sPHENIX

# Final Design of the INTT Ladder and Production Readiness Review (PRR)

## Ladder Assembly at NCU/NTU

WBS : 3.01

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National Central University & National Taiwan University, Taiwan
March $2^{nd}$, 2021

# Content

- Introduction of TSiDF
- Ladder assembly
  - equipments
  - principles
  - procedures
- Production readiness

# Taiwan Silicon Detector Facility (TSiDF)

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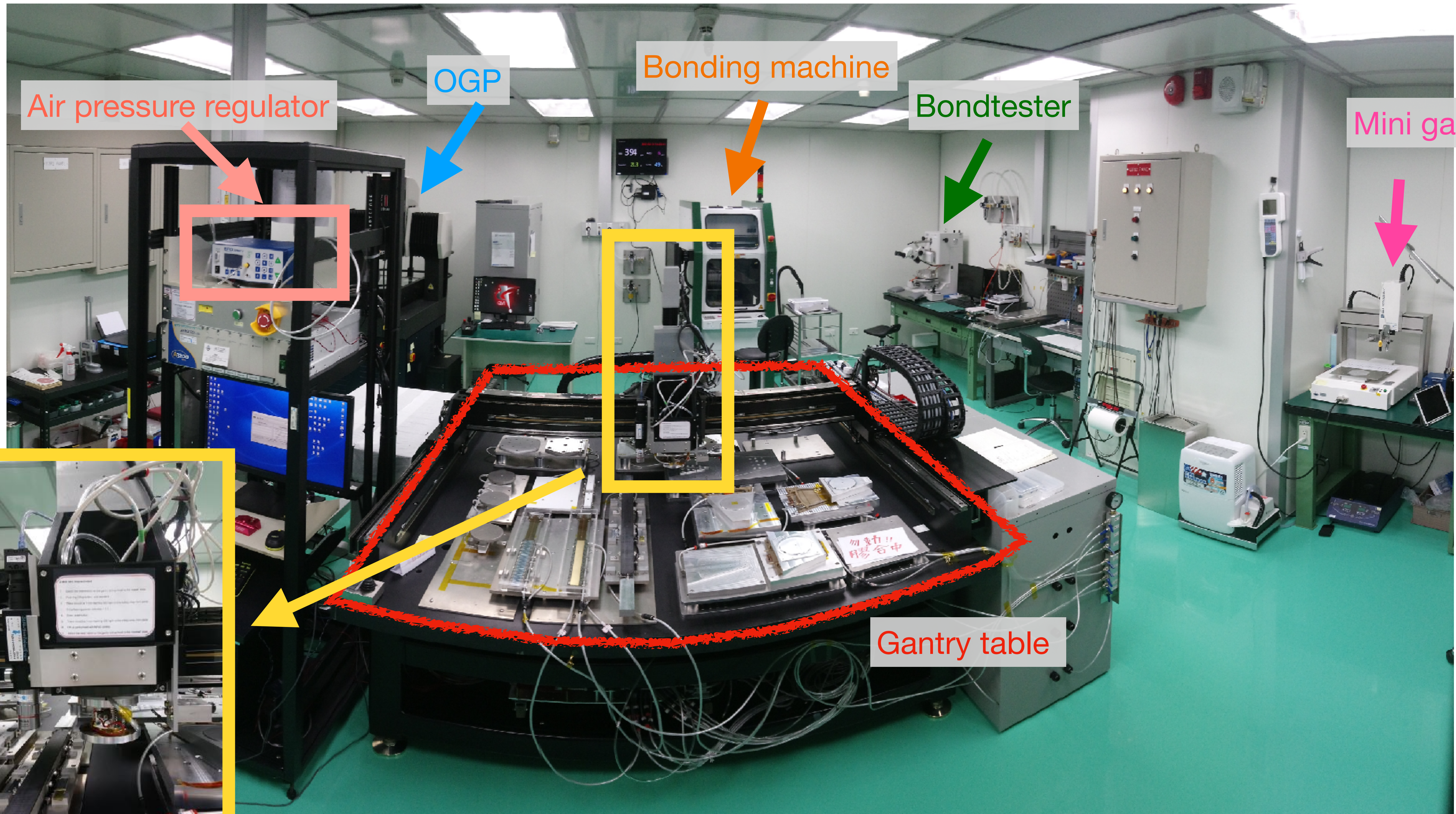


