IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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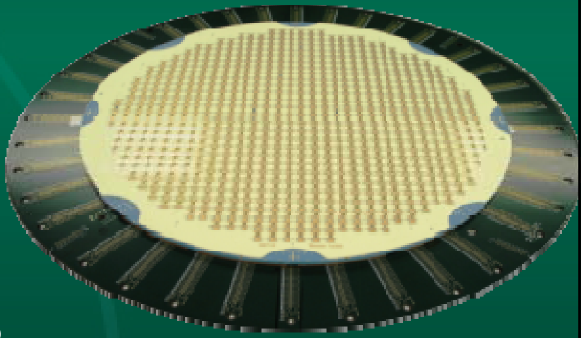
Low-Force MEMS Probe Solution for Full Wafer Single Touch Test

TOUCHDOWN TECHNOLOGIES
a VERIGY company

June 6 to 9, 2010
San Diego, CA USA

Towards 1TD Memory Test

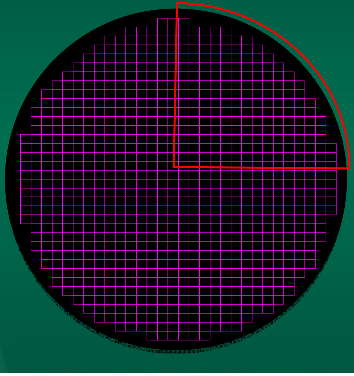
- The challenge of Single-touch test
  - # of I/O channels and resource sharing
  - # of power modules
  - Wiring density limits in the probecard PCB
  - Wiring density limits in the probecard MLC
  - Signal Integrity at High Frequency-
    - More signals in less space


TDT 300mm 1 TD

But what about the probecard mechanics?

For a MEMS probe with 5 gF /pin,
pin count at 100,000:
Force = 1100 lbs!

Contents



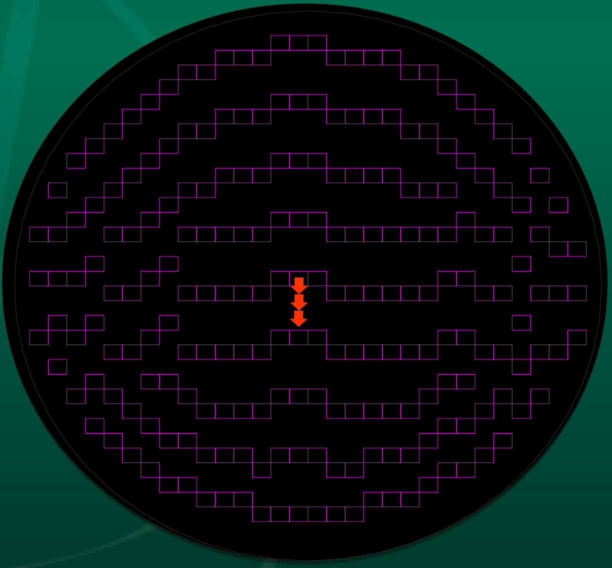
- Case studies to illustrate likely probecounts for 1TD
  - How many probes for a 1TD DDR3 PC?

- Probecard architecture and elements that enable probe counts
  - What is the expected probe density?
  - Is this even possible?

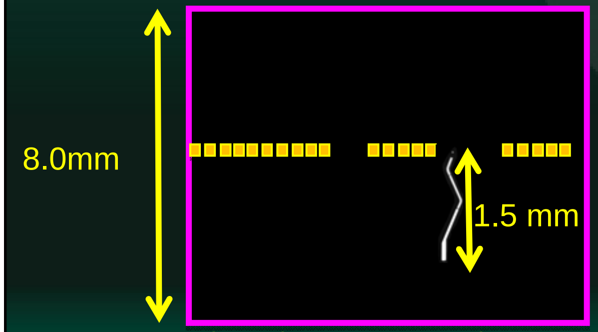
- Examine the mechanics of high probe count:
  - Simulate the probecard deflection based on the tester and probe force
  - Is the deflection within the compliance of the probe?
  - Can we reduce the force of the MEMS?

Probecounts for 1 TD Memory

- Current generation probecards
  - 3TD to 6TD DUT pattern
  - Space surrounding each die available for routing
  - Probecounts < 30,000
- 1 TD for same DUT, resource sharing
  - 60 to 80 probes /die – small changes
  - Die size shrinking– 800 to 1600 die / wafer
  - 50,000 to 100,000 probes



4TD DDR3, 220 DUT, 300 mm
15,000 probes

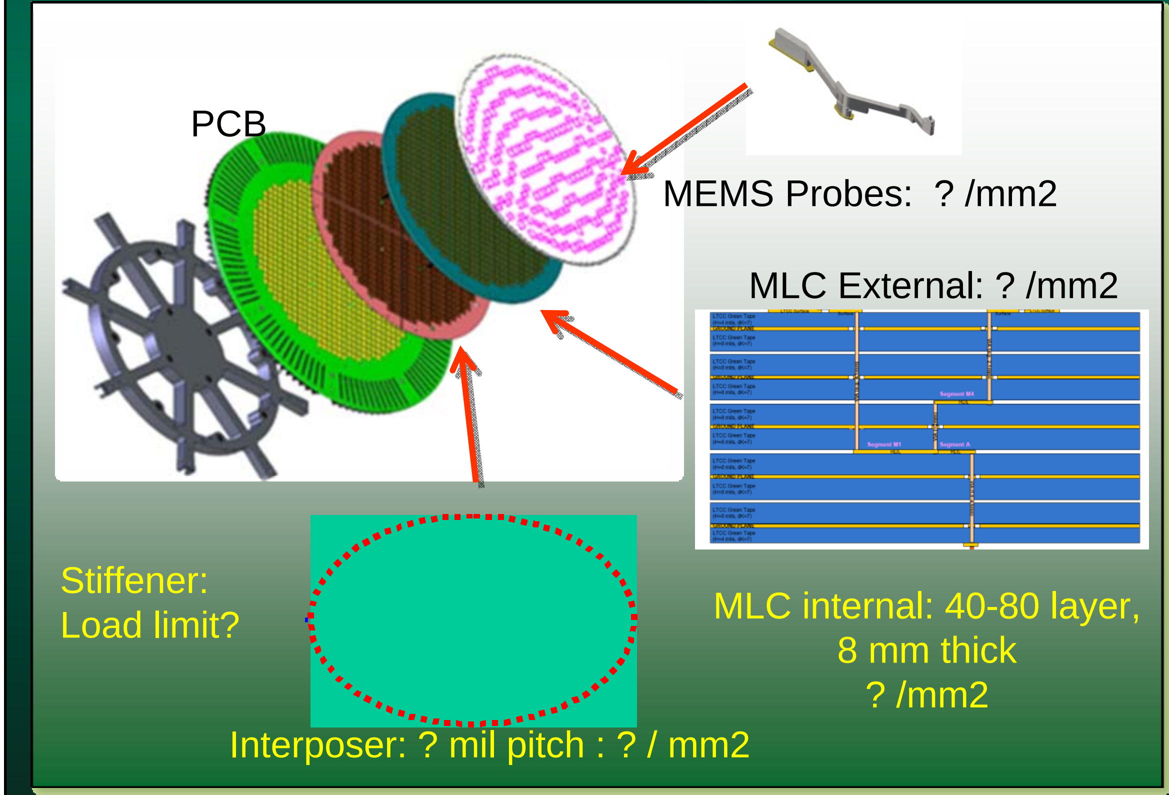


Single line on center pad pattern
60-80 pads per DUT

	"Typical die"	"Small die"	"Small die"-Flash
	DDR3 2Gb	DDR3 1Gb	Flash BIST
Die Size Y (mm)	8	5.7	4.6
# Probes/die	65	80	65
Pitch	70um SLOC	60um SLOC	83um DLOC
Dies/wafer	800	1400	1900
1TD Probes/wafer	53,000	109,000	44,000
Resource sharing	up to X4	up to X6	BIST
#/mm^2	0.8	1.68	1.63

1 TD Probe/Contact density required = 1.7 / mm^2

Probecard Architecture and Density



PCB

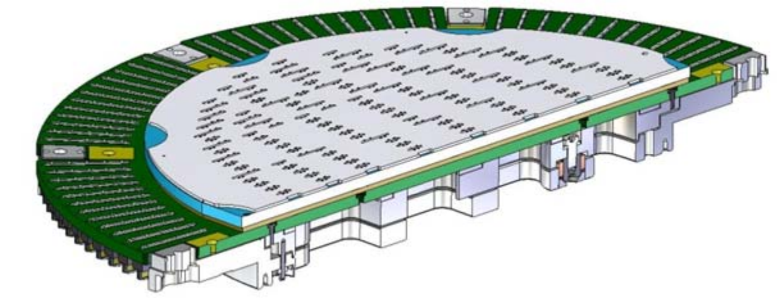
MEMS Probes: ? /mm2

MLC External: ? /mm2

Stiffener:
Load limit?

MLC internal: 40-80 layer,
8 mm thick
? /mm2

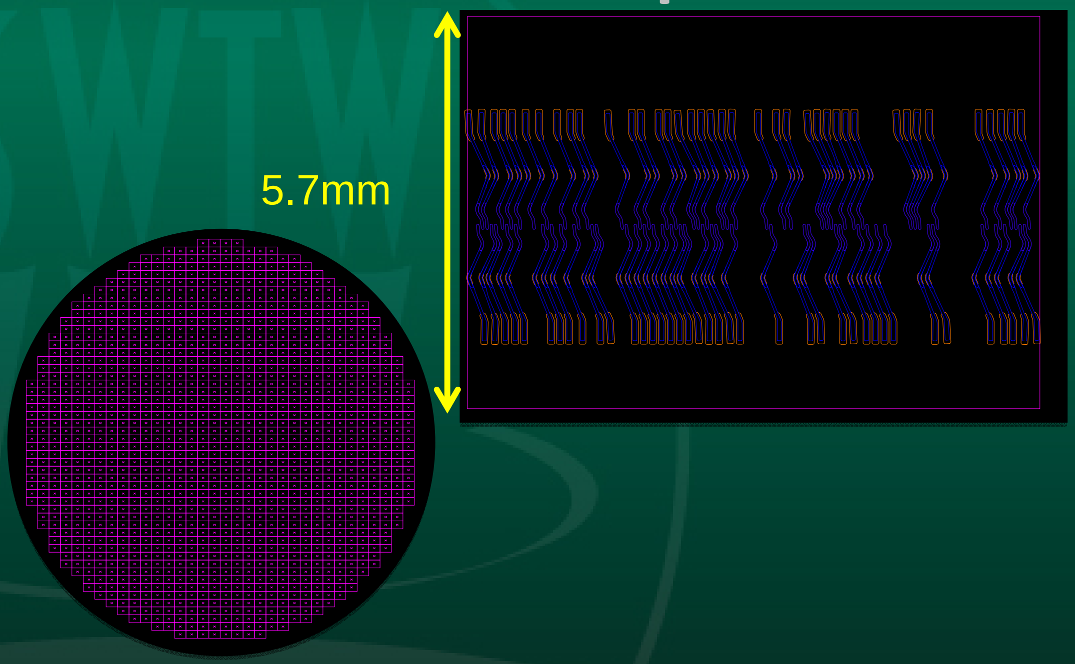
Interposer: ? mil pitch : ? / mm2



- Single piece ceramic for MEMS
  - density limited by probe pitch
  - No boundaries to constrain resource sharing
  - Need space for components (Bypass caps, isolation resistors)
- Pattern density on MLC surface
  - Limited by shrinkage tolerance of MLC
- Wiring density inside MLC
- Interposer density
- PCB wiring density
- Stiffener and mechanical support
  - Preserve planarity with 500 kg of load

Case study: 1 TD, 109,000 probes

- Smaller dies leave less room for routing
- 1400 dies requires ~110,000 Probes
- Resource sharing (DRV X8) reduces channel count requirements
  - Majority of probes are PWR/GND
  - 34k I/O reduces to 10k
  - Less density required in PCB
  - <u>What about MLC Wiring Density?</u>



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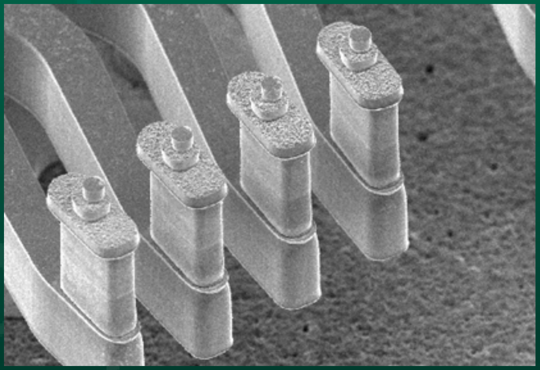
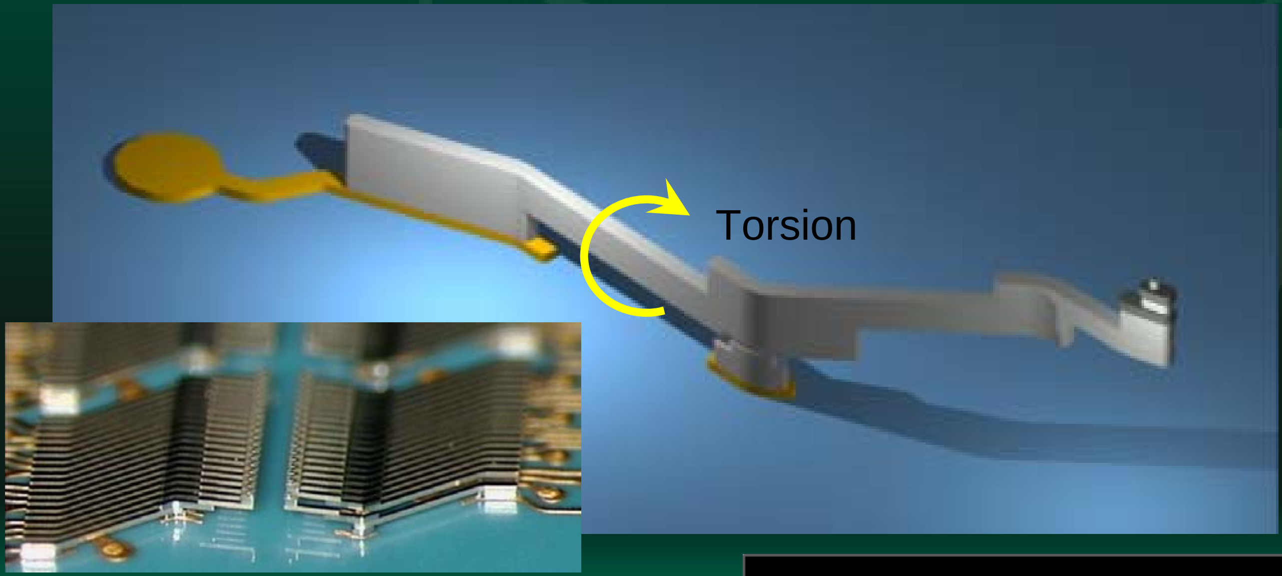
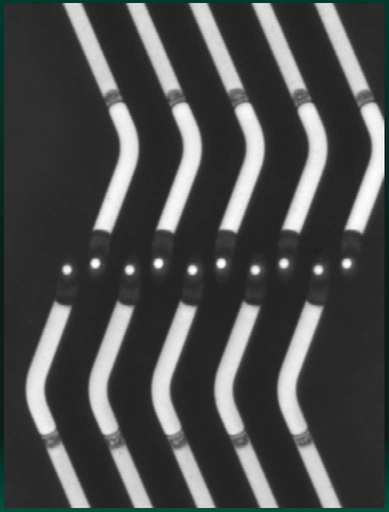
Torsion Probe Design

