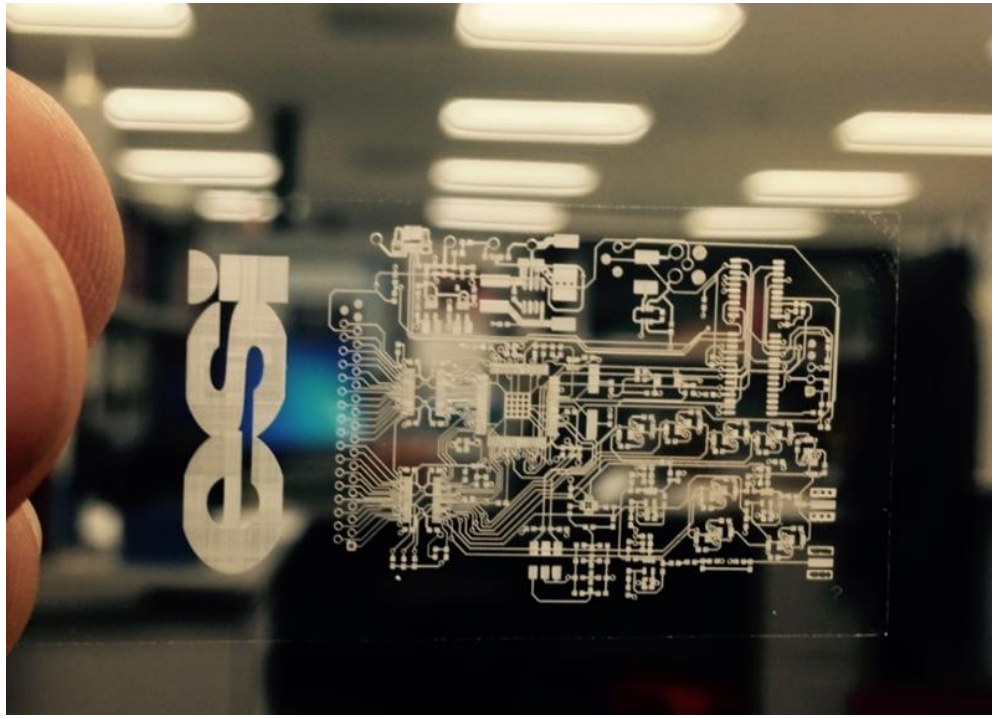


53



Glass interposers and all glass circuits!





Summary

Lasers are widely used in electronics packaging

New end market demand requires rethinking of laser choices and system architectures

System needs to provide high accuracy, high speed, and low cost

Tertiary beam positioning technology enables high speed laser processing

0.2 um -> 20um accuracy
1um -> 100um features
>10,000 via/second/head speed

Acknowlegement to contributing colleagues:

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Thanks for your attention