SW Test Workshop
Semiconductor Wafer Test Workshop

Advanced Laser Bonding of Ultra Fine Pitch Cantilever Spring Pins for Assembly of Flash, DRAM and Logic Probe Cards

PacTech
member of nagase group

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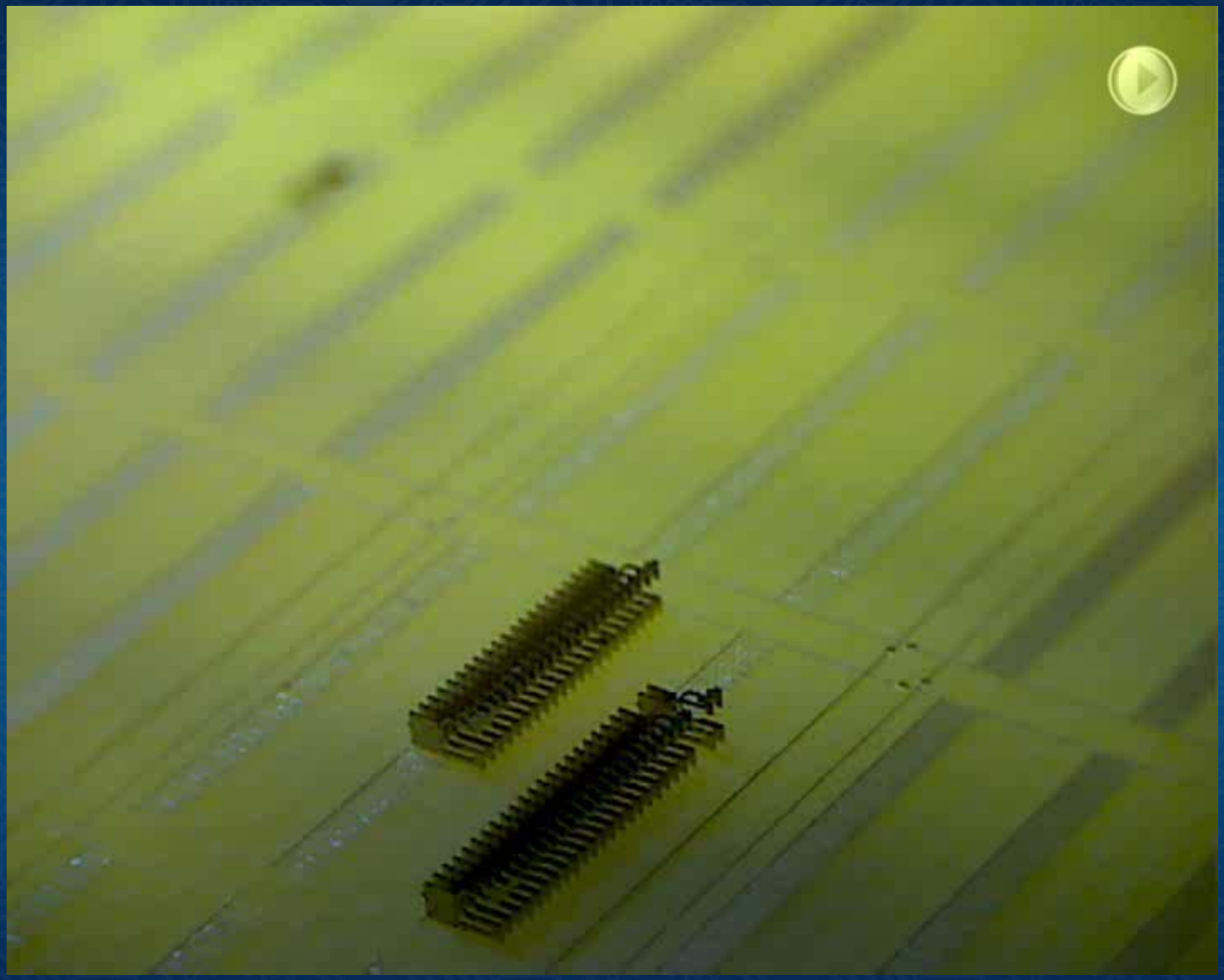
Overview

- **Introduction**
- **Advantages on Laser Soldering**
- **Cantilever Assembly & Laser Cutting**
  - Solder Balling / Solder Jetting
  - Laser Bonding of Cantilever
  - Specifications for laser Bonding Equipment
  - Design Rules
  - Vision System / Fiducial Alignment
  - Process Results / Examples
- **Summary**

Cantilever Bonding Video



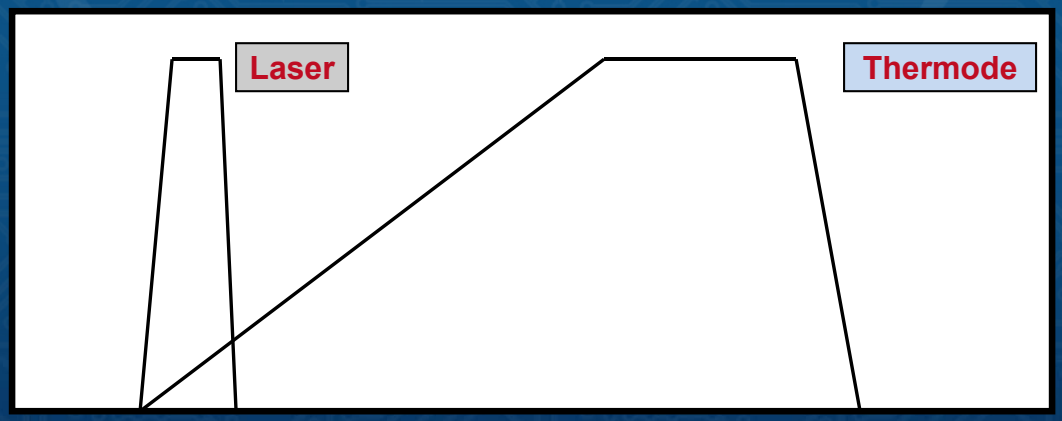
Advantage of Laser Bonding

- **Localized heat**
  - No thermal stress on the areas outside of bonding interface
- **Short Laser Pulse**
  - Low thermal stress on chip (cantilever) / Substrate and interconnection

Thermode Bonding vs Laser Bonding

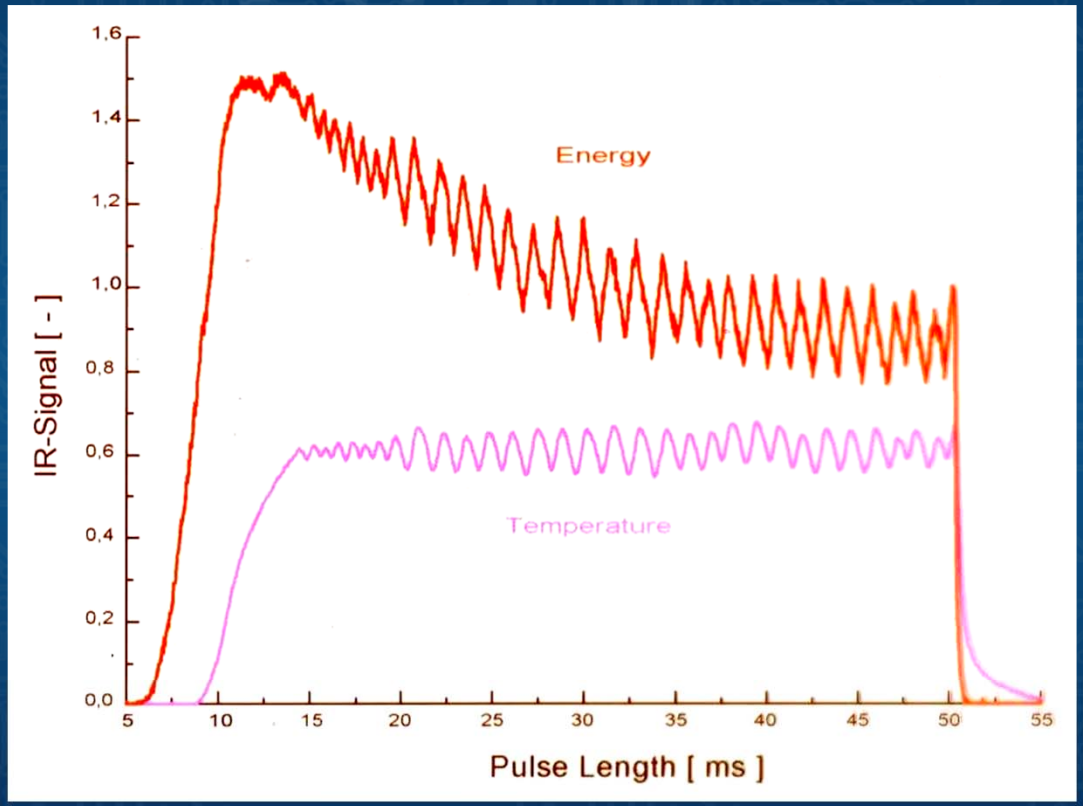
Heating time vs bonding temperature:

- Laser: 0.01 - 0.2 sec => msec
- Thermode: 1 – 10 sec=> sec
- Oven Reflow: 60 – 180 sec => min