Gantry head, 4 dimensions available

# Taiwan Silicon Detector Facility (TSiDF)

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Bonding machine
Wire bond

Bondtester
Bonding wire quality test

OGP
Flatness & position measurement

Mini gantry
Encapsulation

# Taiwan Silicon Detector Facility (TSiDF)

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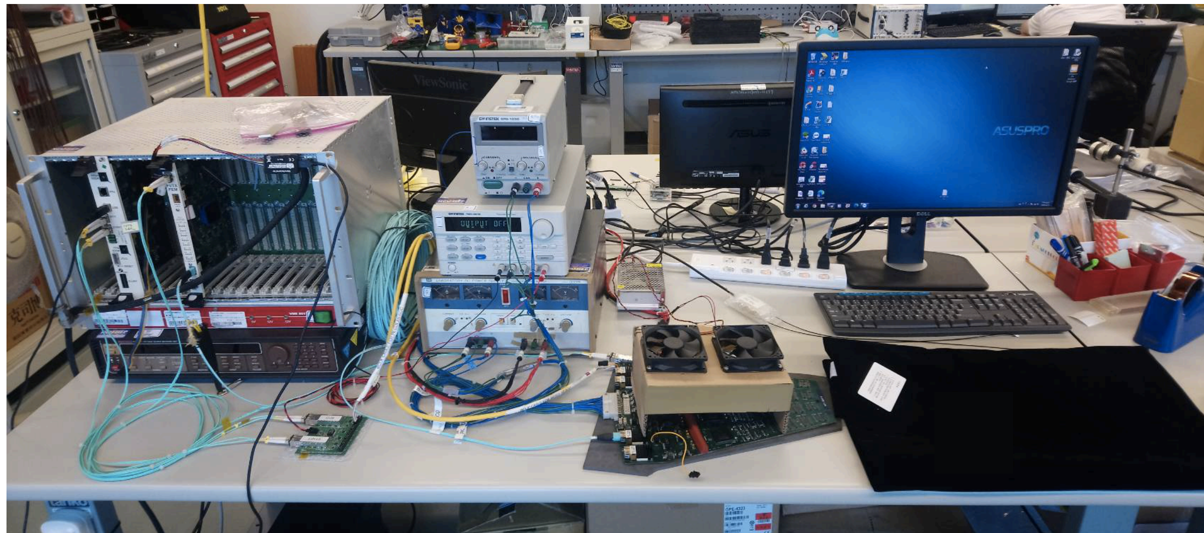
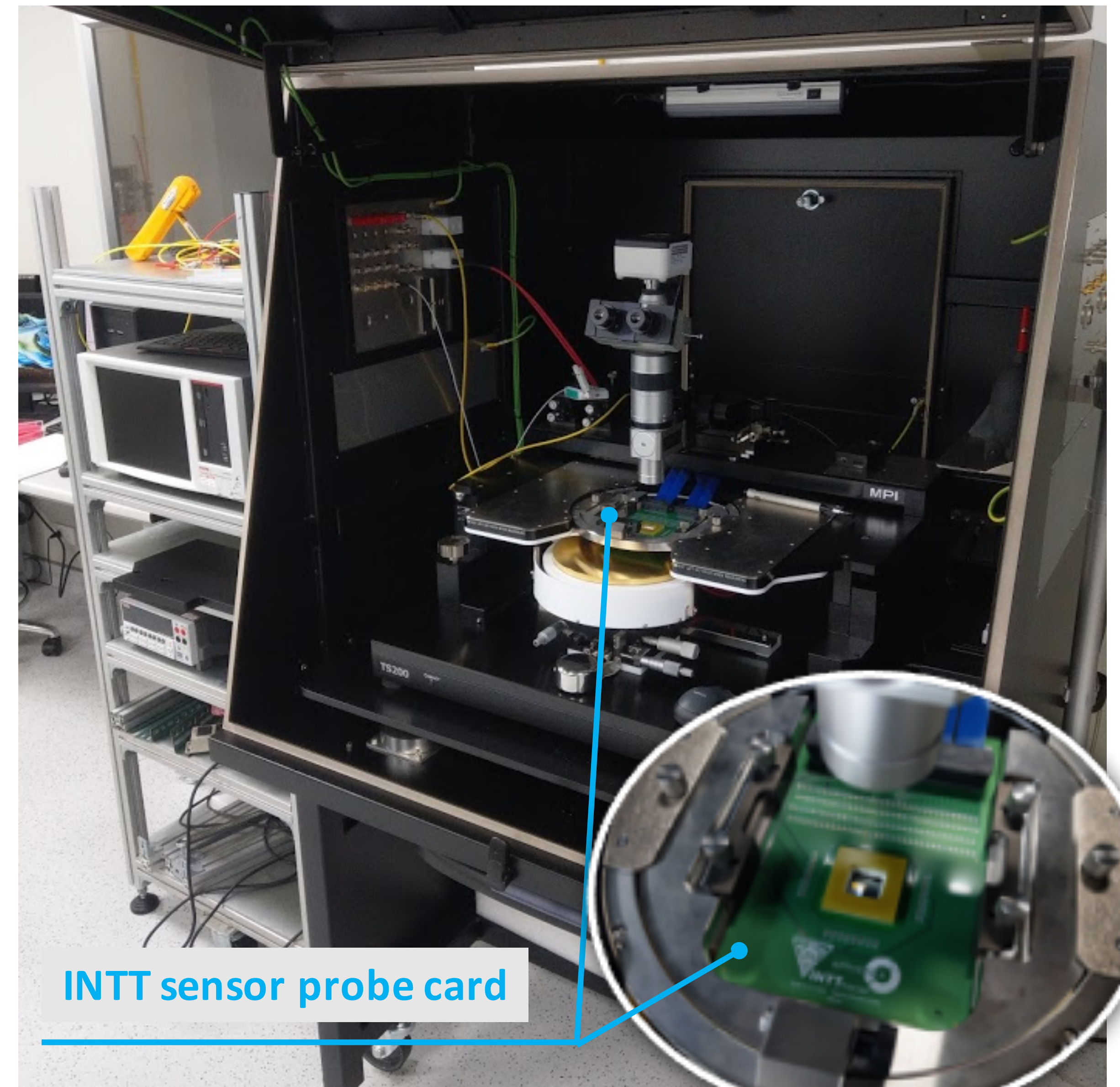
Testbench
DAQ, Calibration test



Temperature & humidity chamber
Half-ladder/Ladder thermal cycle

Probe station
INTT sensor characterization



# Ladder assembly equipments

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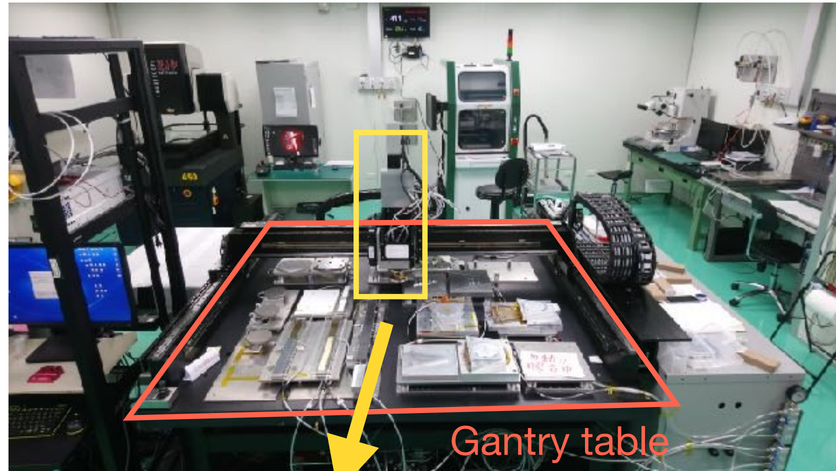
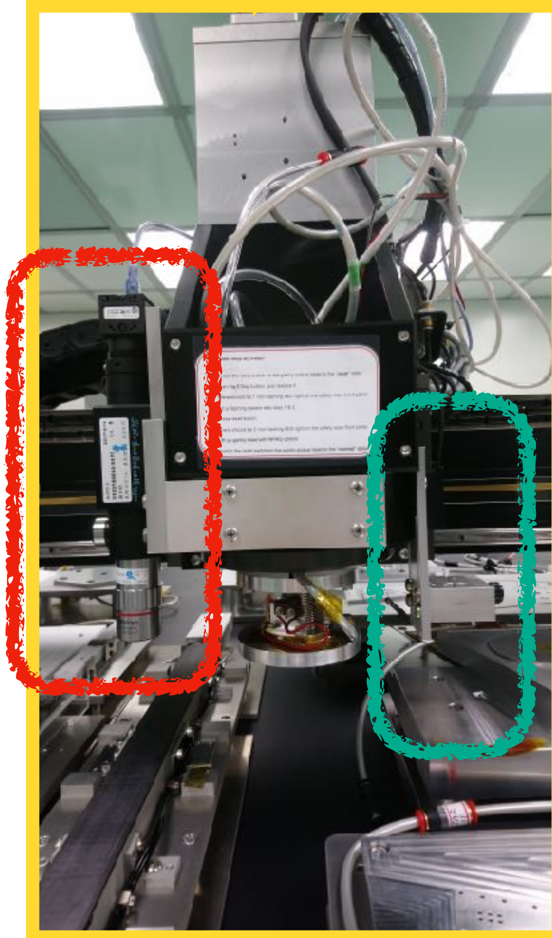
The assembly mainly runs on gantry table



Camera

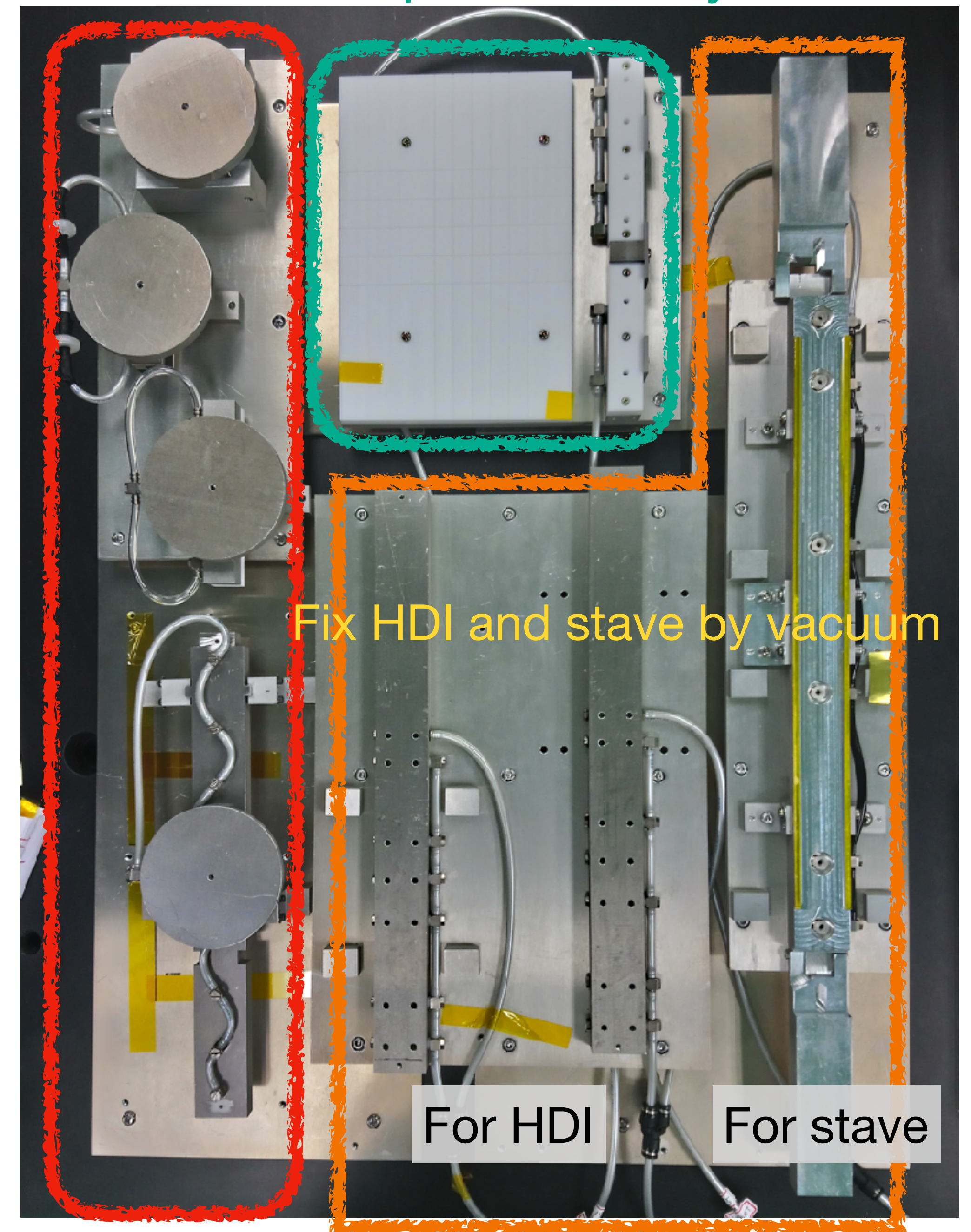
Glue holder

4 dimensional freedom : X, Y, Z & rotation

Gantry head moving accuracy : ~ 5um

Ladder assembly fixtures

Components tray

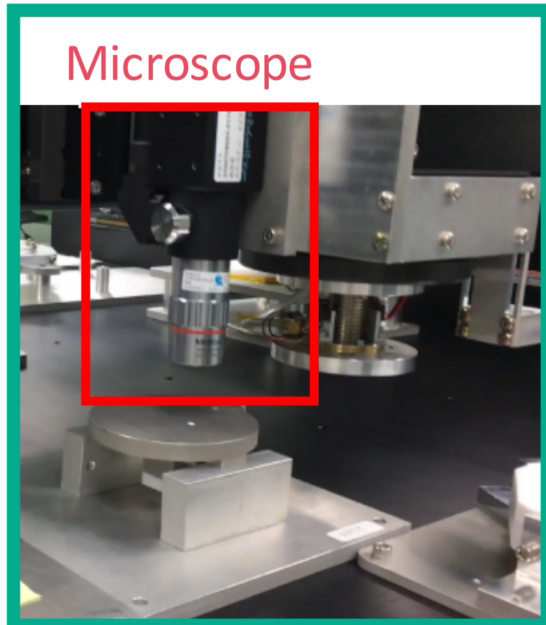


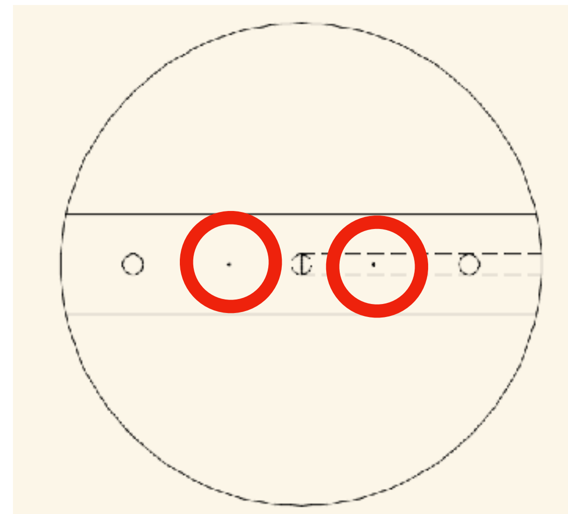

Pick up tools

Assembly tray

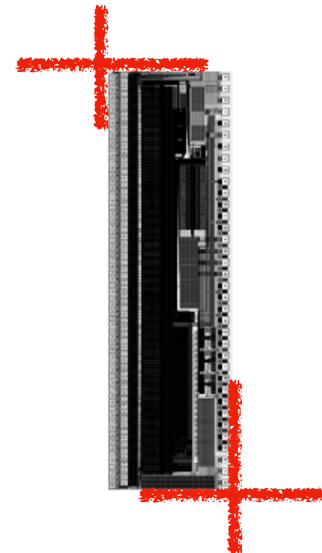
# Component position measurements

The measured positions for each component

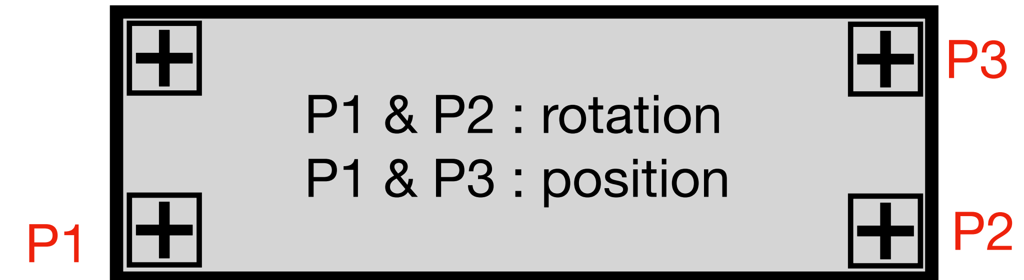


Pick up tools : alignment holes

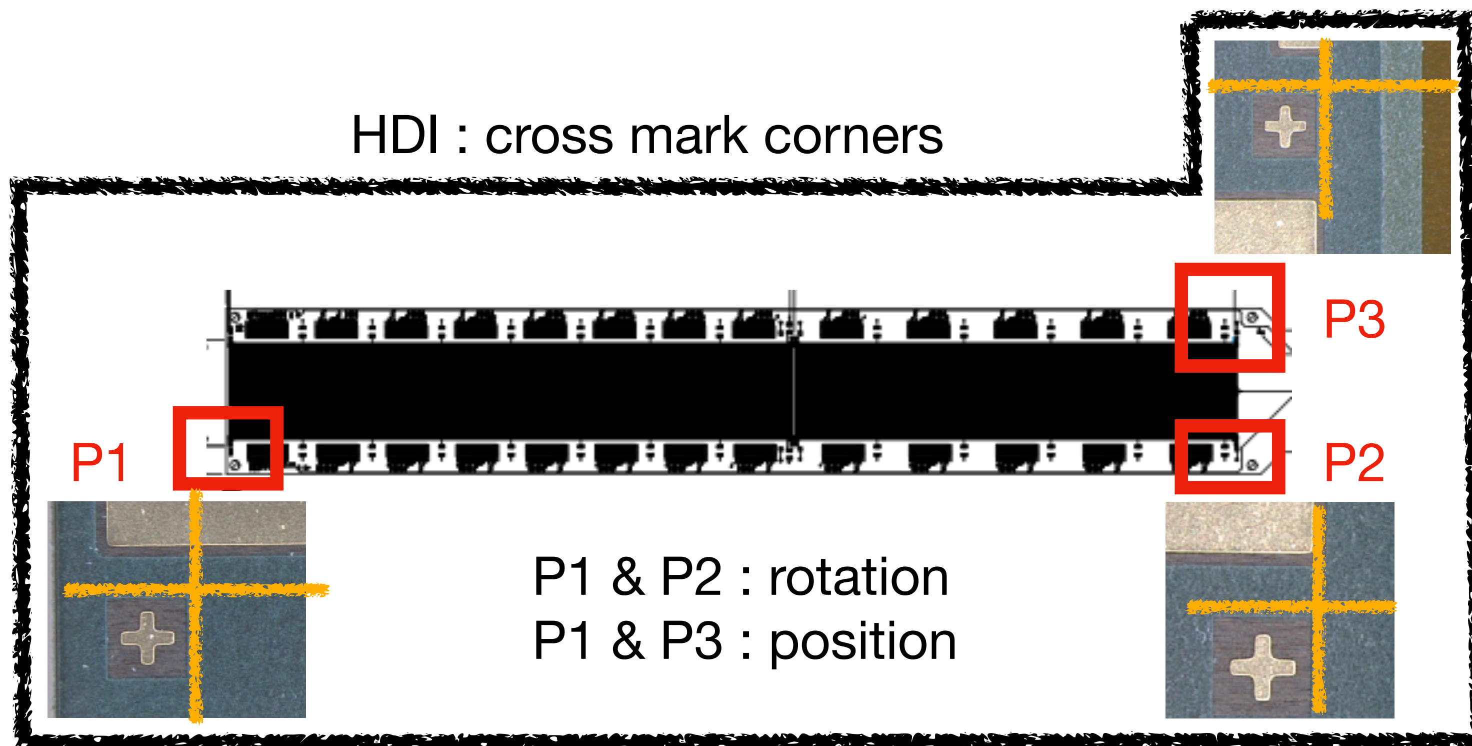


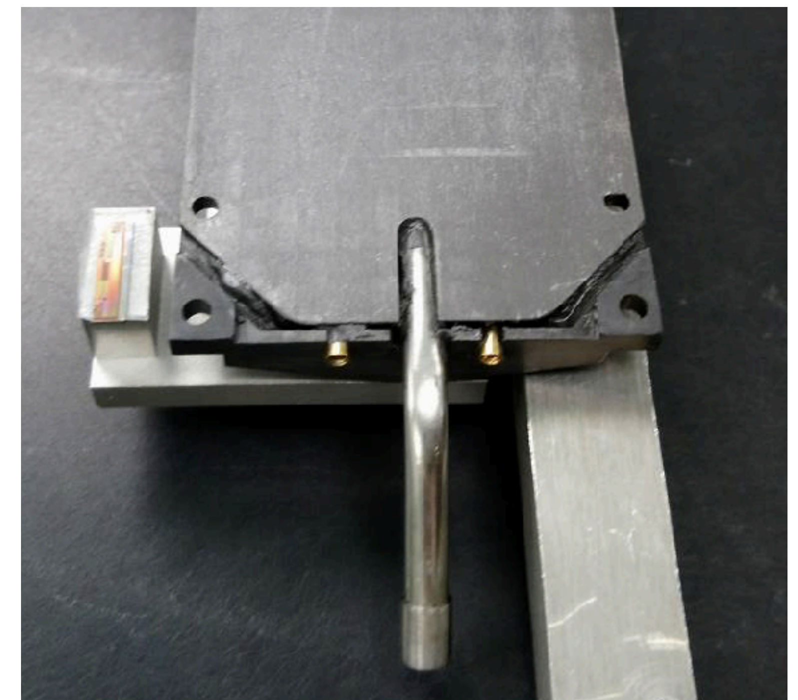
Chip : corners




Sensor : cross marks

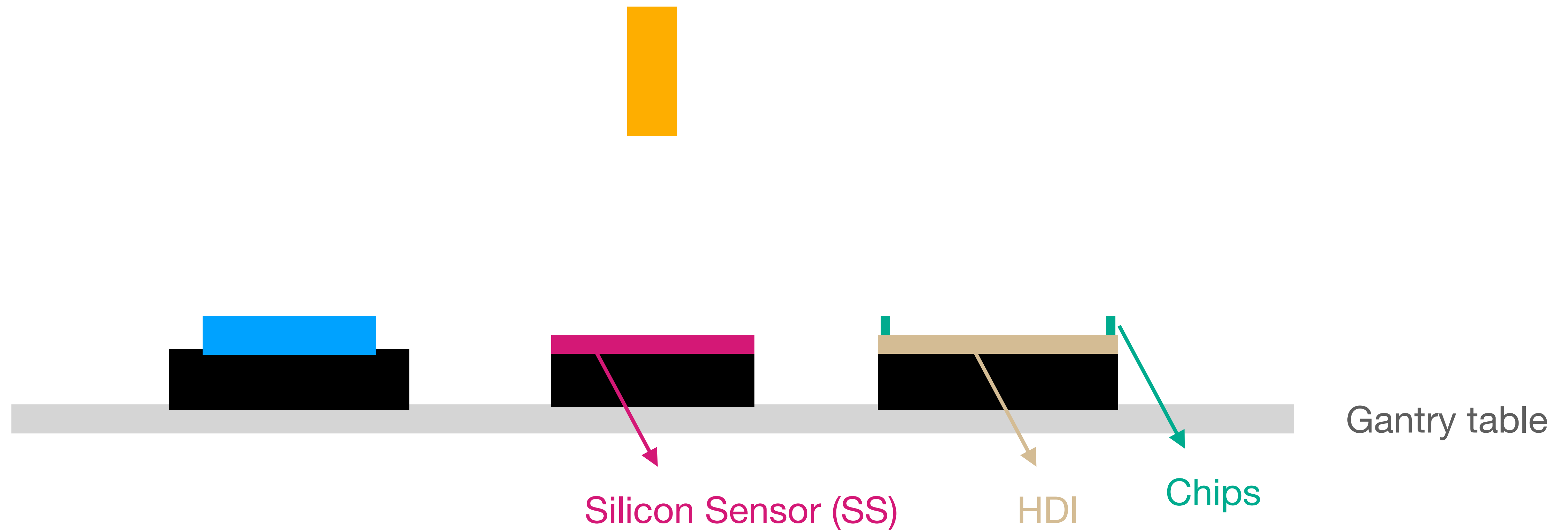
HDI : cross mark corners



Stave : chip cross marks

# Ladder assembly principle




Procedures

| | | | |
|---|---|---|---|
| 1 | GH | pick up | PUT |
| 2 | PUT | pick up | SS |
| 3 | PUT | place | SS |
| 4 | GH | return | PUT |

All the components (chips & sensors) are mounted in an automatic way with gantry

# Assembly procedures in Taiwan

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Components test before assembly

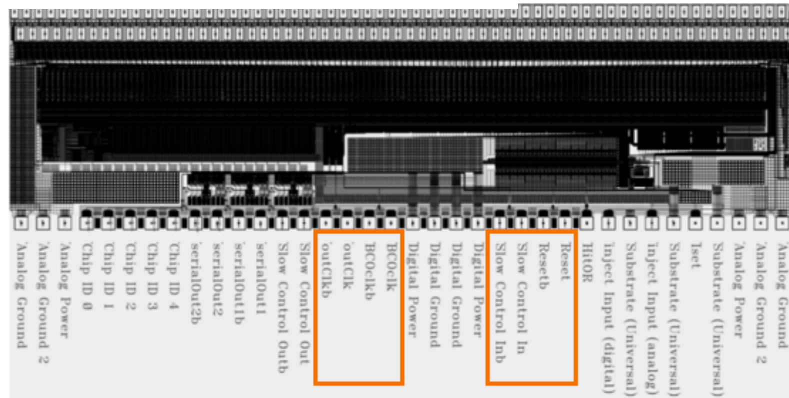
- HDI : pads continuity probing
- Sensor : CV measurement
- Stave : flatness measurement, flow & leakage test

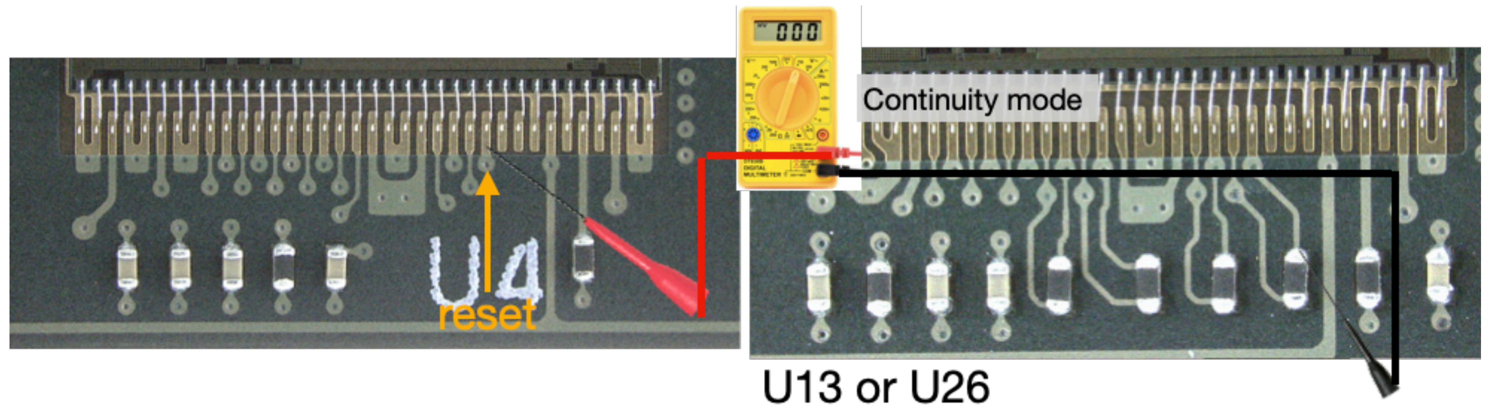
Assembly unit : Half-ladder (26 chips + 2 sensors + HDI)

| | Assembly step | | Calibration test |
|---|---|---|---|
| Half-ladder | Assembly | Chip → HDI | |
| | Wire bond | Chip → HDI | V |
| | Assembly | Sensor → HDI | |
| | Wire bond | Sensor → Chip | V |
| | Encapsulation | Wire bonding | V |
| | Thermal cycle | | V |
| Ladder | Assembly | Half-ladder → Stave | V |

# Components test before assembly

## HDI pads continuity probing

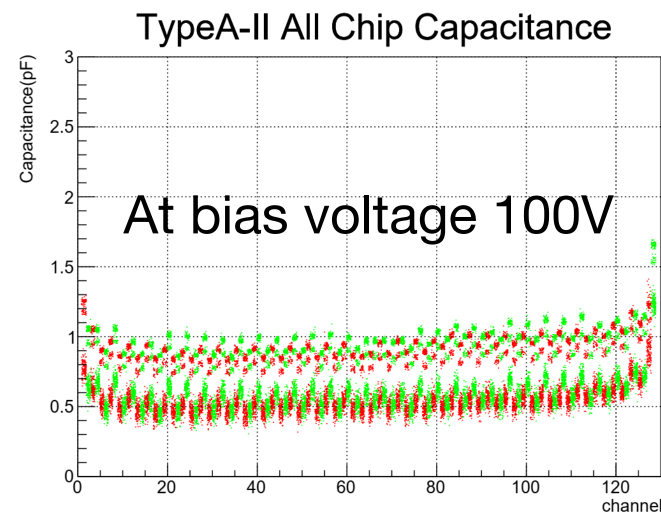


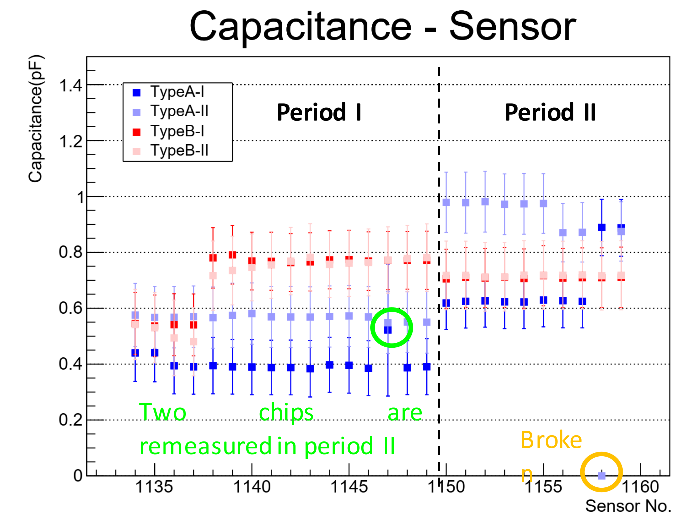



**8 * 26 = 208 receiver pads were tested**

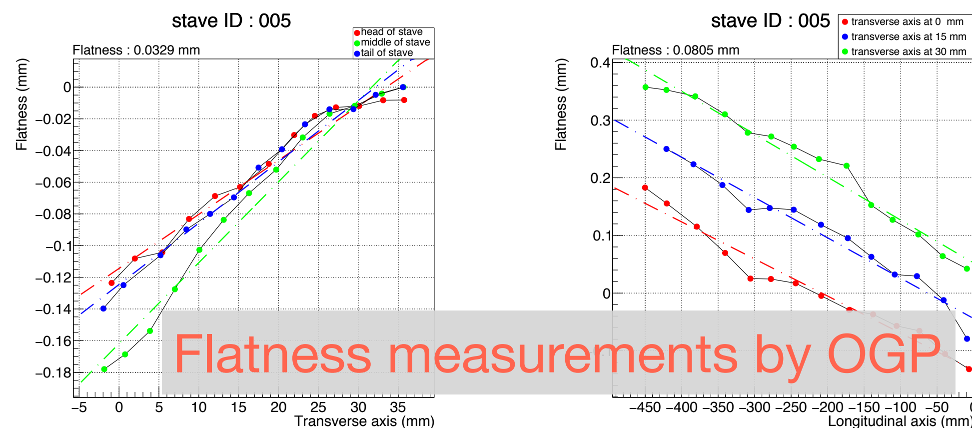
## Sensor CV measurement

Measurements are on going




## