IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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Comparison of Drilling Rates and Tolerances of Laser-Drilled holes in Silicon Nitride and Polyimide Vertical Probe Cards

OXFORD LASERS INDUSTRIAL DIVISION

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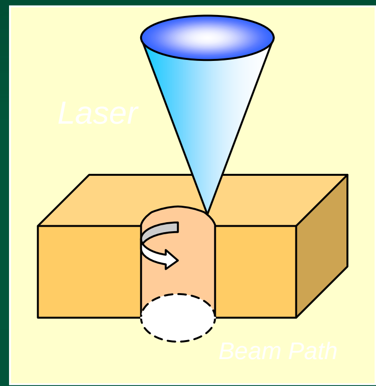
Overview

- Introduction to laser drilling
- Laser drilling examples
- Comparison of laser drilling of SiN and polyimide
- Comparison of laser drilling with mechanical drilling
- Summary

Introduction to Laser Drilling

for Vertical Probe Cards

- Laser beam diameter at focus - typically 0.2 mil (5µm)
  - this is the diameter of the "laser drill-bit"



- Typical required hole diameters are 1.6 mil (40µm) to 4 mil (100µm)

- Latest Systems rotate the beam around the hole center
  - this gives excellent hole circularity

- Laser beam evaporates the material
  - so the laser does not care if the material is hard or soft etc

Introduction to Laser Drilling

for Vertical Probe Cards

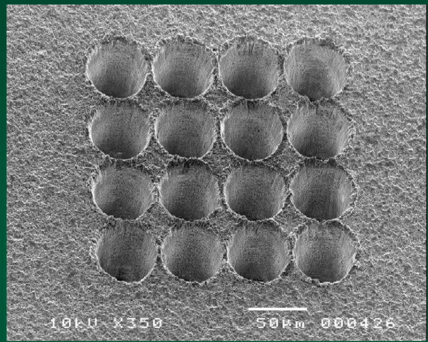
- Laser drilling machine looks and behaves like a modern wafer fab tool
- Latest developments include full software control of the process and hole geometry
- Flexible tool
  - can drill ceramics, polymers, silicon and other materials
- Future proof
  - hole diameters down to 0.8mil (20µm)
  - round holes, rectangular holes & other shapes

Silicon Nitride and Polyimide

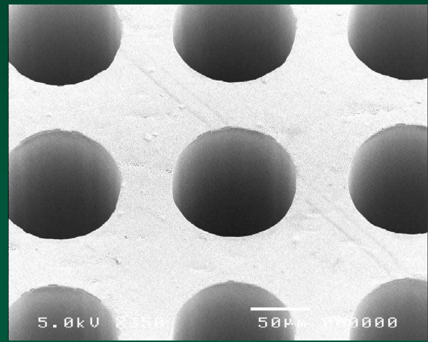
	SiN	Polyimide
Temperature	1900 ^oC sublimes	400 ^oC glassifies
Ablation threshold	~2.5 J/cm^2	~0.05 J/cm^2

- means that it needs more laser power to ablate SiN
- expect process speed of SiN to be slower
- SiN sublimation means that it ablates very cleanly, no melt etc
- too much laser power on polyimide can cause charring

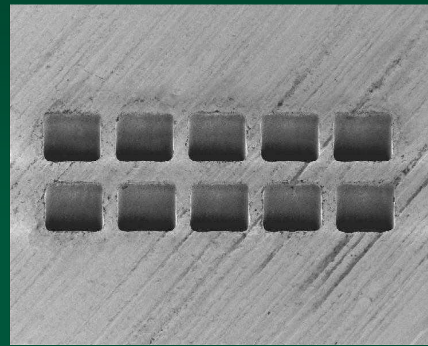
Laser Drilling Examples



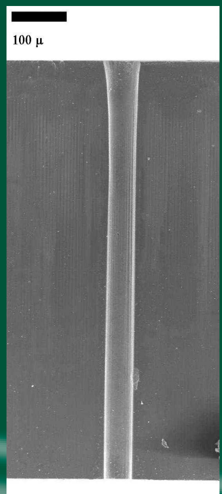
2 mil dia hole, alumina



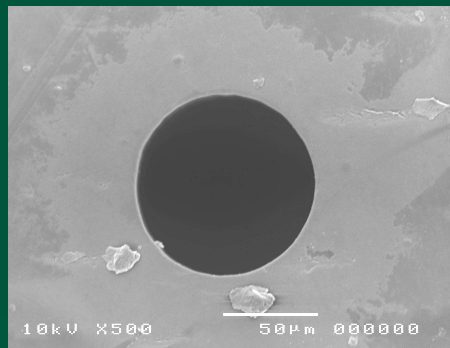
4 mil diameter hole, polyimide



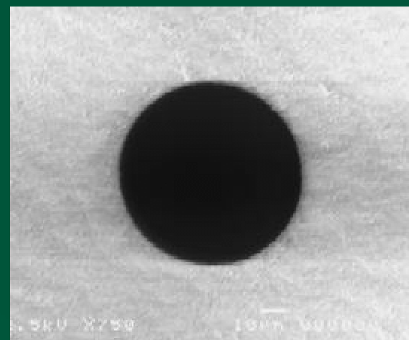
2.4 mil rectangular, SiN



2 mil dia hole, polyimide

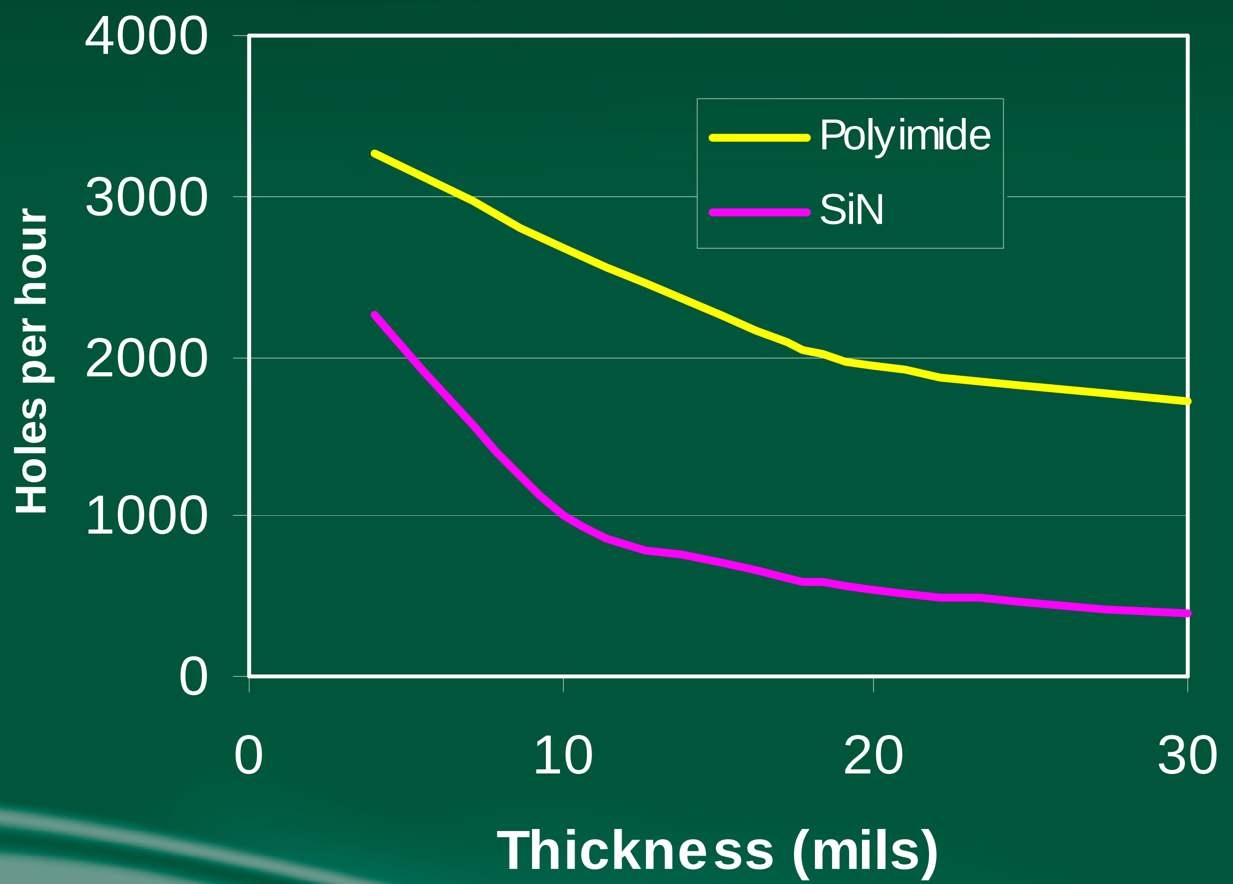


3.2 mil dia hole, polyimide

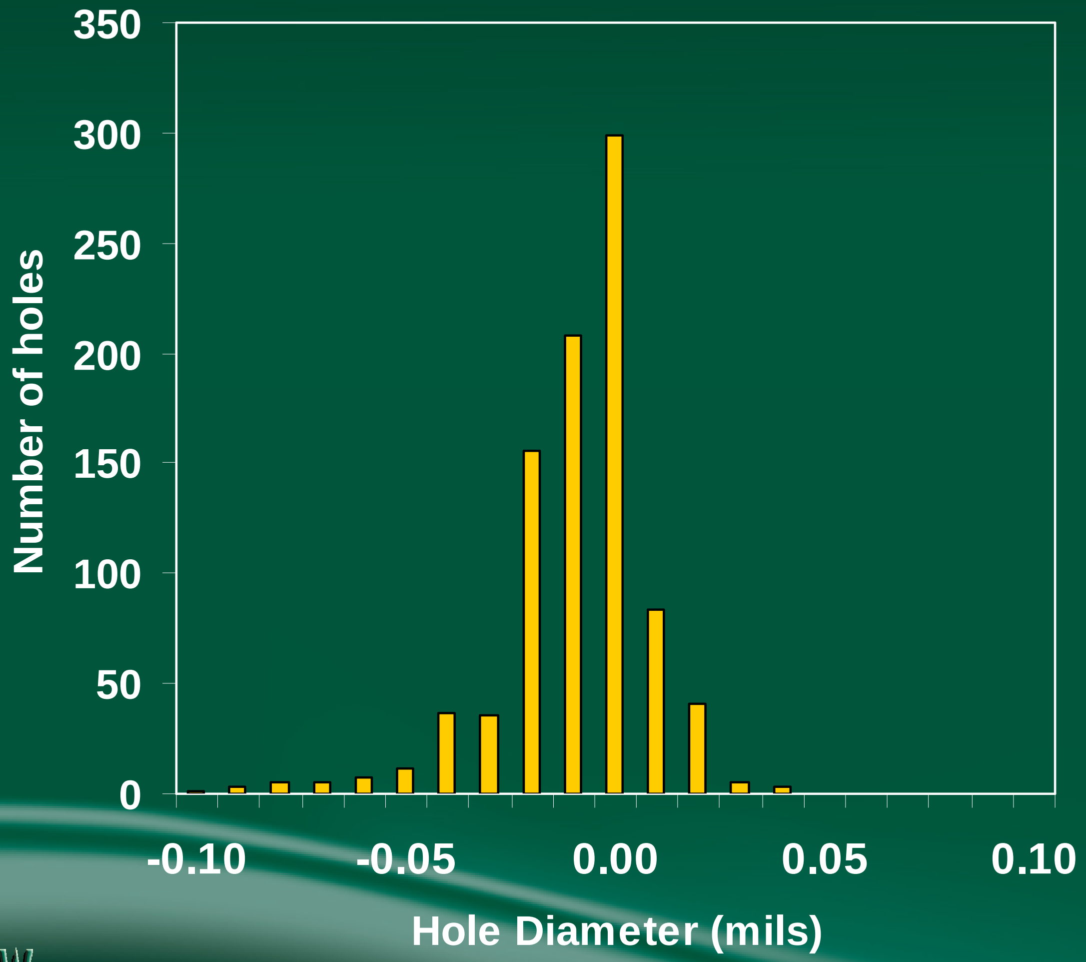


3.2 mil dia hole, SiN

Laser Drilling - Process Rate



Laser Drilling
Diameter Accuracy



Diameter Variation
0.07 mil (+/-2σ)

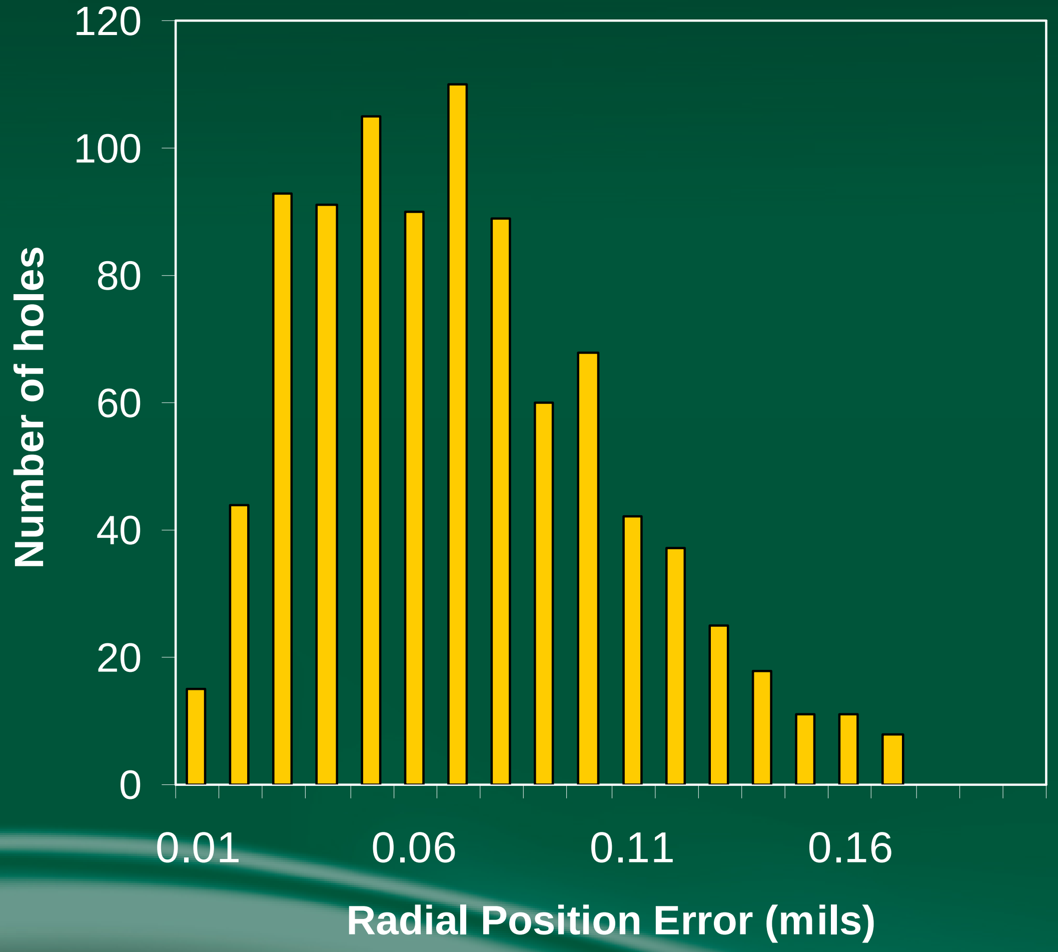
Circularity Variation
0.05 mil (+/-2σ)

Measured with
Mitutoyo SQV 404 PT

Resolution 0.004 mil

Laser Drilling

Position Accuracy



Radial position variation
0.15 mil (+/-2σ)

Measured with
Mitutoyo SQV 404 PT

Resolution 0.004 mil

Accuracy 0.07 mil

Probe Card Industry Challenge

From Intel presentation at SWTW 2007

Technical challenge

- to meet next generation of probe cards

Cost challenge

- to reduce probe card costs in line with other manufacturing costs

Probe Card Industry Challenge

Why we needed to find new alternative technologies

Next generation requirements extend past current capabilities.

Pitch → 175um ⟶ X

Cu Bump Φ →105um ⟶ X

- Tighter scrub control capability
- Tighter alignment and scrub variance control

Parallel Sort → 2x ⟶ X

- Large array size
- High probe count (beyond 5000)

Bottom Line: Intel's current probe card suppliers cannot meet next generation technical requirements.

Probe Card Industry Challenge

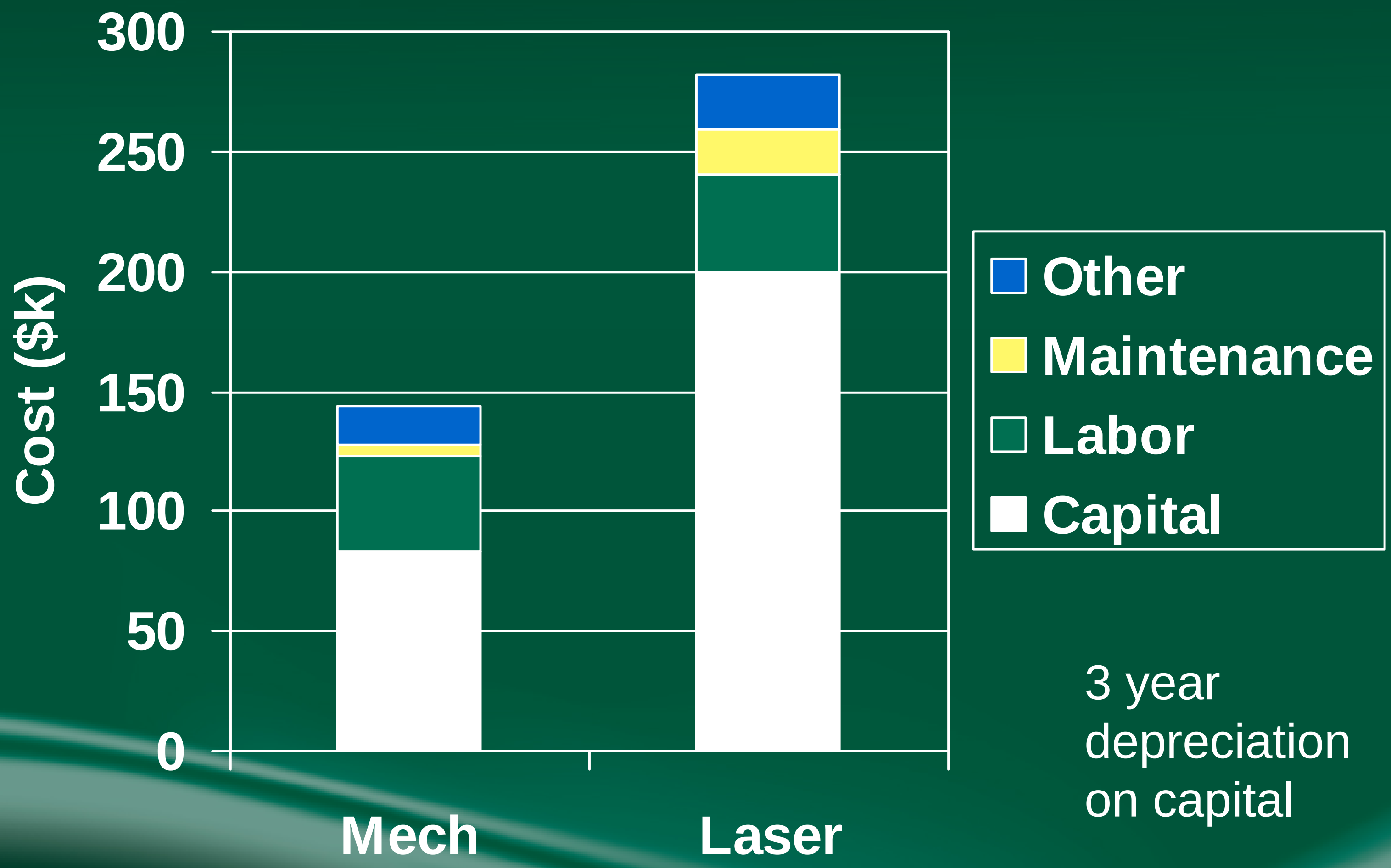
Why we needed to find new alternative technologies

- **Current technologies bound to high cost**
  - Manufacturing process is Labor intensive
  - Manufacturing Process highly complex
  - Cost scales with probe count
    - Limits the ability to extend to parallel sort

Bottom line: Probe card cost is the key limiter to Intel's wafer test process cost reduction capability.

June 3-6, 2007 IEEE SW Test Workshop 4

Laser & Mechanical Investment Costs per Year



3 year depreciation on capital

Mechanical versus Laser Drilling

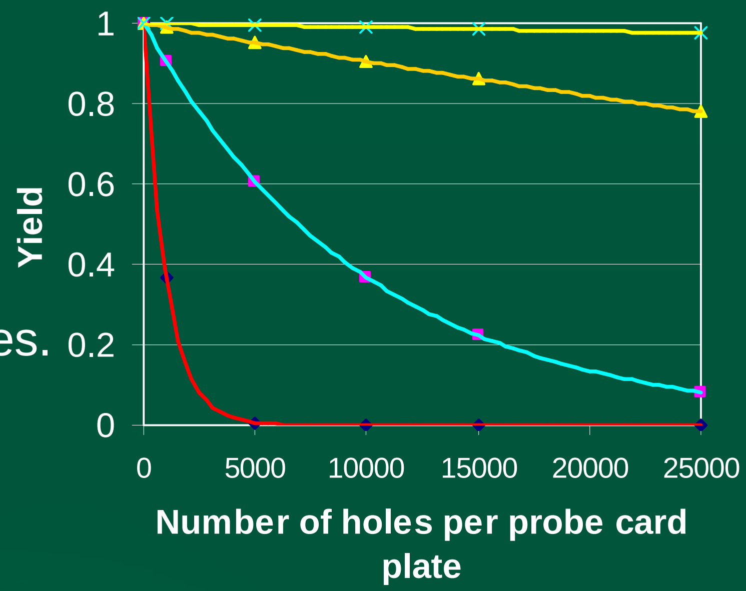
	Laser	Mechanical
Variation on Diameter	+/- 0.1 mil	+/- 0.1 mil
Process Complexity	Moderate	Moderate
Inherent Limitations	None	Drill Bit wear/breakage Drill Bit wander
Yield	>95%	70% - 98%
Drill time per hole	1 – 3 secs	4 – 15 secs
Time for 5000 holes	1.5 – 4.5 hours	6 – 21 hours

Laser & Mechanical Drilling
Effect of Hole Number on Yield

- Demonstrates that drilling process must be robust

- Mechanical drilling
  - yield is a strong function of number of holes
  - yield lies between the blue and orange curves

- Laser drilling
  - yield is a weaker function of number of holes
  - yield lies between the orange and yellow curves.



Calculation based on single hole success rates of 99.9999%, 99.999%, 99.99%, 99.9%

Laser & Mechanical Drilling
Costs per hole - Silicon Nitride

Assumptions

5000 hrs/yr
3 mil dia hole
10000 hole plate

	Mech	Laser
Holes/hr	360	1200
Yield	70%	95%
Cost/hr	36	55
Cost/1000 holes	144	48

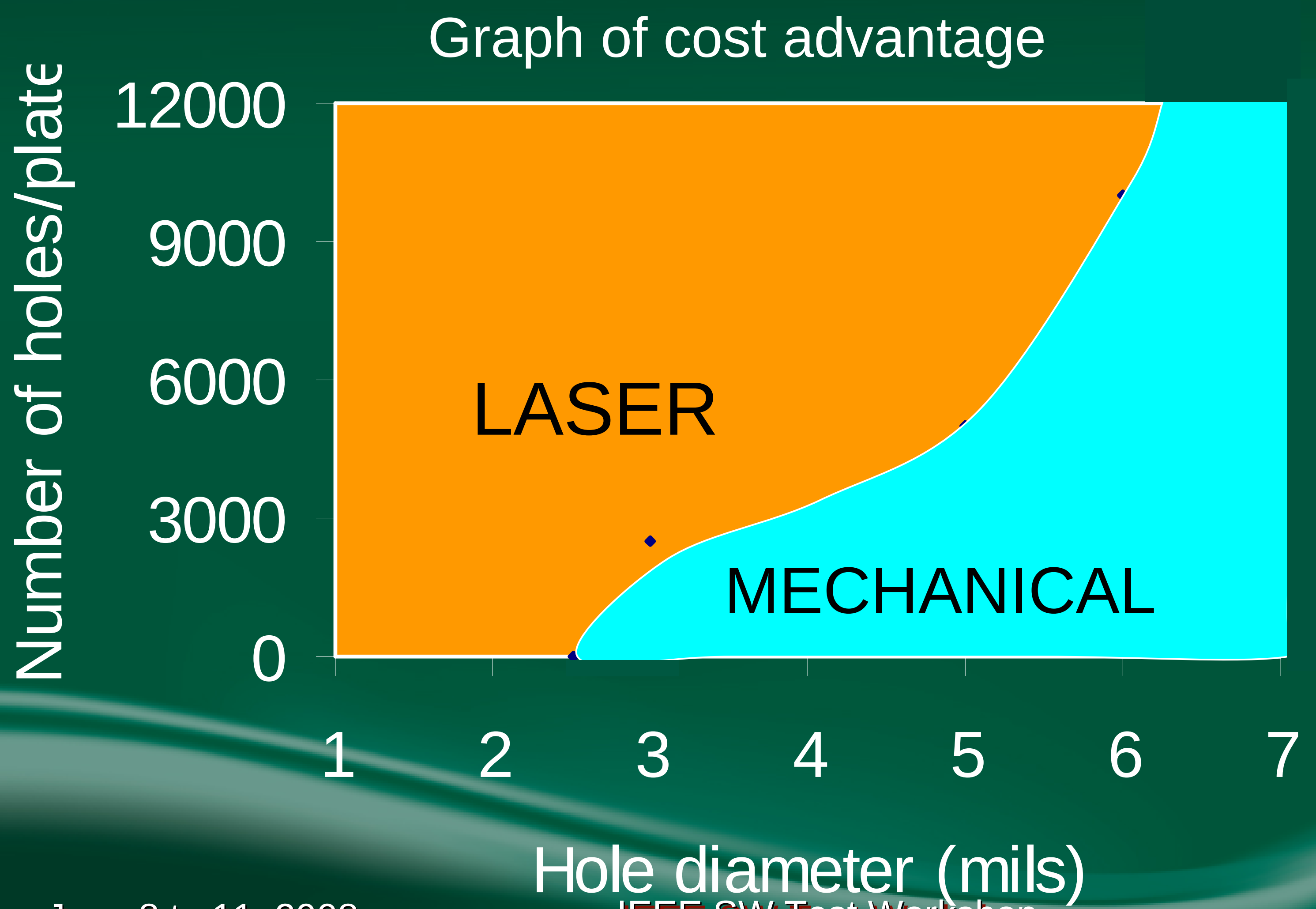
Laser & Mechanical Drilling
Costs per hole - Polyimide

Assumptions

5000 hrs/yr
4 mil dia hole
10000 hole plate

	Mech	Laser
Holes/hr	600	2060
Yield	70%	95%
Cost/hr	36	55
Cost/1000 holes	87	28

Laser versus Mechanical Drilling Cost Trade - Offs



Conclusions

- Drilling Rates and Tolerances for Silicon Nitride and Polyimide have been reported
- Comparison between Mechanical and Laser drilling demonstrates the area where each is most cost competitive
- **Laser Drilling offers the capability to meet some of the challenges laid down by Probe Card customers**