Temperature Control

In Situ Laser Energy Tuning during Laser Bonding



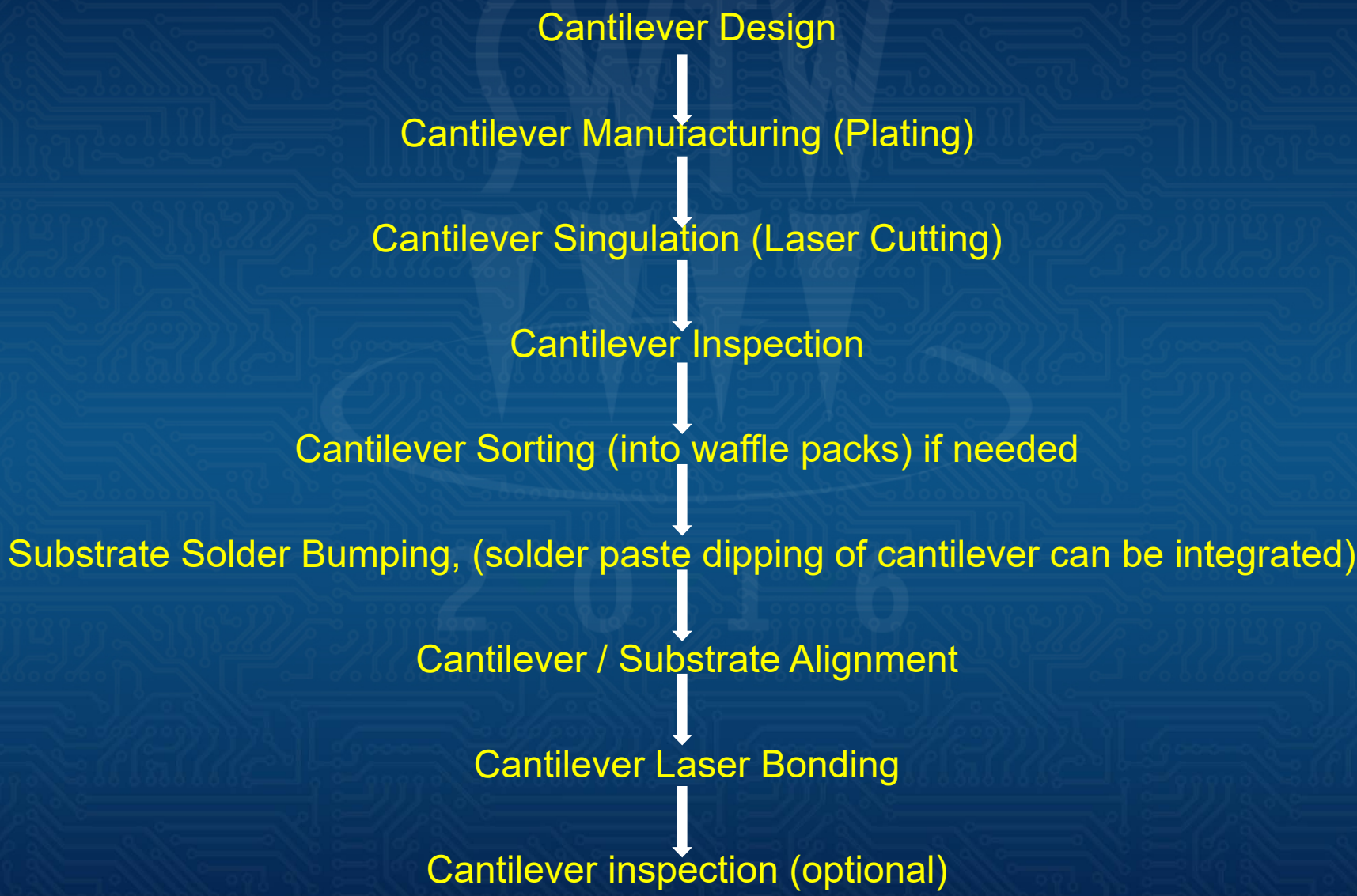
Substrate Materials for Laser Soldering

- **Substrate**
  - FR4, BT- Epoxy, Polyimide, Ceramic, Silicon
  - TG above 150 ° C
  - most applications: rigid
- **Pad metallization**
  - Copper with NiAu, Sn, Au
  - Thin Film : Cr/Au, NiAu, Au

Advantages for Probe Card Assembly

- **Flexibility**
  - Layout change by software only (no tooling)
  - Parallel processing of multiple spring designs
  - Independent from substrate material
- **Repair Capability**
  - Individual spring replacement
  - No thermal influence on other springs
- **Customer Support**
  - Close to customer site

Cantilever Assembly Process Flow



Cantilever Assembly Line for Probe Card

Cantilever Sorter

Features

- Input: MEMS substrates
- Inspection of cantilever
- Laser cutting with the Laser
- Placement of cantilever in waffle packs

SB²-Jet: Solder Jetting

Features

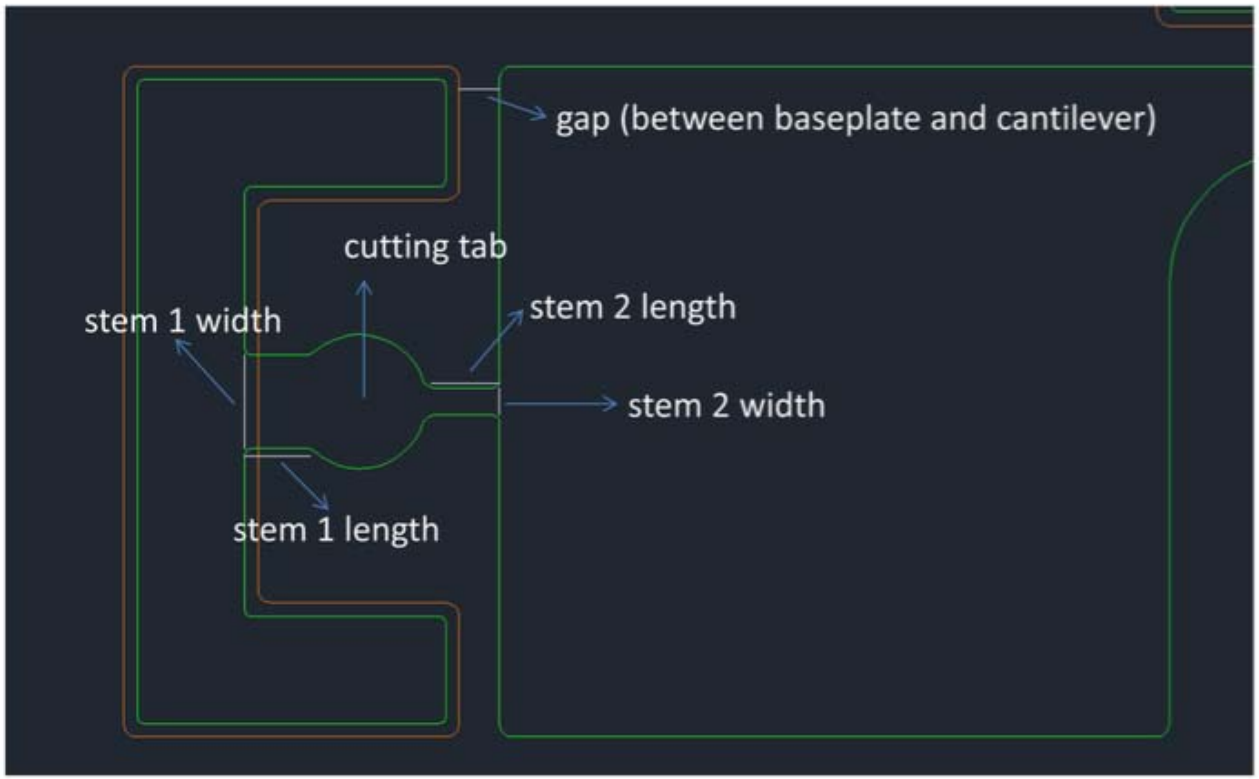
- Solder Jetting on ceramic substrate
- Solder Balls sizes: 30 – 760 µm
- Solder alloys capability: PbSn, SnAgCu or AuSn

Cantilever Bonder LAPLACE-Can

Features

- Cantilever supplied in waffle packs
- Cantilever pick & rotation in vertical position
- Substrate height measurement
- Dual camera for x, y alignment of cantilever to the substrate
- Probe tip z alignment
- Laser bonding of cantilever
- Post inspection
- Cantilever rework capability

Cantilever Cutting – Design Requirements



stem 1 – stem between baseplate and tab
stem 2 – stem between tab and cantilever

Cantilever Cutting – Design Requirements

- relation between stem-2-length and gap:

  - stem-2-length should be about three times longer than gap

  current dimensions
  stem-2-length : 42,72 µm
  gap: 30 µm

  ideal dimensions (for example)
  stem-2-length : 45 µm
  gap: 15 µm

- relation between width of stem 1 and stem 2

  - width of stem 1 should only be two times thicker than width of stem 2

  current dimensions
  stem 1 width: 70 µm
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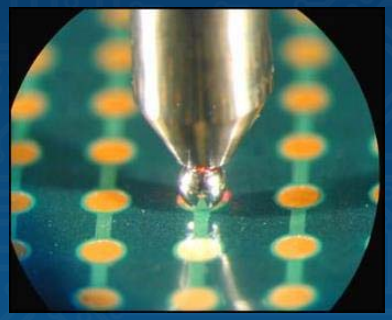
  ideal dimensions (for example)
  stem 1 width: 40 µm
  stem 2 width: 20 µm

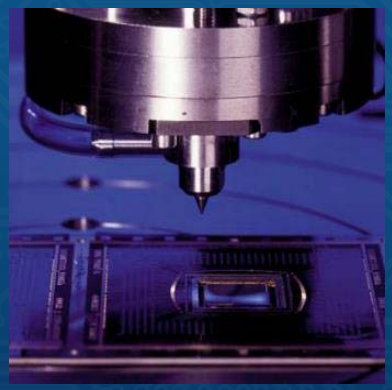
- diameter of tab should be about 100 µm

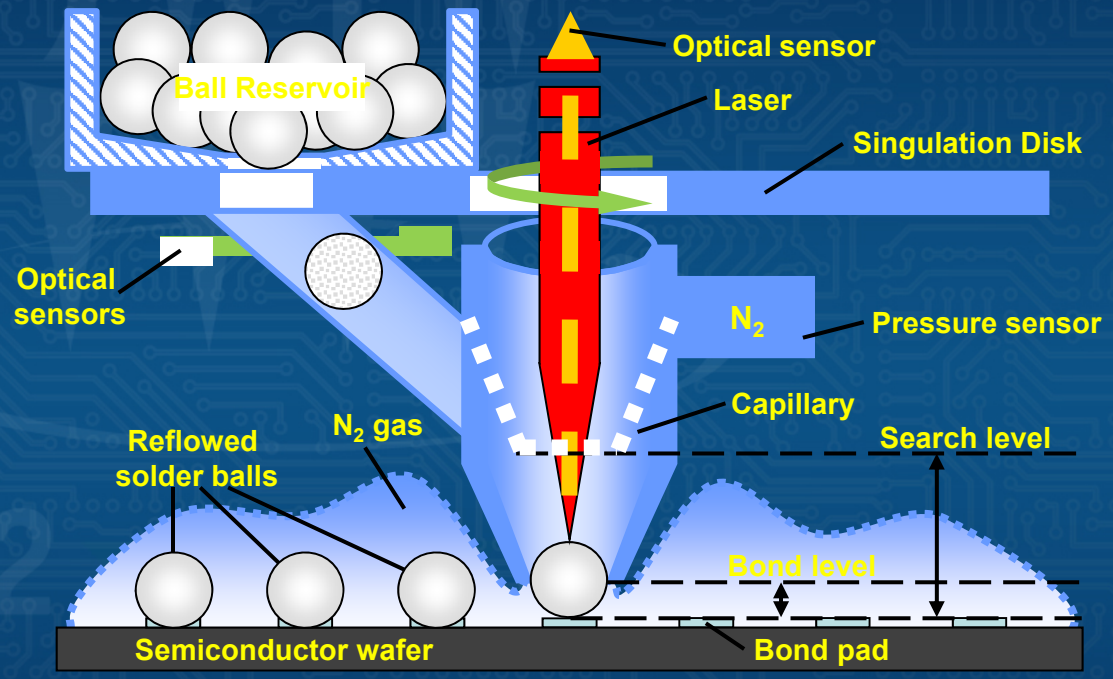
- moreover both stems and cutting tab should not be connected to ceramic substrate