- More efficient energy storage for better dimensions
  - *"Novel Method to Store Spring Energy in Probes,"* S. Ismail, SWTW 2008
- Pitch down to 50 um
- Probe density more than 5 / mm^2



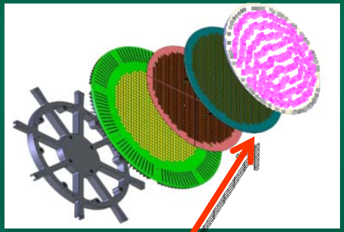


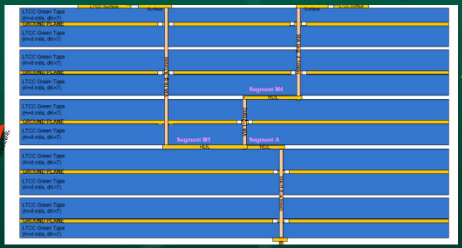


MEMS Probe density >5 / mm^2

MLC Wiring Density

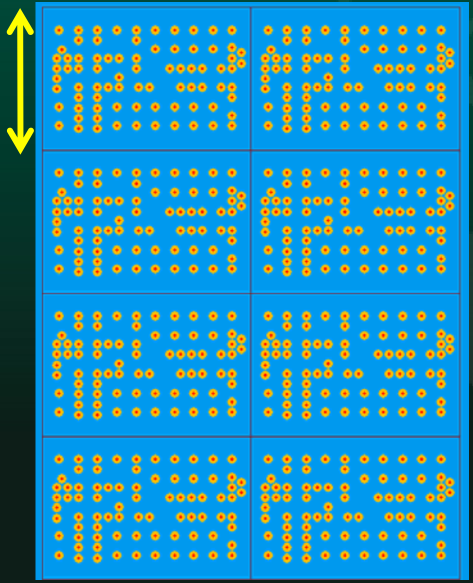
- X8 resource sharing layout feasibility
  - 80 connections MEMS side reduced to 60 tester side
  - Internal Via pitch to 0.4mm (8 / mm^2)
  - Surface pad pitch to 0.7mm (2 / mm^2)
    - Restricted by shrinkage tolerance.
    - LTCC advantage
      - : 0.13% Shrinkage tolerance vs 0.21% for HTCC



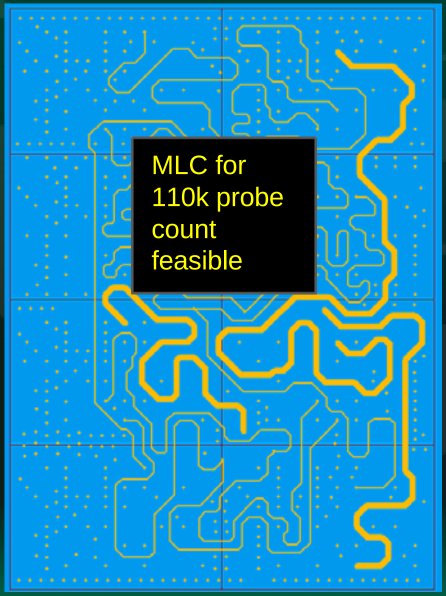


40 -80 layer,
8 mm thick
MLC

MEMS Side MLC Via Layout

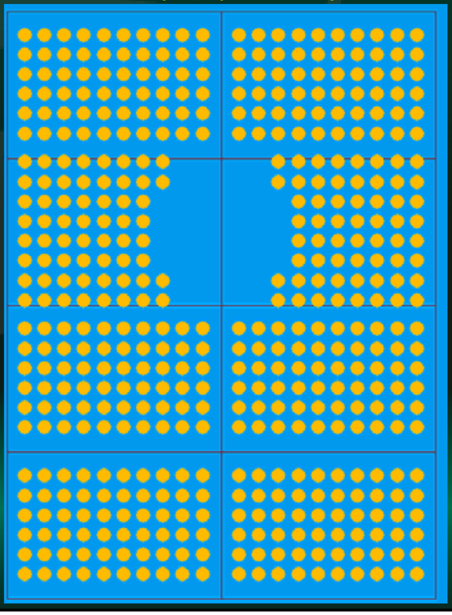


Internal MLC Layout

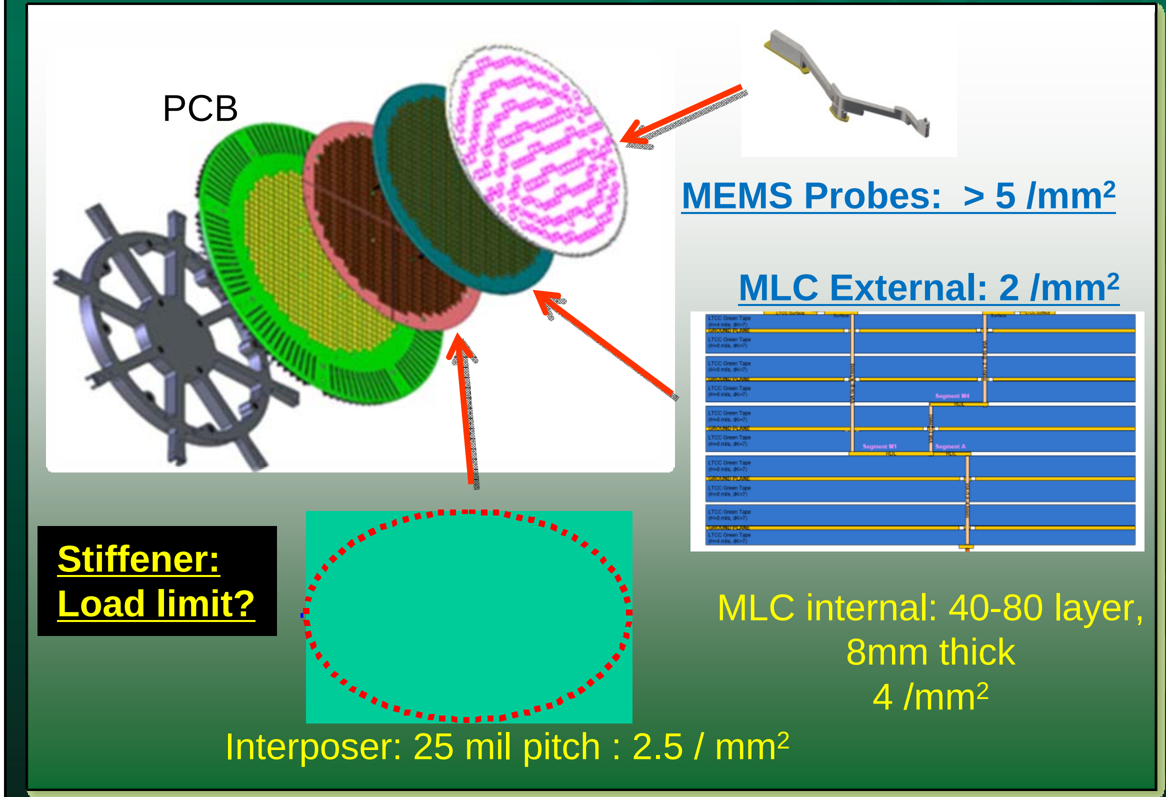


MLC for
110k probe
count
feasible

Tester side (PCB) MLC Layout



Probecard Architecture and Density



MEMS Probes: > 5 /mm²

MLC External: 2 /mm²

Stiffener: Load limit?

MLC internal: 40-80 layer,
8mm thick
4 /mm²

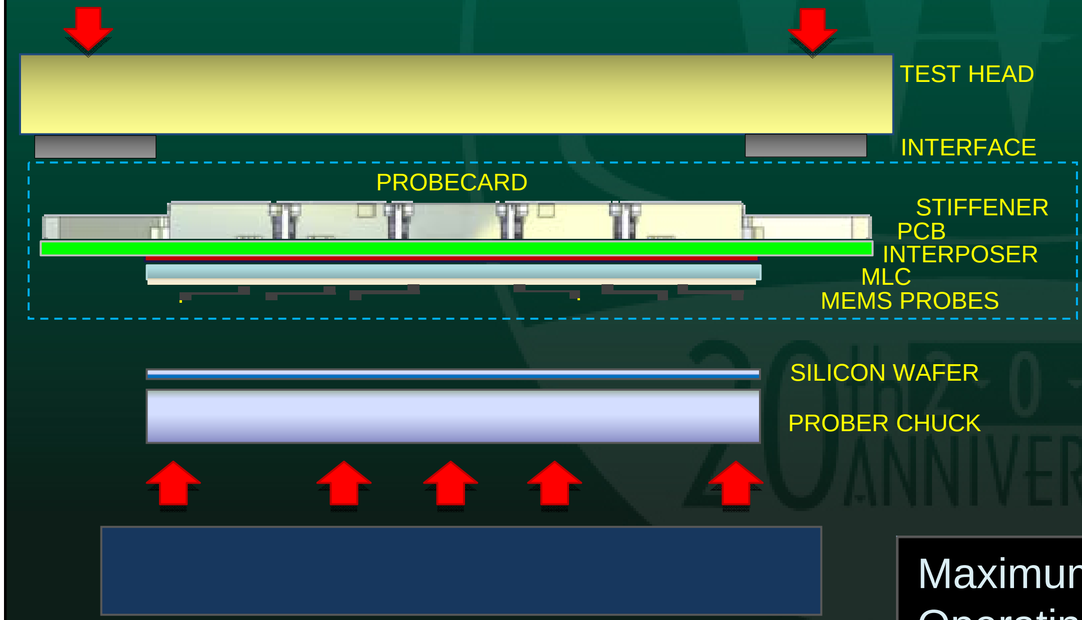
Interposer: 25 mil pitch : 2.5 / mm²

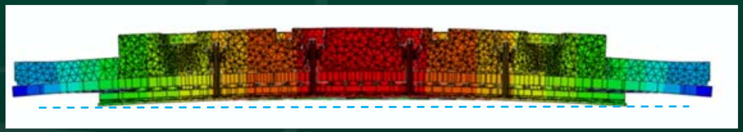
Probe Density Summary	
Die Type	**Probes per mm²**
Typical DDR3 Die	0.8
Small DDR3 Die	1.7
Density Limits	**# /mm²**
MEMS probe (60um SLOC)	4.6
MLC Surface /Front	2.4
MLC Internal	4
MLC Tester (PCB)	2.4
Interposer	4

- 110,000 probes requires 1.7 / mm²
- Torsion Probe MEMS
  - 50um pitch capable: > 5 / mm²
  - No boundaries to constrain resource sharing
- Pattern density on MLC surface
  - LTCC enables 2 / mm²
- Wiring density inside MLC
  - Routing studies show feasibility to 4 /mm²
- Interposer density
  - 25mil pitch available: 2.5 / mm²
- PCB wiring density
- Stiffener and mechanical support?

FEA Simulated Probecard Deformation

- Probecard planarity under load
  - Model includes Stiffener, PCB, Interposer, STF, Probehead
  - MEMS probes simplified as uniformly distributed force
  - No other system deflection included (prober chuck)





Probecard center to edge deformation under load must be absorbed by MEMS probes

Maximum Probecard Deformation allowed = Operating range of probe
- Planarity
= 20 um

Mechanical Performance

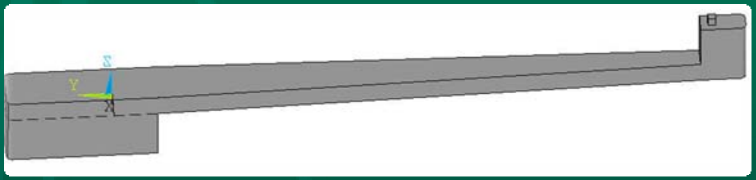
- Probecard retreat at overdrive
  - Limits actual overdrive to probes
  - *See Large Array Probing Session 5, SWTW 2008*
  - *"Electrical Planarity Characterization of High Parallelism Probe Cards,"* J. Caldwell, SWTW 2008
  - Restrict to 20% of Probe's nominal overdrive

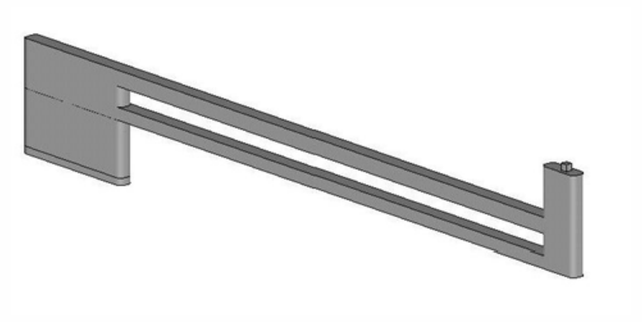
- Probecard deformation at overdrive
  - Requires larger operational range of the probe's overdrive
  - Restrict to <30% of Probe's nominal overdrive
- Factors
  - Tester interface mechanical supports
    - Current generation tester vs next
  - Probe count
    - Up to 100,000
  - Stiffener design- restrictions to meet thermal requirements
  - Probe force
    - Typical probe force?

1TD Probecard designs will be challenged by existing tester platforms

MEMS Probe designs

- 3 Common Styles of MEMS probes:
  - *Mechanical Design of MEMS Probes for Wafer Test, C.* Folk, SWTW 2008
  - Cantilever.
    - Long probe (2mm), but wide (60um) for stress control.
    - Short scrub
    - Moderate force (4 gF)



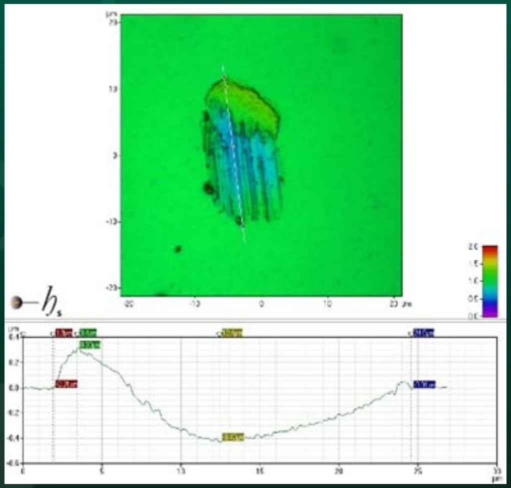


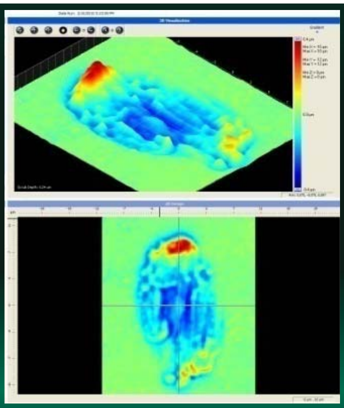
  - Dual-beam cantilever
    - Short probe (1.1mm).
    - Moderate to high force (5 to 6 gF)

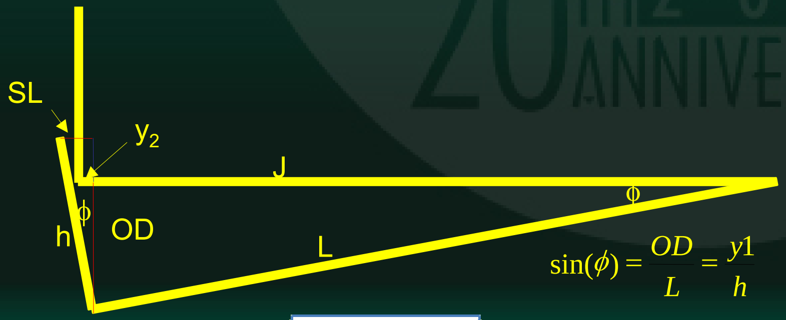
  - Torsional probe
    - Long probe (2mm), but narrow (35um)
    - Good scrubbing action with low force
    - How low can the force go?

MEMS Probe design constraints

- To achieve low-force, must balance:
  - Scrub pressure required for good contact,
  - Scrub length and scrub depth,
  - Maximum stress and probe material limits
  - Operating overdrive range
- As Overdrive ↑ , Scrub length ↑
- As Probe length ↓ , Scrub length ↑
- Height of probe: Clearance from tip to bar
  - Scrub length increases for taller post



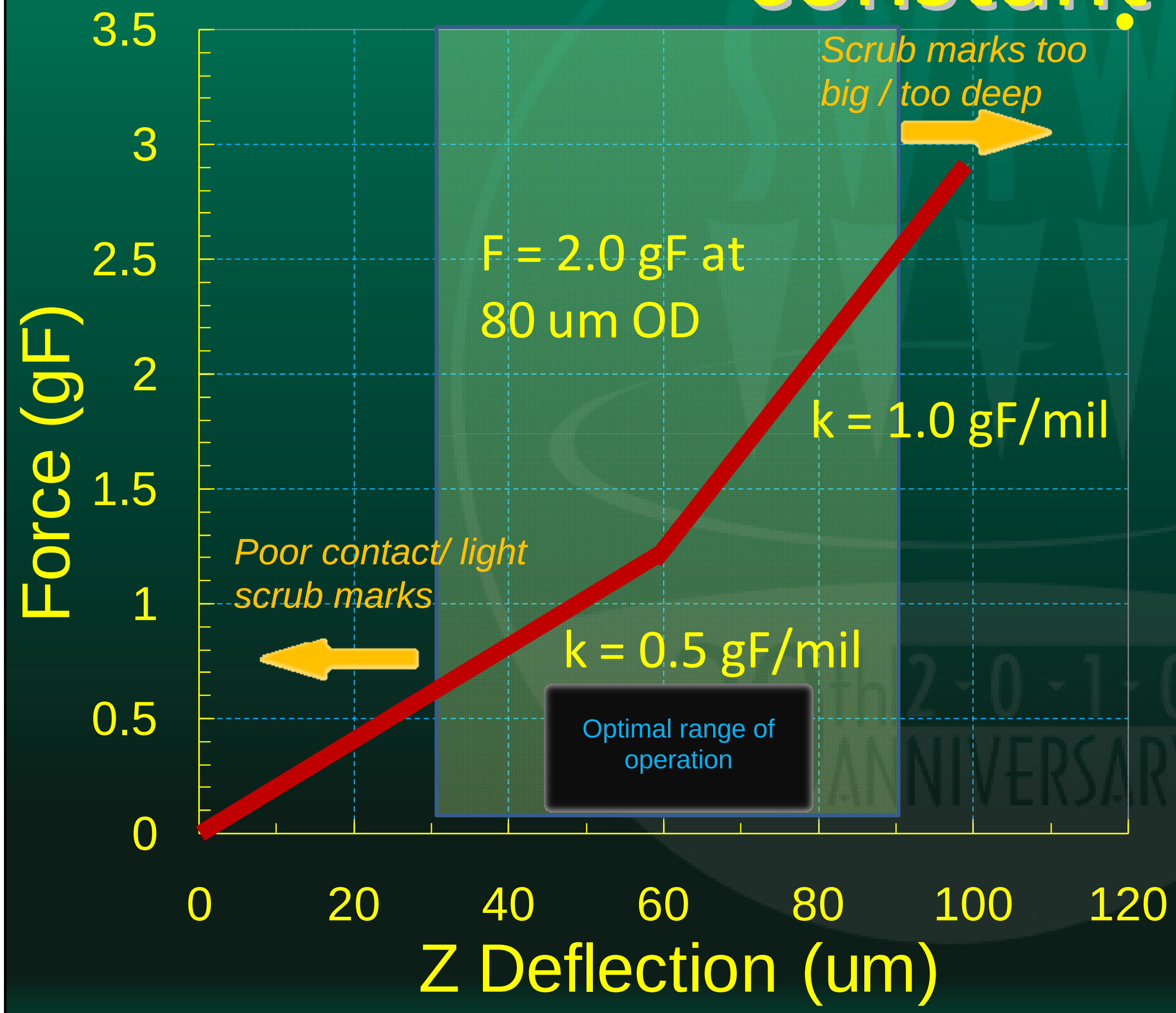




$$\sin(\phi) = \frac{OD}{L} = \frac{y1}{h}$$

$$SL \sim \frac{OD}{L} \cdot h$$

Torsional Force and Spring constant

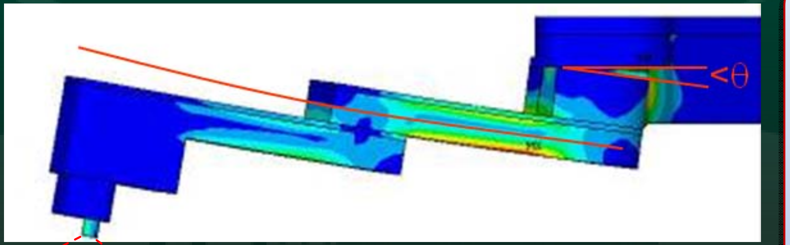


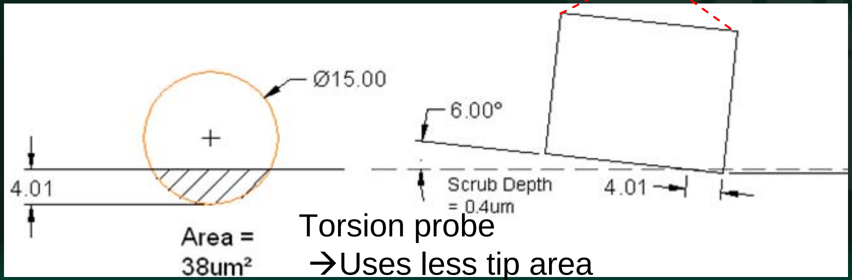
- MEMS Torsional Probe
  - 2.0 gF at 80um OD
  - K = 1 gF/mil at scrub end
  - 50+ um range of operation
  - 15 um Scrub Length
  - 10-20 um Tip
    - Scrub Pressure =400MPa

Scrub pressure

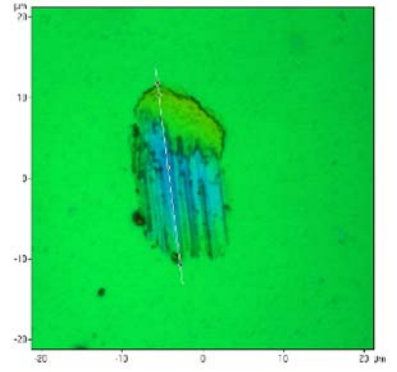
- Need optimal scrub pressure
  - Scrub Pressure = Probe Force / Contact Area
  - Minimize pad damage (<700 MPa)
  - Achieve robust electrical contact
- Necessary to reduce tip size with reduced force
  - Contact area also determined by probe style
  - Torsion probe decreases contact area
    - → Enables lower force

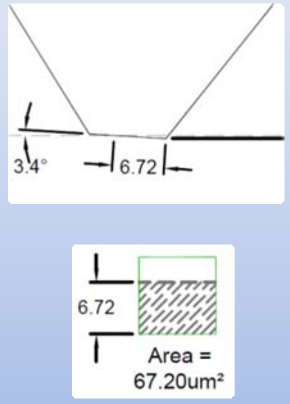
Probe	Force	Tip size	Contact Area	Contact Fraction	Scrub Pressure
Cantilever	4 gF	10 um	67 um^2	67%	600 MPa
Cantilever-LF	2.0 gF	10 um	67 um^2	67%	290 Mpa
Torsion	2.5 gF	20 um	50 um^2	20%	500 MPa
Torsion-LF	2.0 gF	15 um	38 um^2	20%	520 MPa





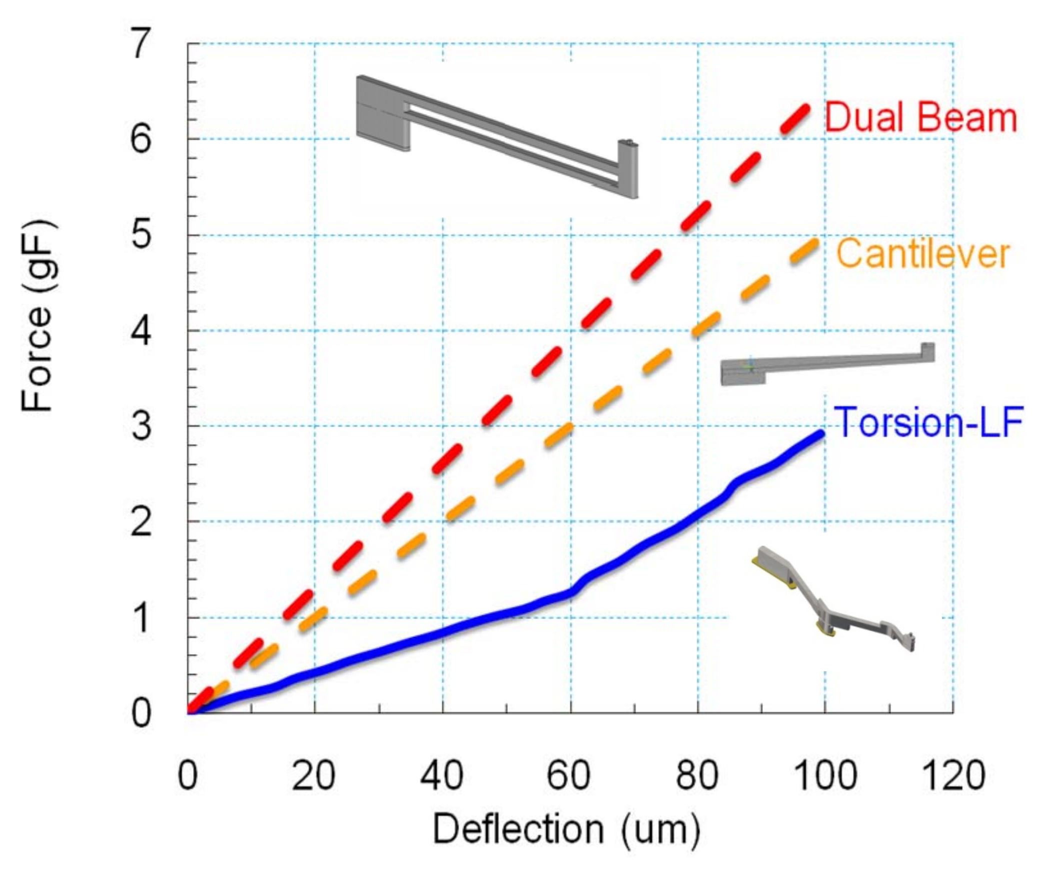
Torsion probe
→Uses less tip area





Cantilever probe
→Uses more tip area

Force vs Probe deflection

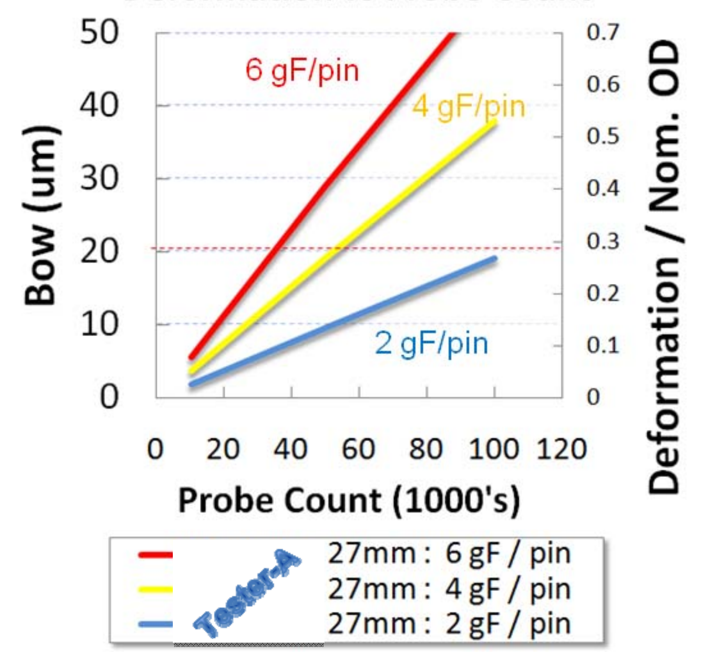


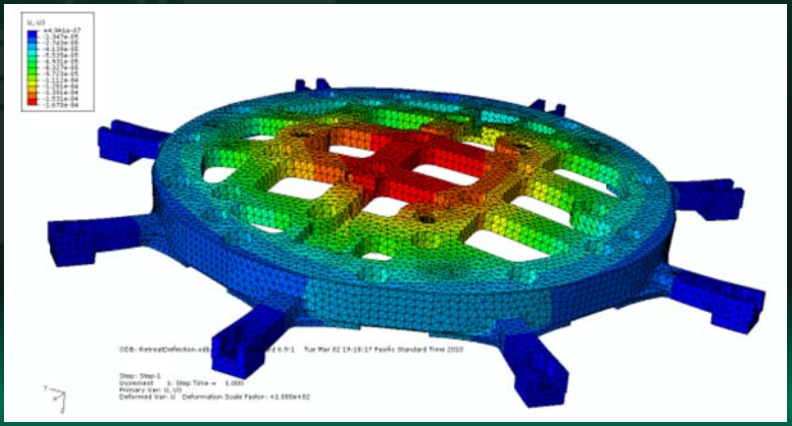
- Force deflection curves generated with ANSYS
  - Young's modulus Ni 200GPa
  - Dimensions from SWTW

MEMS Probe force in the range 2 gF to 6 gF

Results: Probecard Deformation

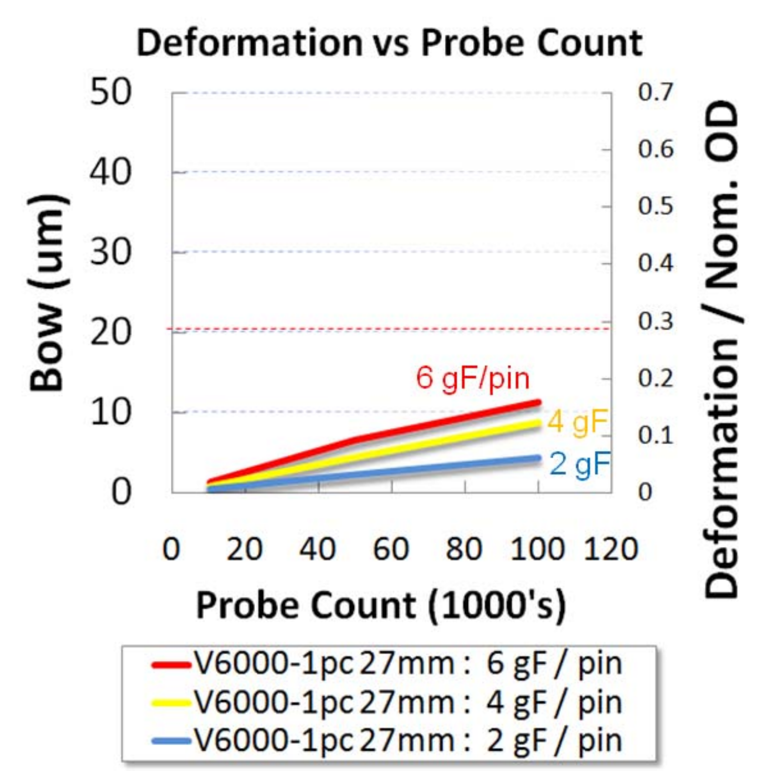
- Factors
  - Common Tester- current gen
  - 1” thick SST Stiffener
  - Open-style stiffener for rapid thermal soak
- Results
  - Probecard deformation is a global planarity change (bow)
  - Deformation exceeds 20um if MEMS probe force > 2gF
  - Difficult for 1TD Probecards unless MEMS force is low

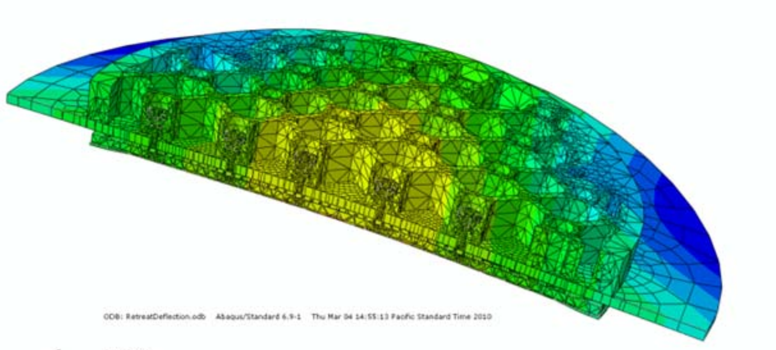




Results: Probecard Deformation

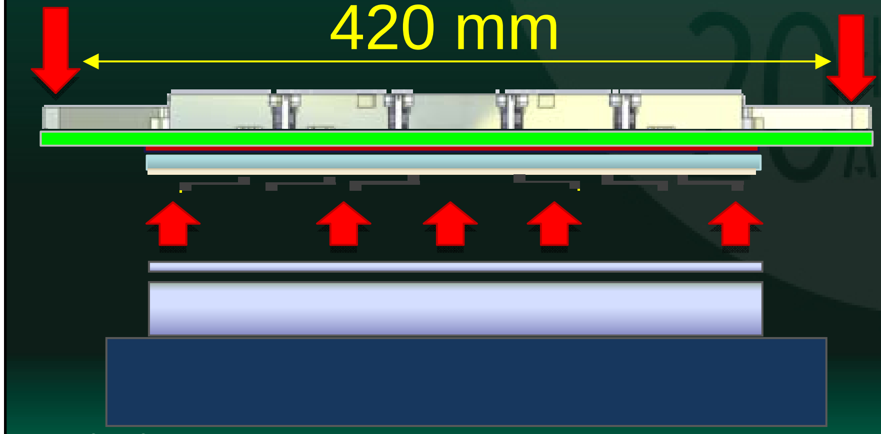
- Factors
  - Next Gen Testers
  - 1 piece, 1” thick SST Stiffener
  - Open style stiffener for rapid thermal soak
- Results
  - Acceptable deformation for all conditions
  - However, common probers limited to 200 kg, so still need low-force probe
    - *"Highest Parallel Test for DRAM,” M. Huebner SWTW 2009*

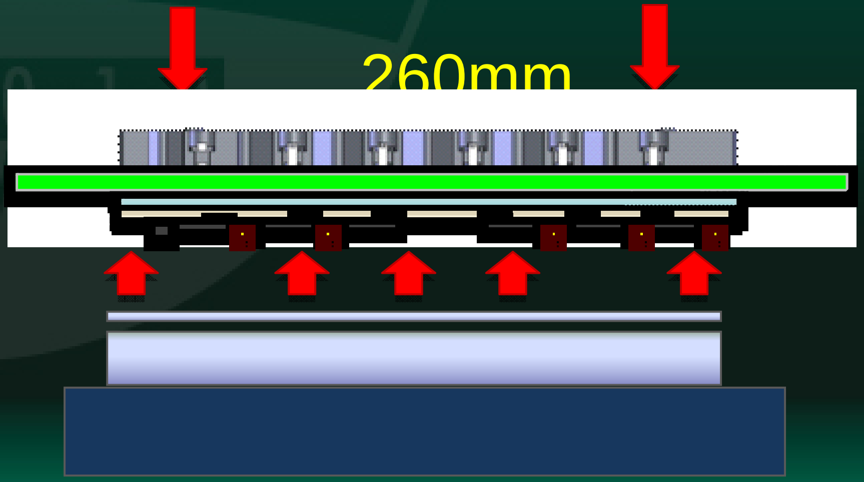




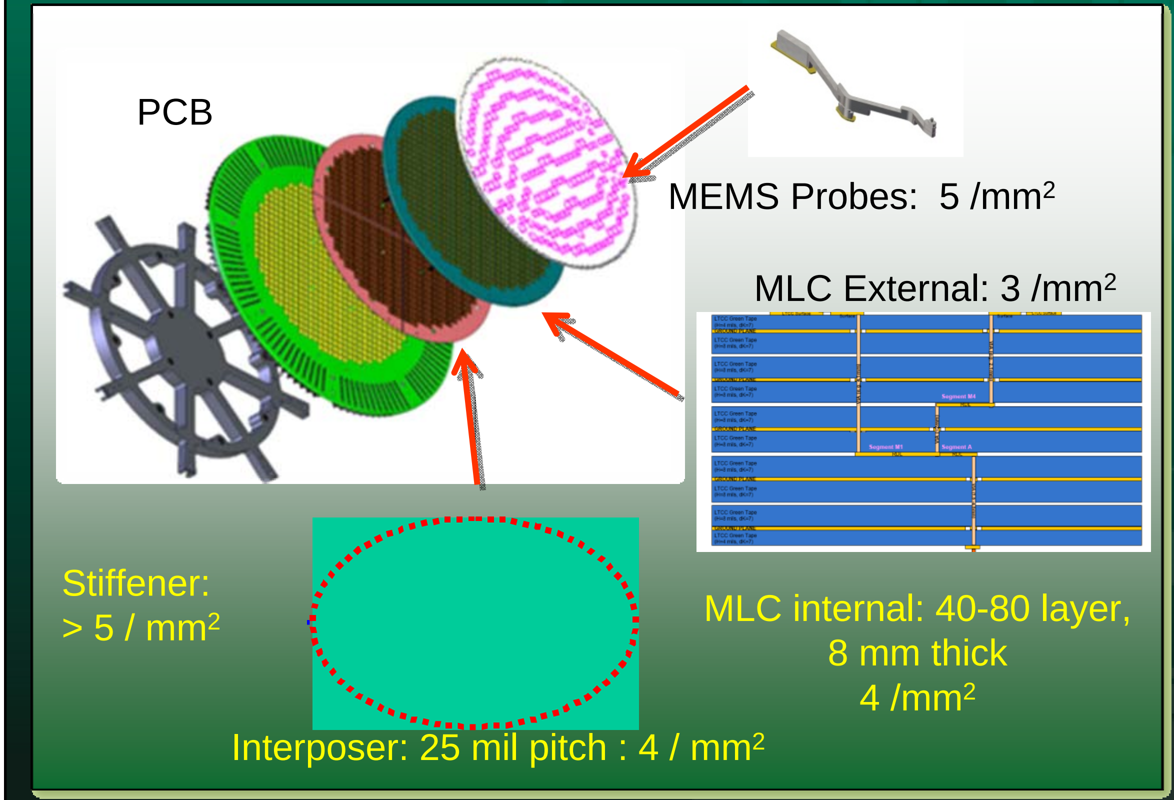
Interface design impact

- Larger stiffener span on older test interfaces greatly impacts resulting probecard deformation
  - Next Generation Testers and interfaces with reduced span, provide better structural support for probecard deformation
  - 1 TD Test will require more than just resource sharing
    - Need lower force probes and/or better interface support
    - Higher load probers
    - Balance between thermal performance and structural support





1TD Summary



PCB

MEMS Probes: 5 /mm^2

MLC External: 3 /mm^2

Stiffener:
> 5 / mm^2

MLC internal: 40-80 layer,
8 mm thick
4 /mm^2

Interposer: 25 mil pitch : 4 / mm^2

- 1TD Requires up to 1.7 / mm^2 probe / contact density
- MEMS Probes, MLC pattern and routing density, Interposer densities are more than sufficient
- Mechanical performance dependant on:
  - Tester interface span
  - Probe force
  - Prober force limits

Summary

- 1 TD Probecards will require 50k to 100k probes
- Resource sharing will provide acceptable wiring densities on MLC, in MLC, Interposer, PCB
- However, mechanical deformation of the probecard under load will be an issue, unless:
  - The MEMS probe force is reduced to 2 gF
  - A next generation tester interface is used
- Even with a solid tester-interface design, prober chuck limits (450 lbs) necessitate lower force probes
- TdT's Low-force MEMS Torsion probe provides appropriate scrub pressure and size at low force

Acknowledgments

- Special thanks to
  - – TdT Mechanical and Engineering design groups
  - – TdT Process Integration group