Soder Sphere Jetting

Schematic diagram of **S**older **B**all **B**umping (SB²) process:



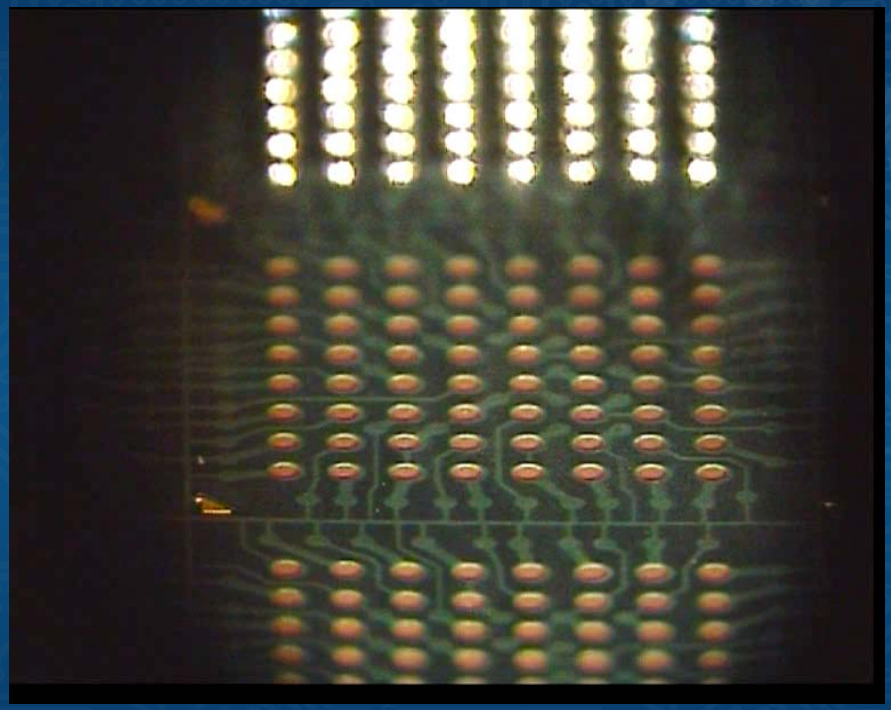


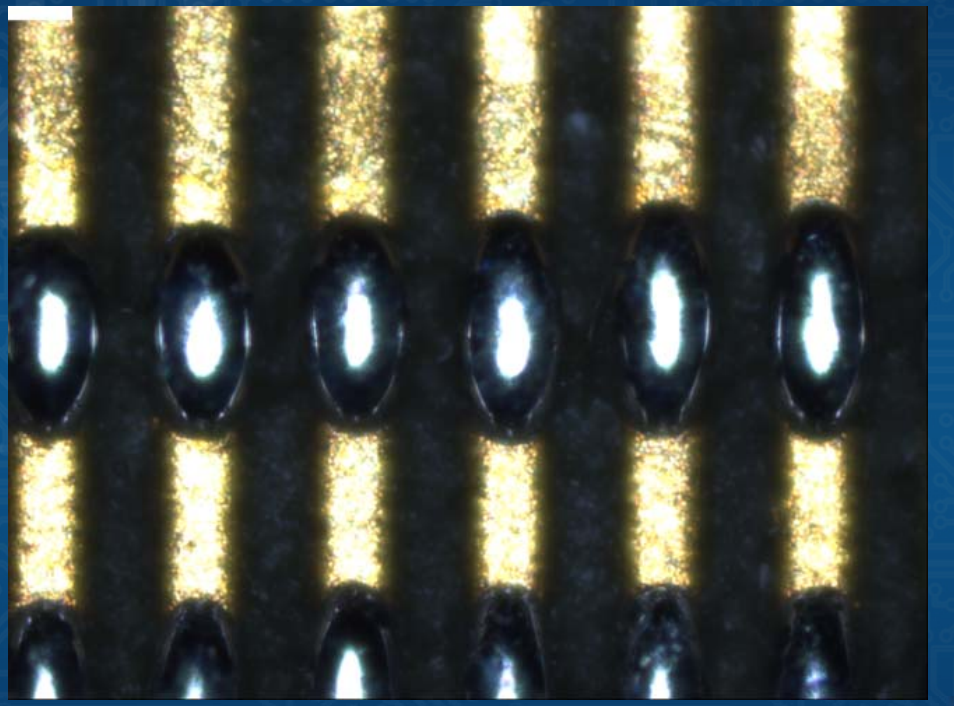


Solder Alloys: SAC, PbSn, AuSn, etc.

Solder Sphere Jetting

Process video for solder jetting

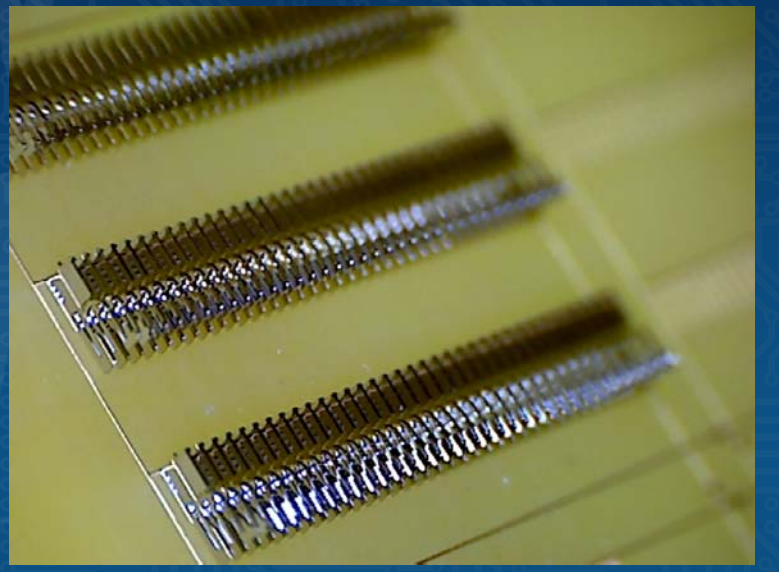




Solder depots placed on probe card substrate pads

Cantilever Bonder Specification

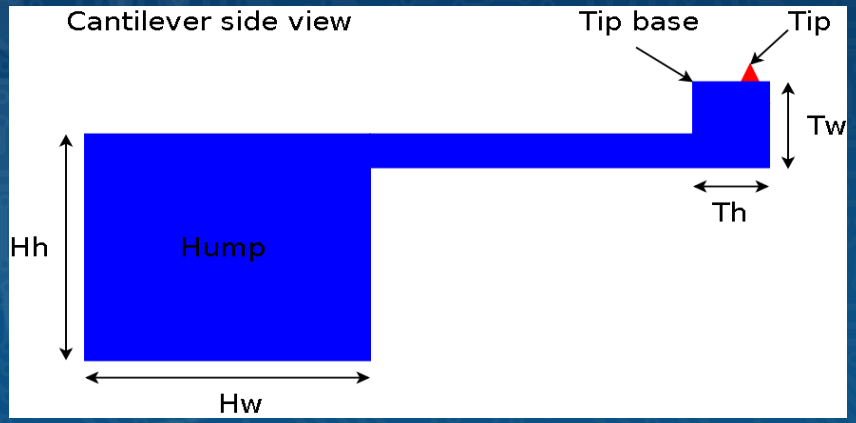
- Linear axis or gantry system
- Probe card sizes up to 14 inch
- Alignment by precision optical system
- Tip correction (bend)
- Placement Accuracy: down to +/- 1.5µm
  typ. +/- 3.0µm

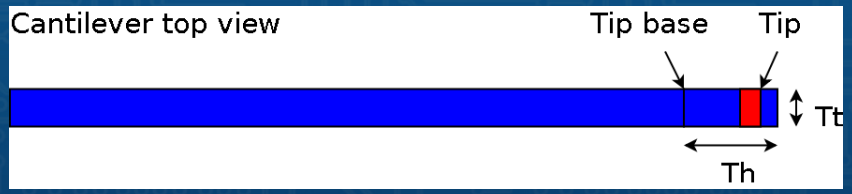


- High power IR laser for bond reflow
- Z height control
- Cantilever thickness: 20µm – 100µm
- Min. Pitch: 50µm
- Process suitable for rework and complete card assembly
- Post Bond inspection

Cantilever Design Rules

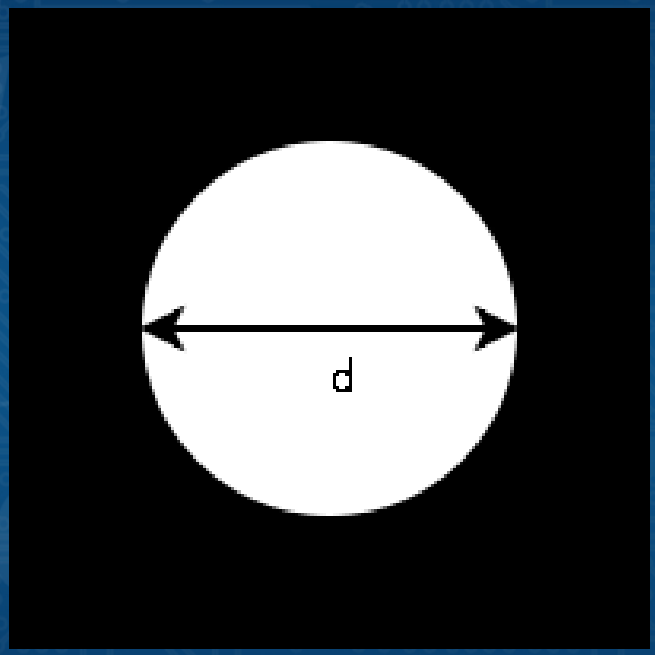
- **Hump needed for handling and laser energy absorption**
  - Hh ≥ 250 µm
  - Hw ≥ 250 µm
- **Tip base needed for alignment**
  - Th ≥ 10 µm
  - Tw ≥ 10 µm





Pattern recognition & Fiducial Alignment

- Automatic X,Y substrate alignment after loading and bond stage rotation (W-axis)
- Pattern recognition with bond head camera
- Alignment accuracy: +/- 1 µm
- High contrast simple mark needed



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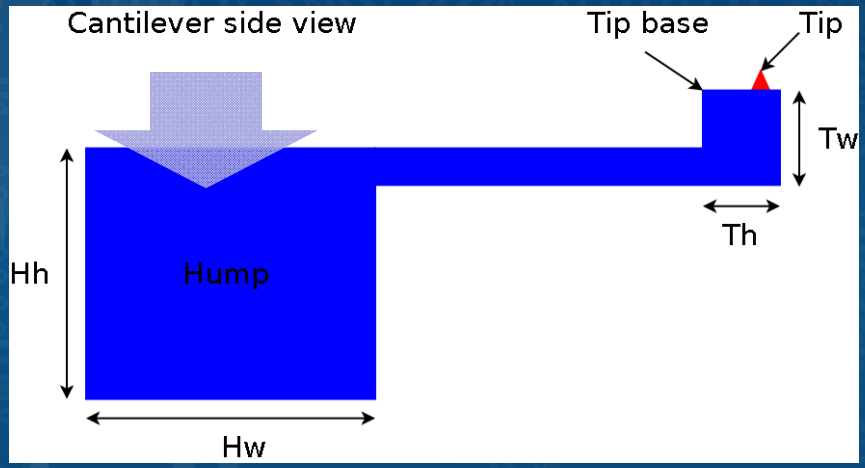
- **Cantilever recognition in waffle pack, R2R, or other carrier system**
  - Pattern recognition of whole cantilever
  - Detects position in waffle pack pocket (A,B axis)
  - Discards defect cantilevers
  - Sensor: Camera 4 on Pick & Flip unit
  - Alignment accuracy: +/- 2.5 µm
- **Rotation and alignment for tool transfer**
  - Pattern recognition of whole cantilever
  - Detects transfer offsets for bond tool (B,D,Z axis)
  - Discards defect cantilevers
  - Sensor: Stationary Camera 2
  - Alignment accuracy: +/- 2.5 µm, +/- 0.3°

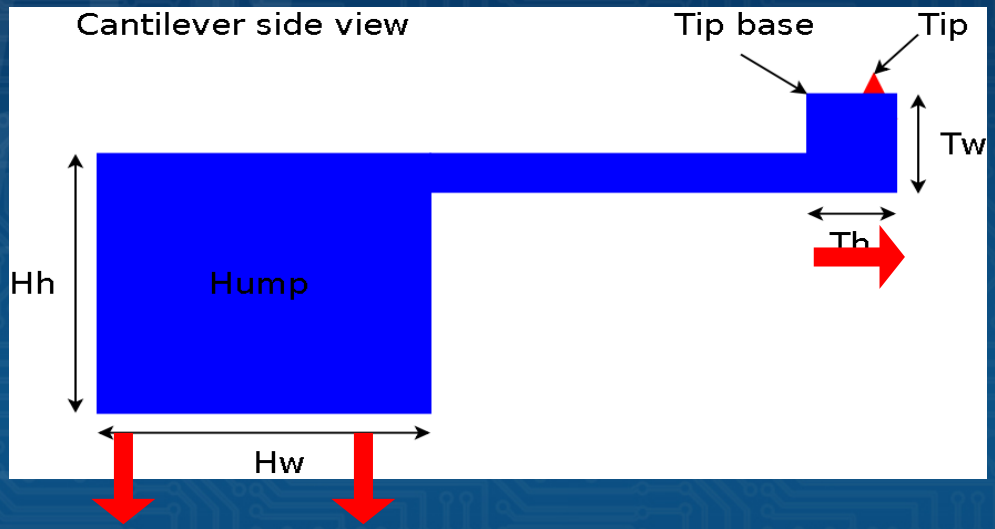
Mechanical Correction

- Fitting of Cantilever into bond tool by touching down on a mechanical spring
- Force controlled



Optical Tip Alignment

- **An optical system determines**
  - X offset for bonding
  - U angle correction
  - Tilt (hump bottom <-> tip base
  - Z-offset for bonding
- **Two scans per measurement**
- **+/- 0.01 µm optical scan repeatability**
- **+/- 0.3 µm accuracy**



Alignment Summary

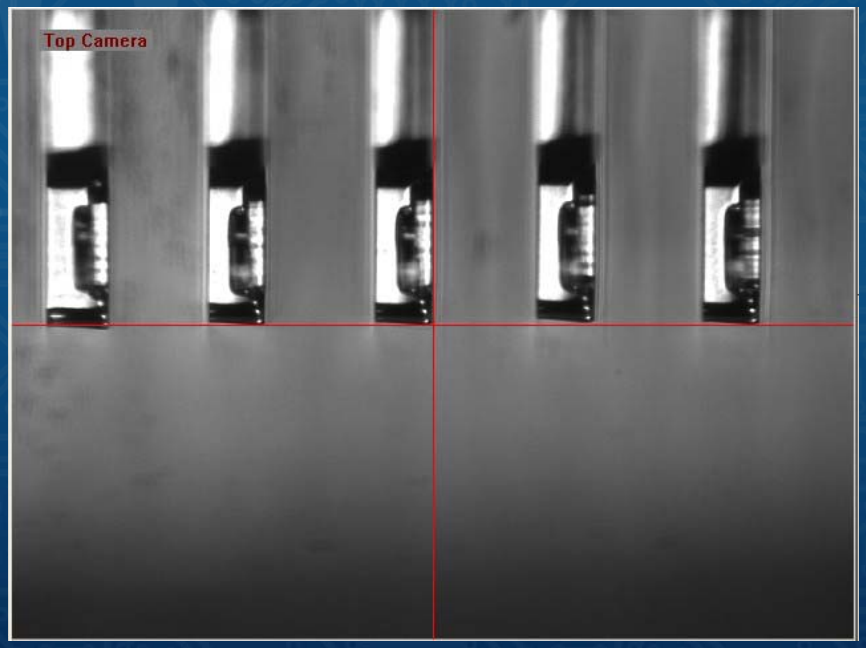
Step	Alignment procedure	Corrected axis	Sensor	Measured feature	Alignment Accuracy
1	Fiducial marks on substrate	X, Y, W	Bond head – Camera 1	100 µm high contrast circle or other geometrical shape	+/- 0.5 µm
2	Substrate height	Z	Laser Scanner or Touch Down	200 µm diameter height measurement mark or other location	+/- 0.05 µm (Laser) +/- 1 µm (Z-axis)
3	Detect cantilever in waffle pack	A, B	Pick & Flip Unit - Camera 4	Cantilever	+/- 2.5 µm
4	Rotation and alignment for spring transfer	Z, B, D	Stationary Camera 2	Cantilever	+/- 2.5 µm +/-0.5°
5	Mechanical spring correction	Z	Mechanical spring	Force detection	+/- 2 g
6	Optical scan alignment	X, U, Z, Tilt	Optical system	Tip	+/- 0.03 µm +/- 0.5 µm (axis) +/- 0.003°
7	Post bond hump/tip inspection	X, Y	Bond head – Camera 1	Hump or tip	+/- 0.5 µm

Alignment Summary

- **Tip accuracy (machine capability):**
  - in X +/- 1 µm
  - in Y +/- 1 µm
  - in Z +/- 2.5 µm

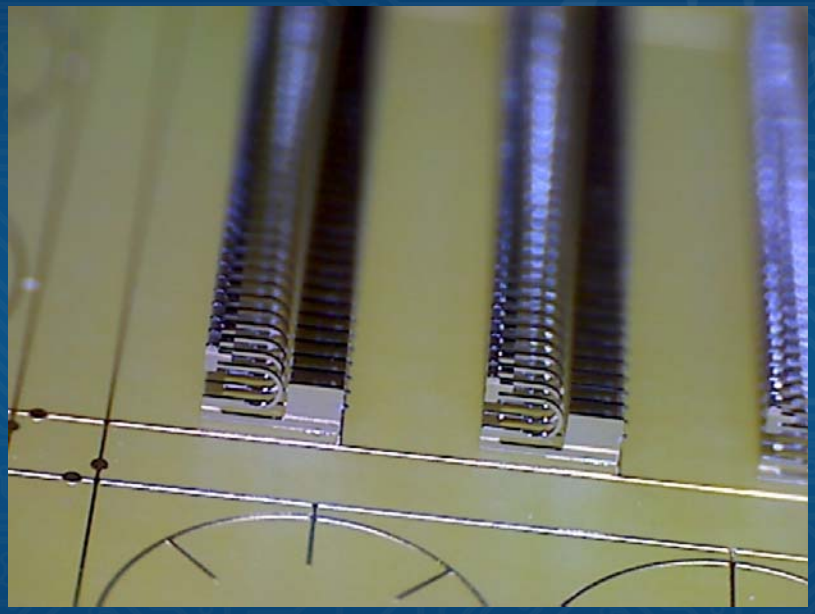
Post Bond Hump / Tip Inspection

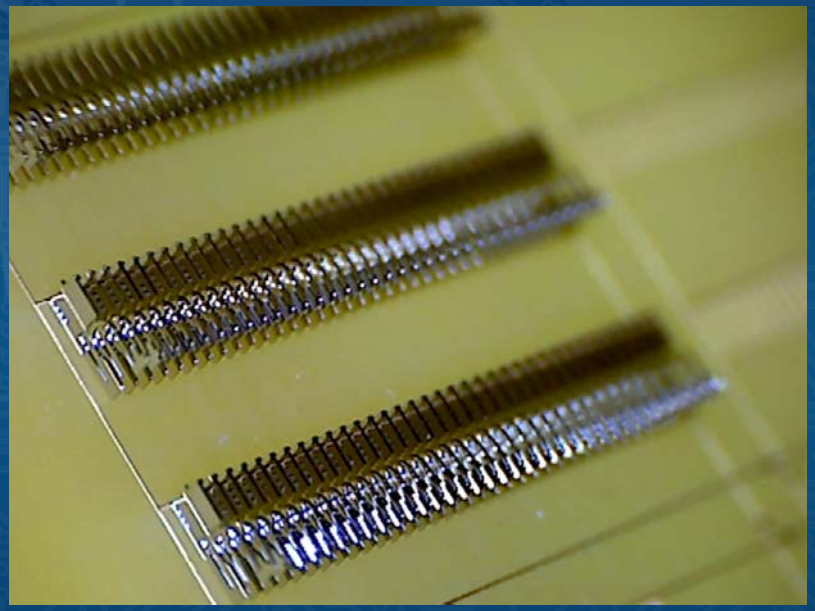
- Sensor: Bond head camera 1
- Accuracy +/- 0.5 µm
- Results used for smart correction of next bond process
- Well defined edges for repeatable pattern detection needed



Cantilever Bonding Results

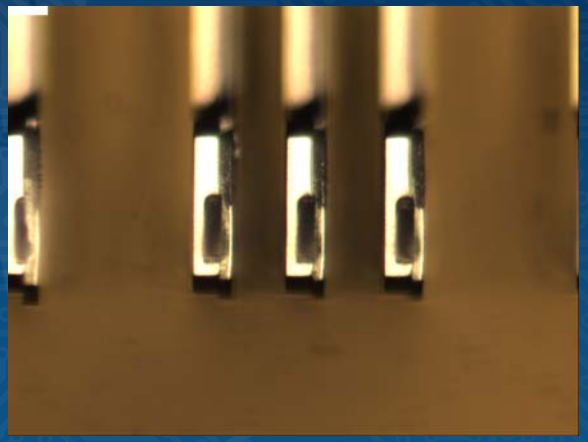
Cantilever Placement with LAPLACE-Can (80µm pitch)



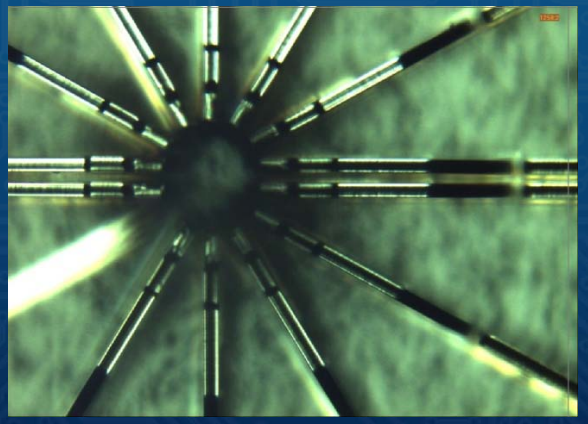


Cantilever Bonding Results

Cantilever Placement with LAPLACE-Can (60µm pitch)



Cantilever Placement with LAPLACE-Can (360°)



Process Data

X,Y Placement Accuracy

Depends on cantilever quality

Summary		
Min Value [mm]	-0.0035	-0.0033
Max Value [mm]	0.0013	0.0021
Range [mm]	-0.0048	-0.0054
StDiv [mm]	0.00101357	0.00126077

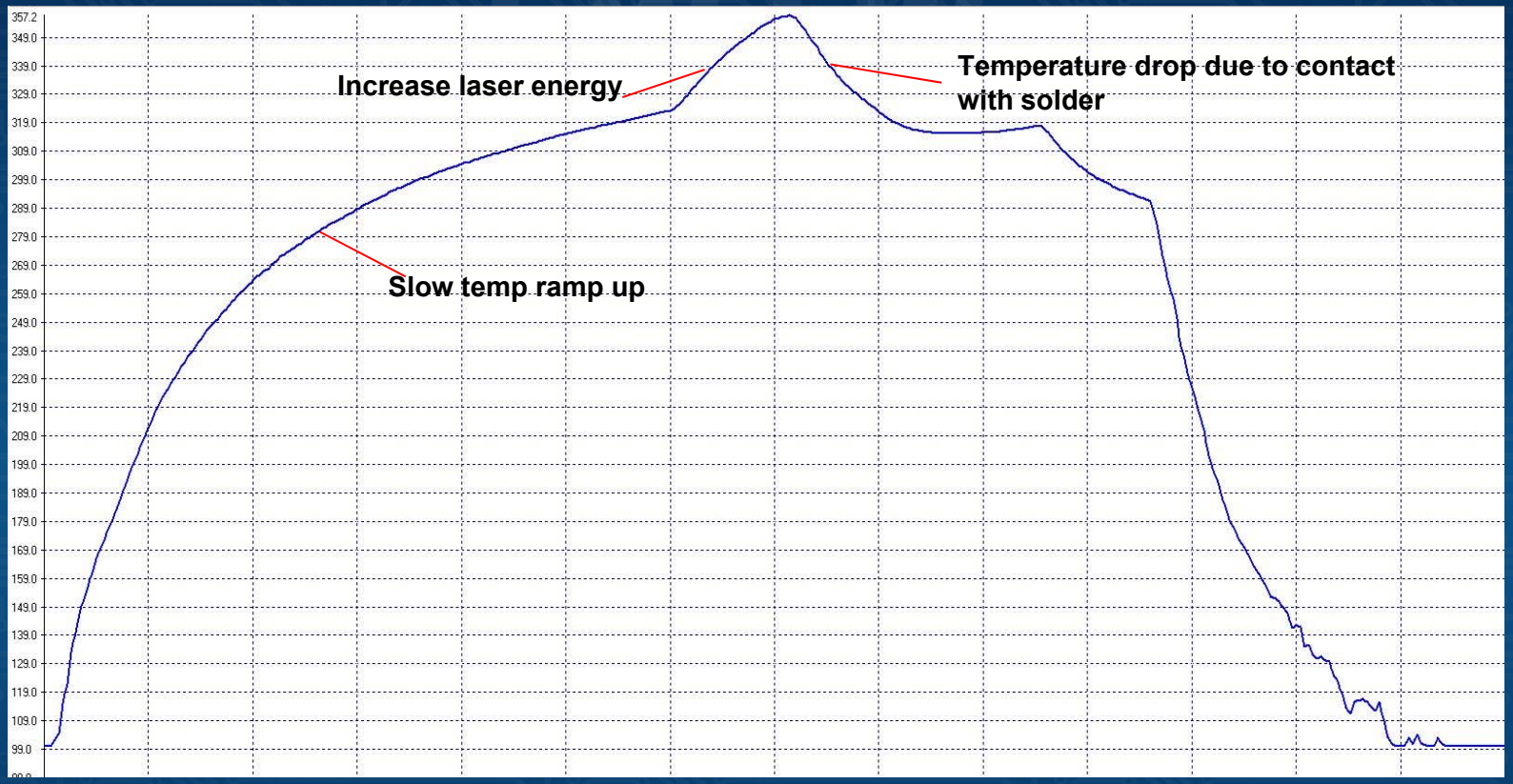
Placement Speed
30µm cantilever width,
80µm pitch

9.5 sec per cantilever (w/o post inspection)
< 13 sec per cantilever (with post inspection)

Probe Cards assembled
NAND & DRAM: ~ 100+

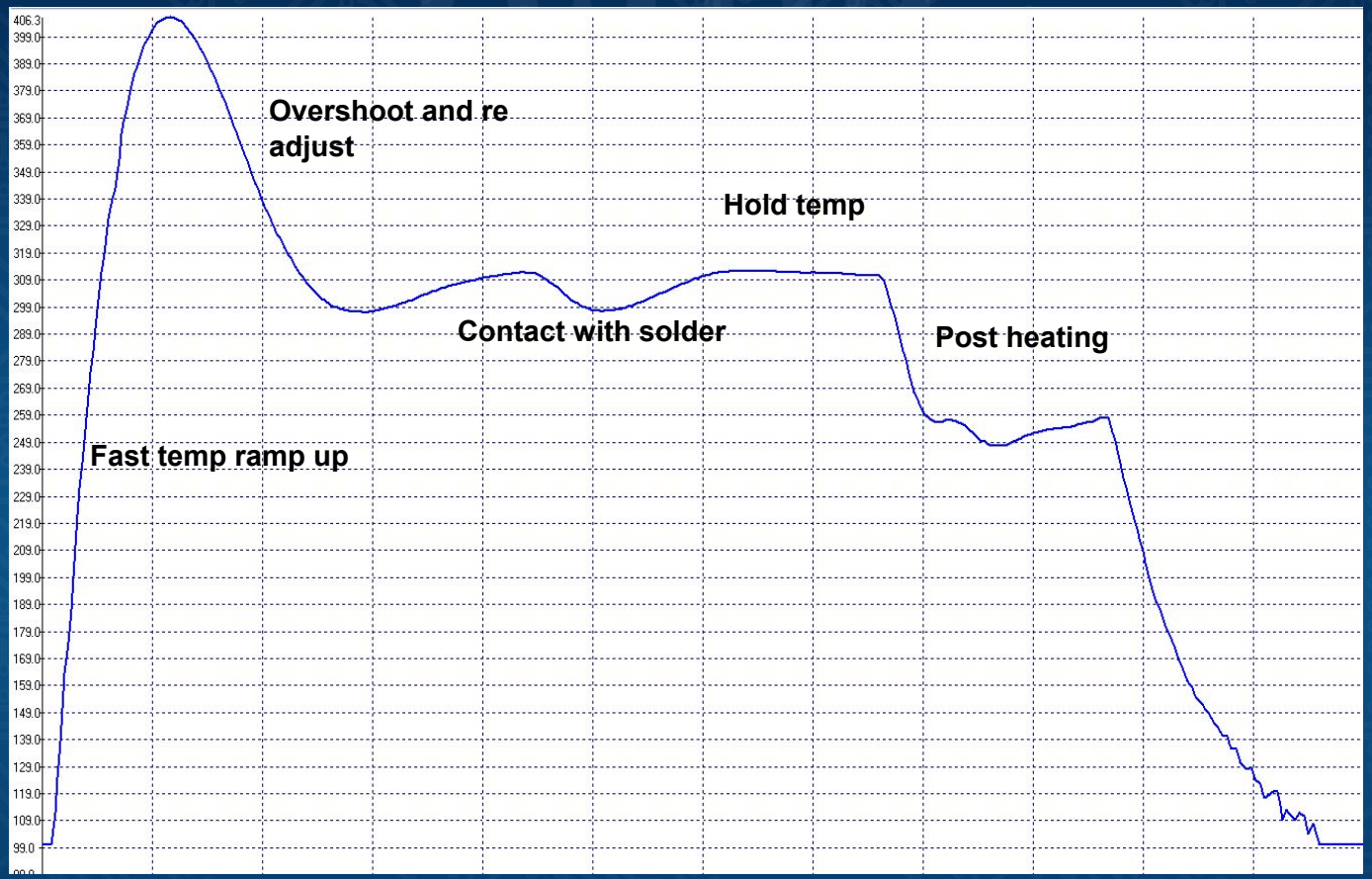
Reliability
Touchdown (mechanical): passed
Electrical test: passed

Temperature Profile- Current



Temperature profile without temperature control

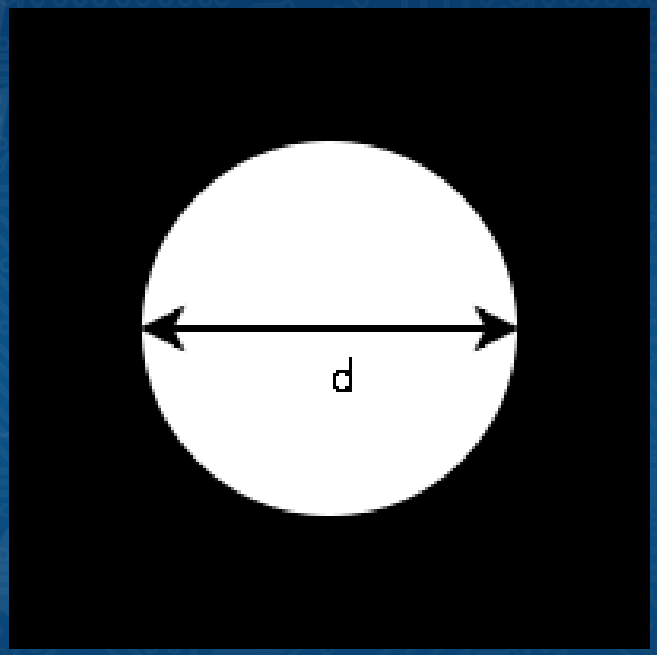
Temperature Profile - Development



Temperature profile with temperature control

Substrate Height Measurement

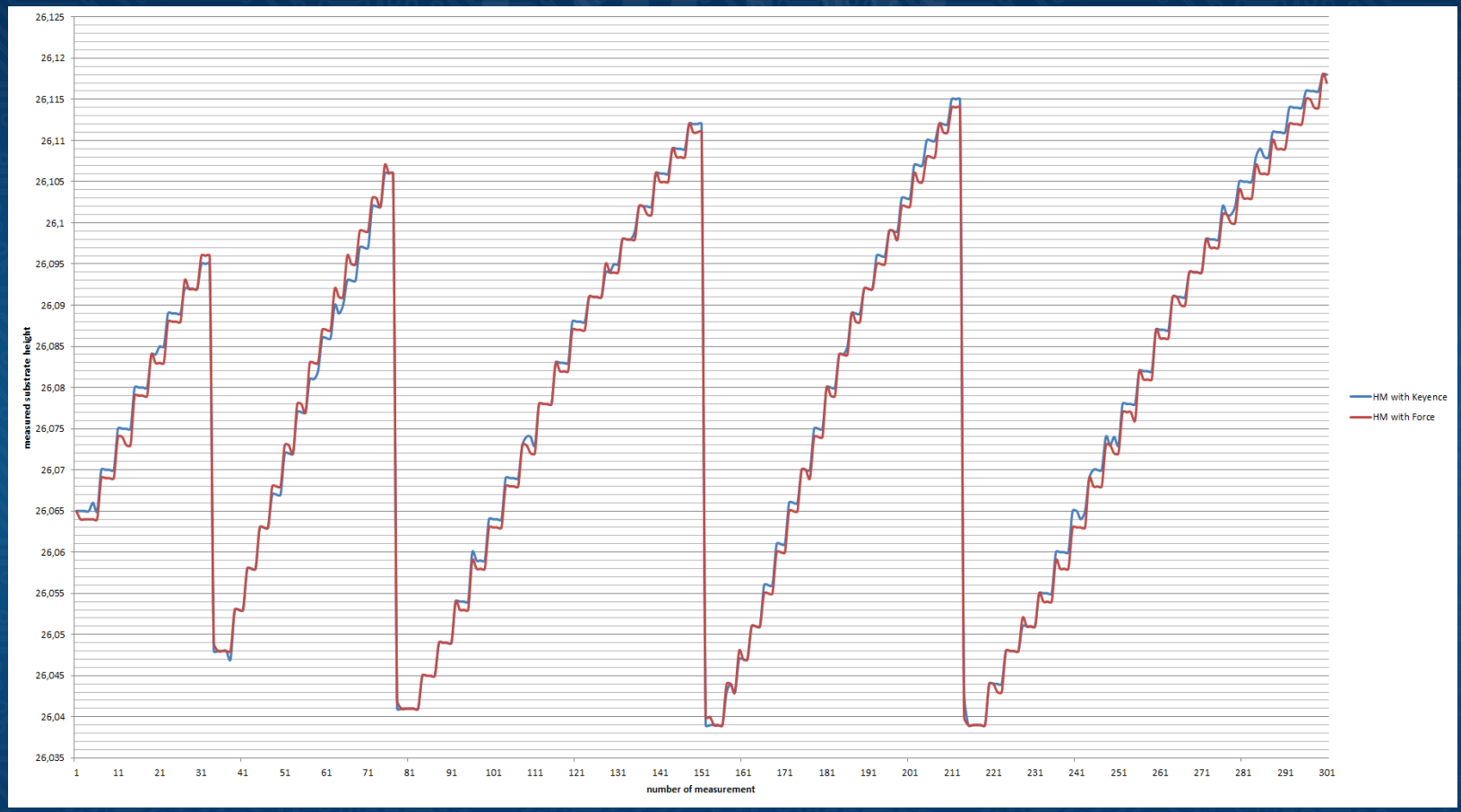
- Continuous substrate height measurement during bond process
- Height check via touch down on substrate
- Force resolution 5 g – 2000 g
- Alignment accuracy: +/- 1.5 µm (Z-axis)
- Measurement location on UBM or other locations



Available Height Measurement Methods

- 4 measurement methods
  - Force (Standard)
    - Accurate, but slow and touch of substrate
  - Laser (Triangulation)
    - Accurate, contactless,but very sensitive to surface roughness
  - Laser (Spectrometry)
    - Accurate, fast and contactless
  - Laser (Confocal)
    - Accurate, fast and contactless, small measurement spot (in test for tip z-height)

Result – Substrate Height Measurements



Comparison Laser Measurement vs Force Measurement

Result of Substrate Height Measurement

Laser spectrometry & force reached nearly the same results. The maximum deviation was 3µm.

Percentage distribution of deviations for all measurements:

- 0µm: 46%
- 1µm: 30%
- 2µm: 22%
- 3µm: 2%

Laplace-Can Test Run: Cantilever Positioning Accuracy

Positioning Accuracy	Tip X Error [mm]	Tip Y Error [mm]
Average	0,0002	0,0000
Min Value	-0,0033	-0,0021
Max Value	0,0033	0,0026
Range	-0,0066	-0,0047
StDiv	0,001819	0,000970

Sample: 1000 cantilever, Pitch: 100µm

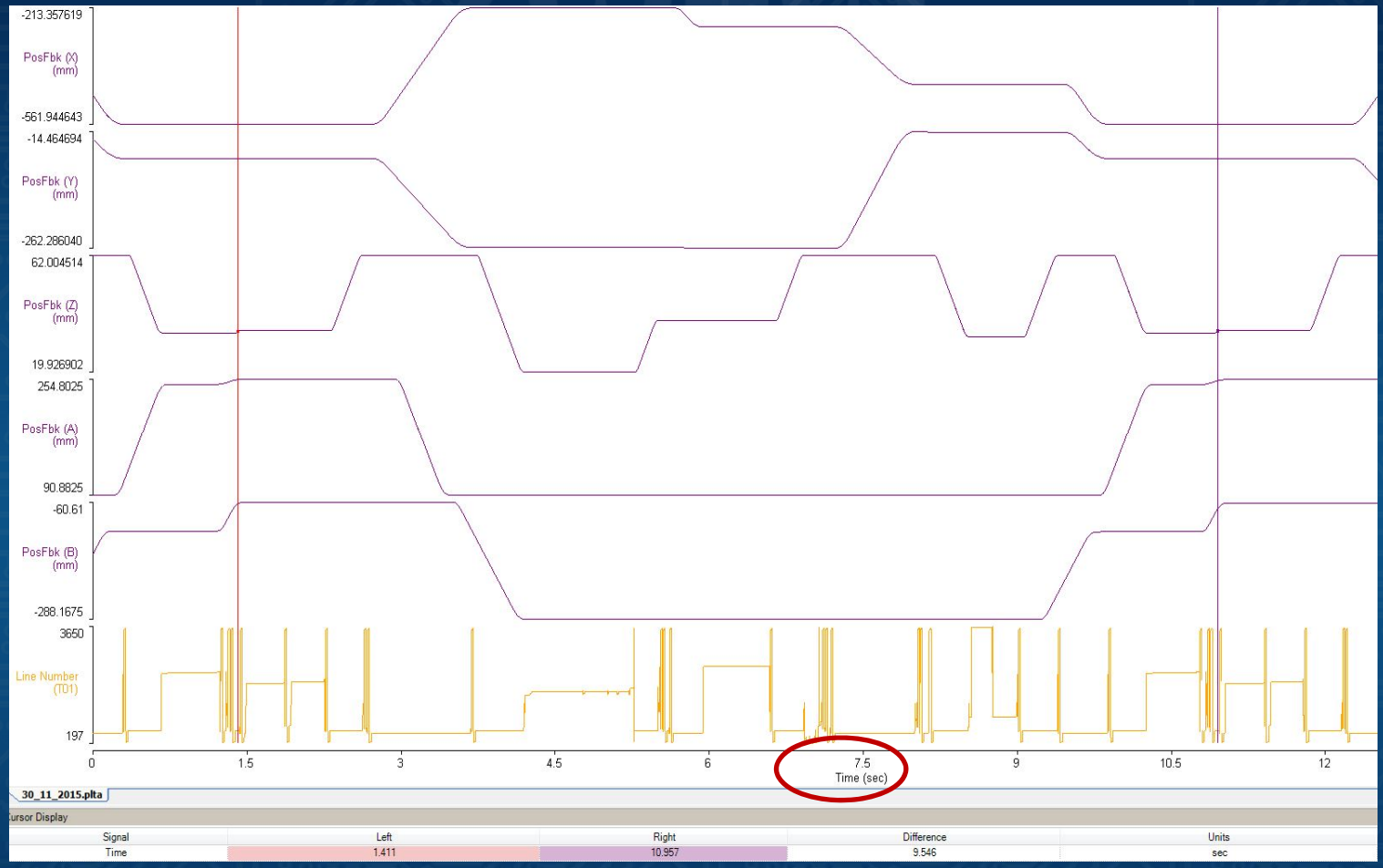
Cantilever Rework Video - Removal

Cantilever Rework Video - Soldering

Summary

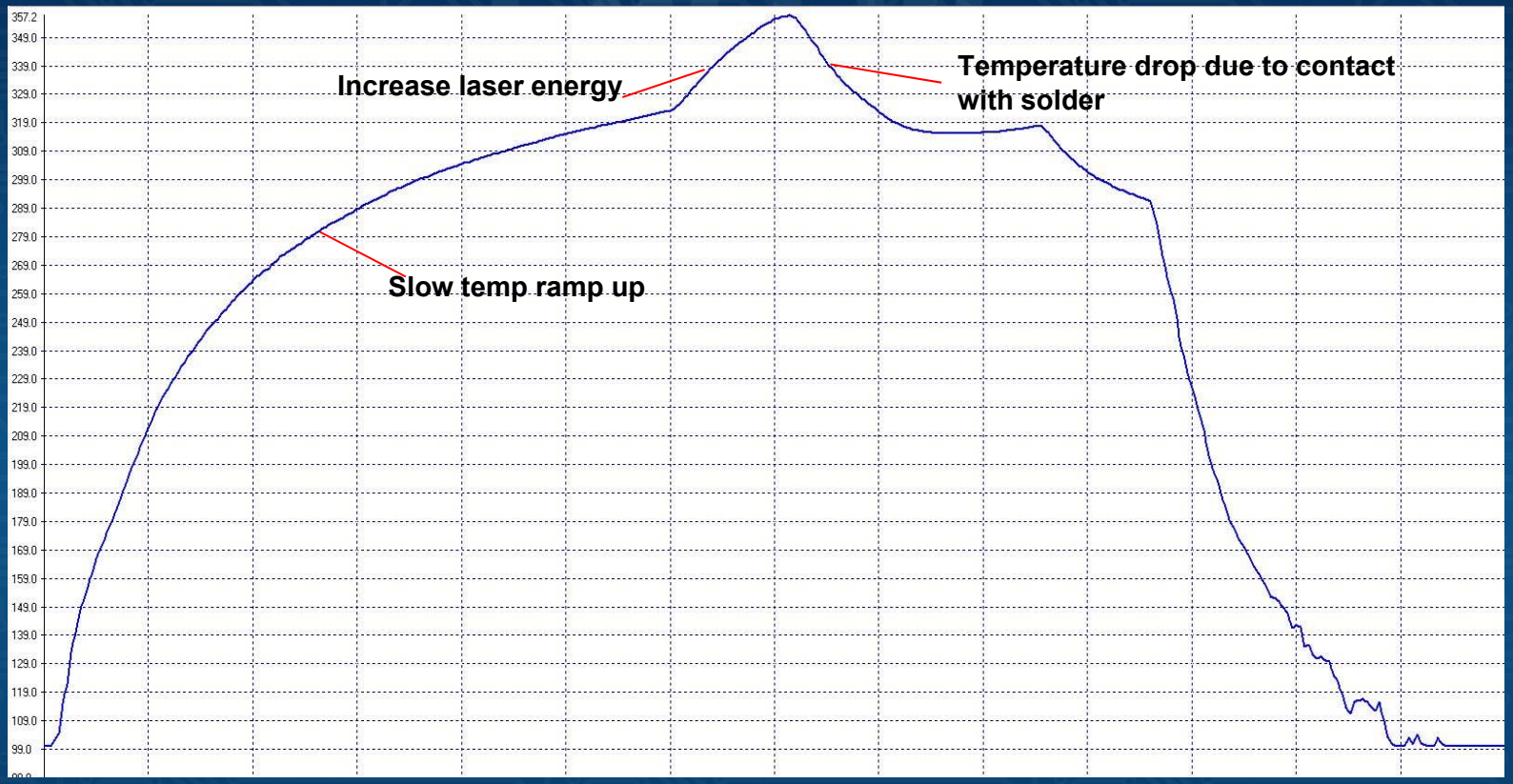
- A new laser assisted sequential cantilever attach process has been presented
- Placement accuracies down to +/-1 µm in X,Y have been demonstrated
- Assembly throughput of 9.5 sec per spring has been observed
- Probe springs can be assembled with free 360 deg orientation
- A fine pitch capability down to 50µm has been accomplished
- The assembly process is capable of single spring rework

Process Cycle time



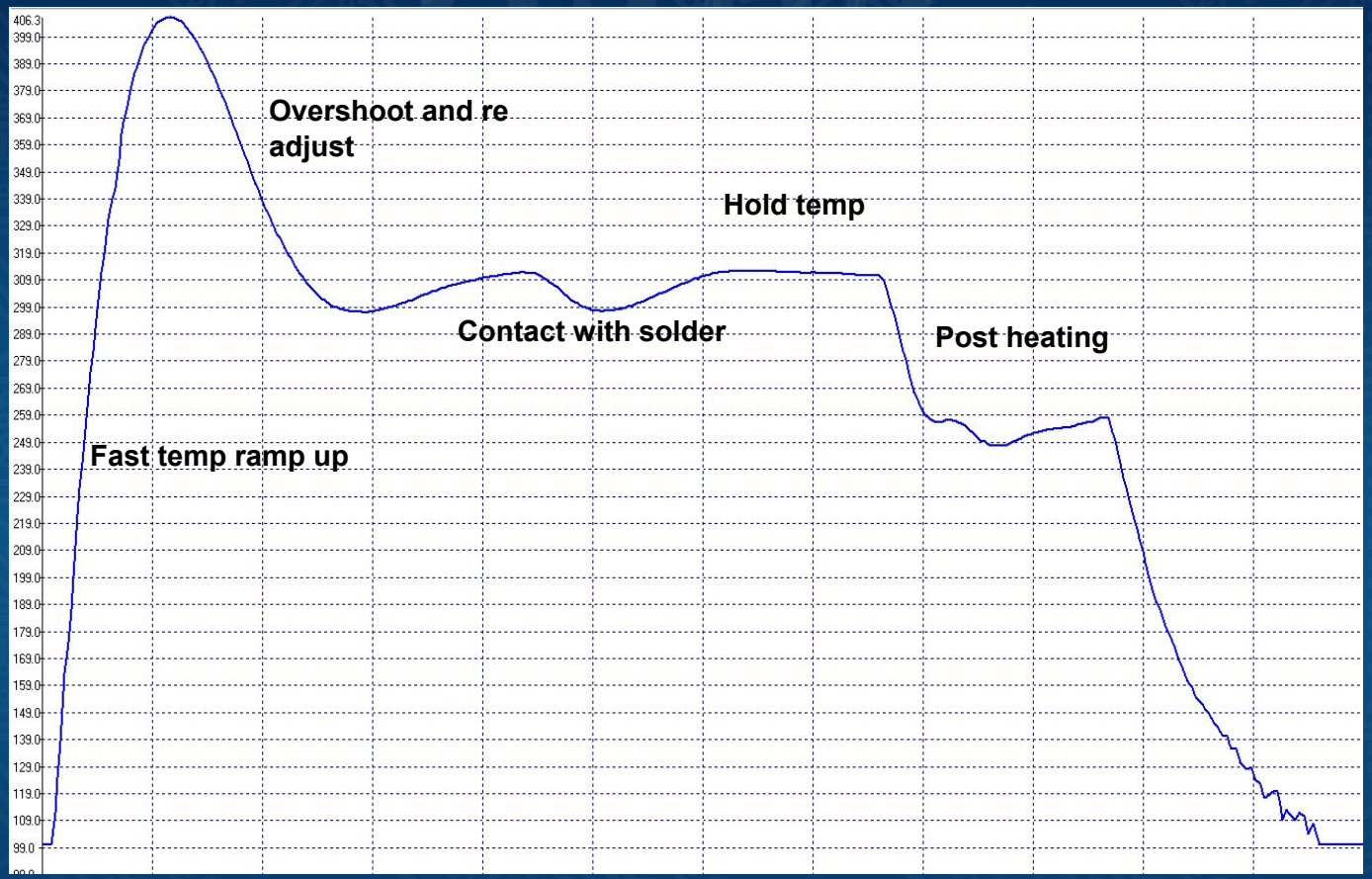
Complete process cycle time incl. Laser: 9,5sec

Temperature Profile- Standard



Temperature profile without temperature control

Temperature Profile - Improved



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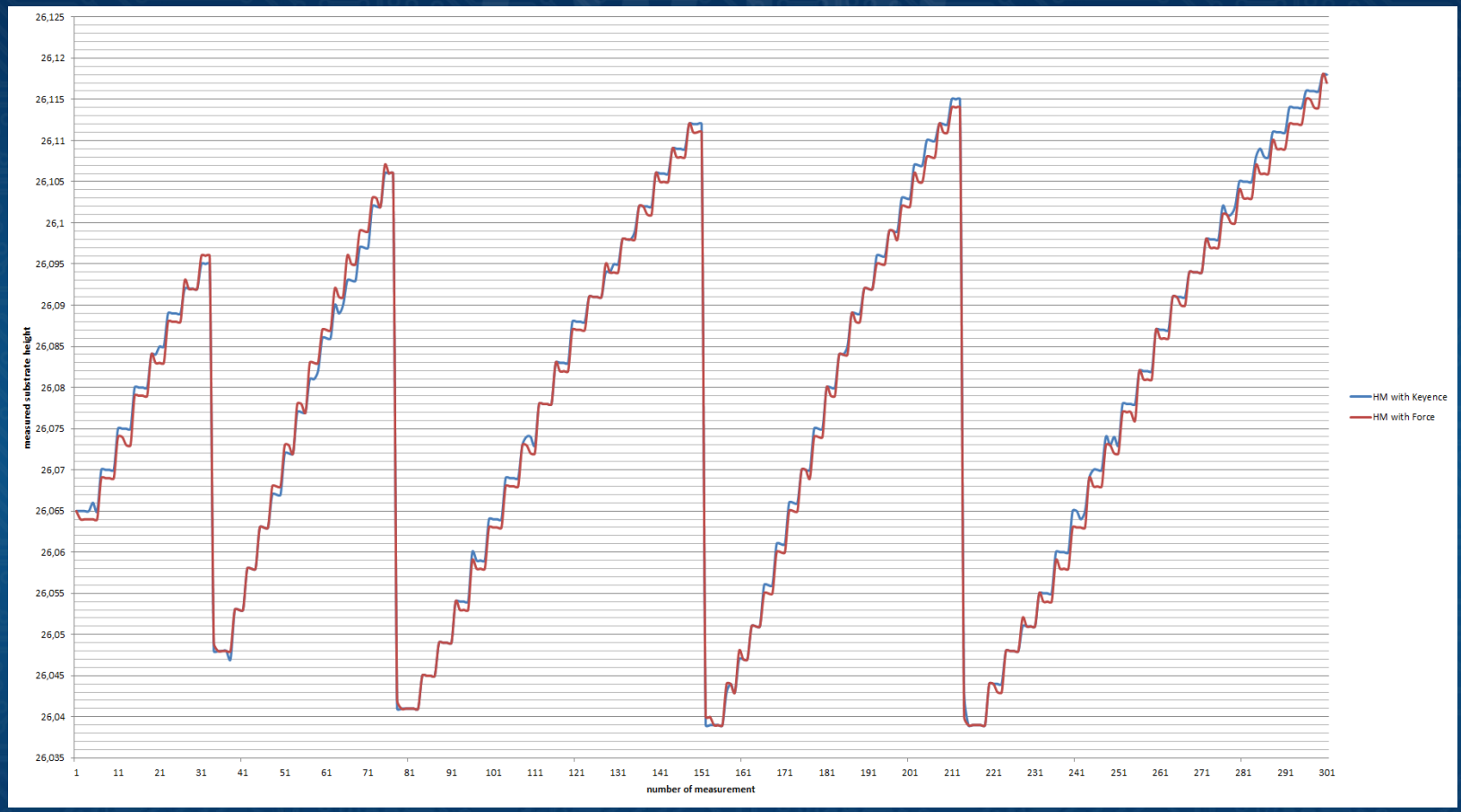

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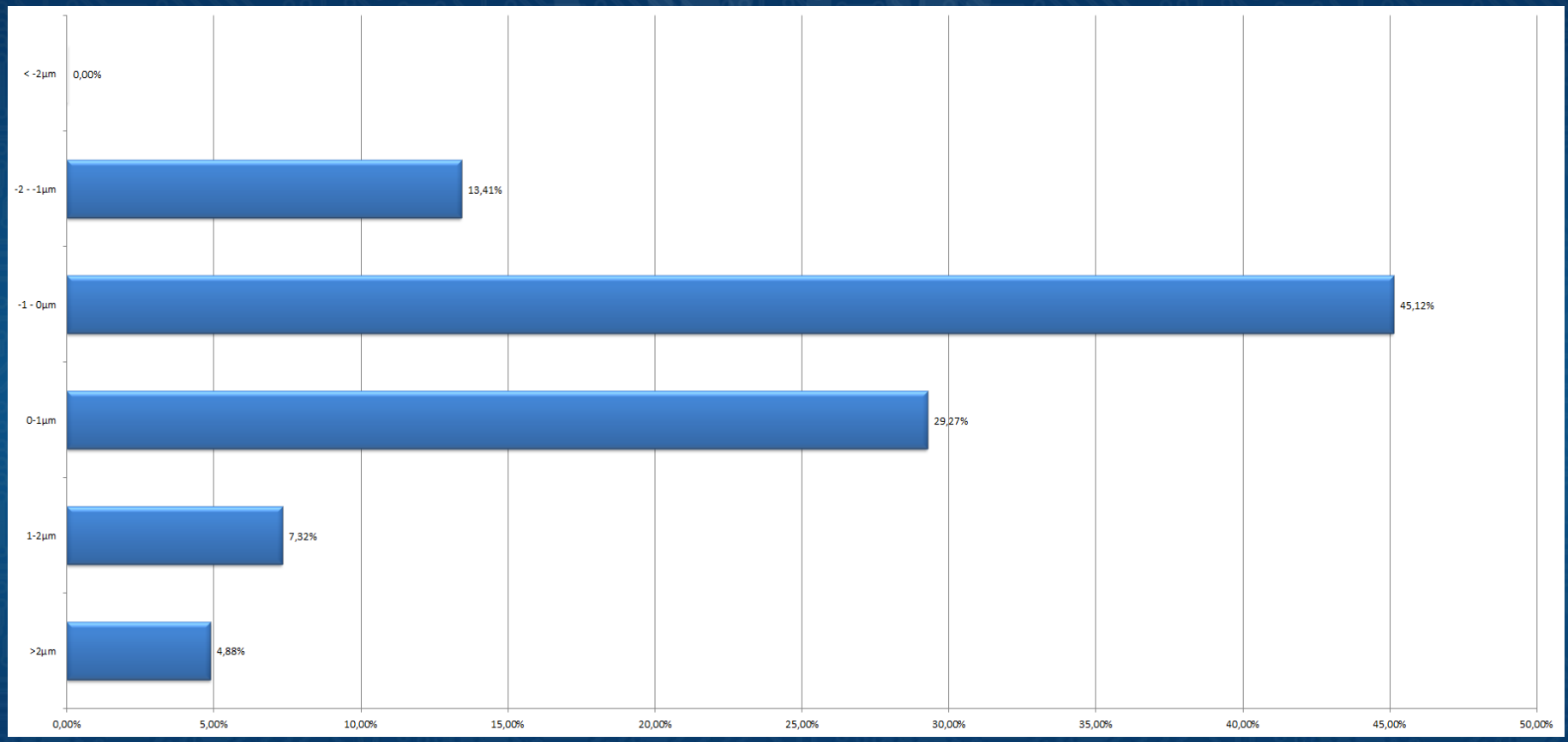
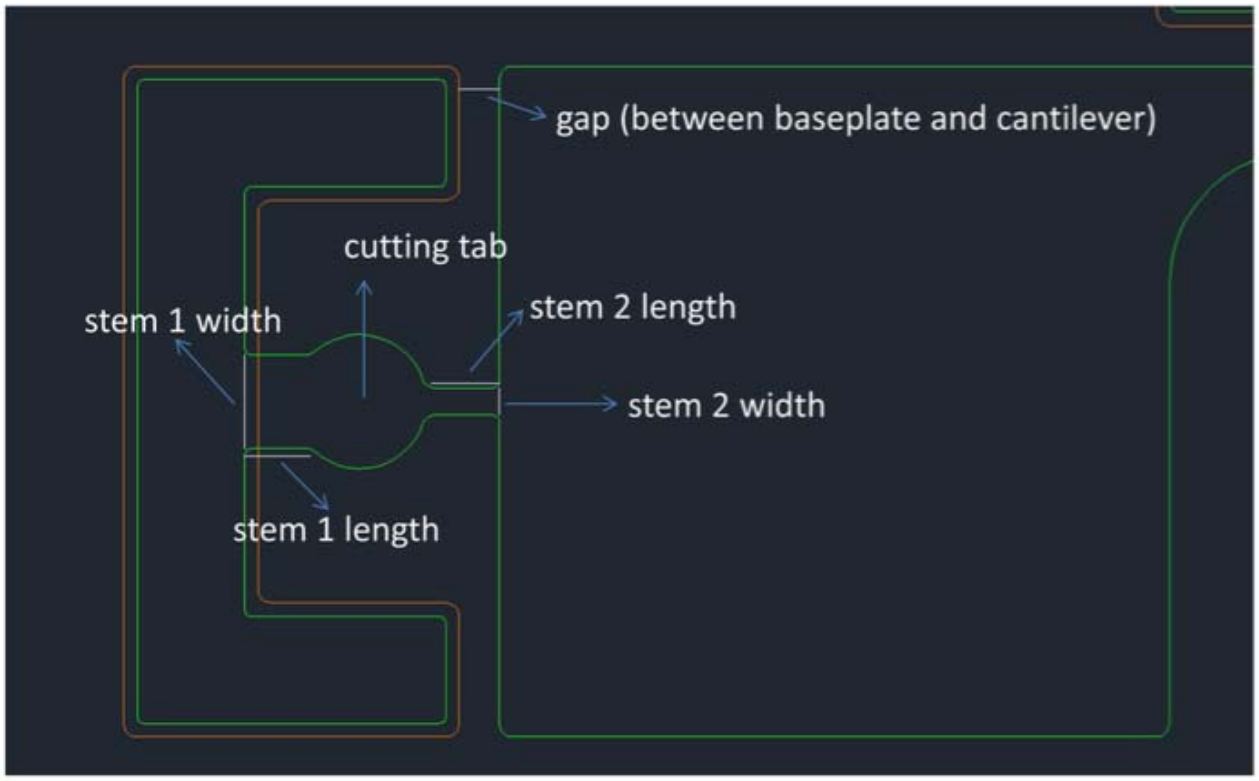


Mean values per chip

Cantilever Cutting – Design Requirements



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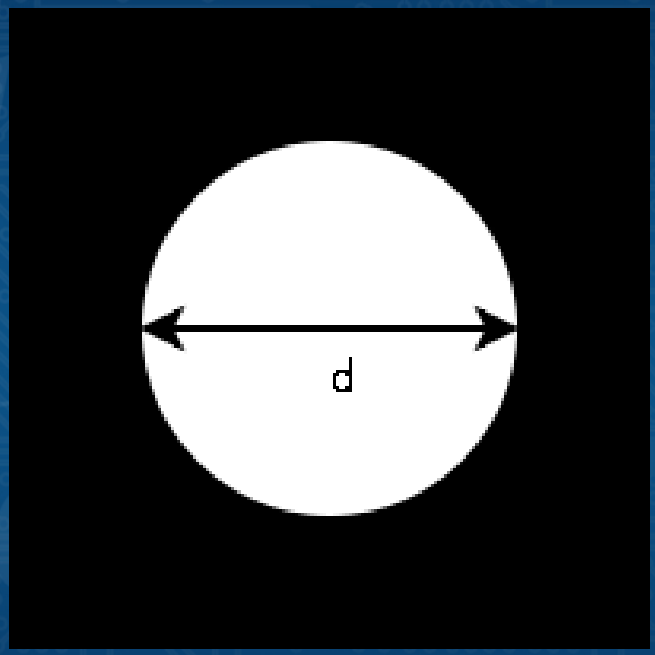

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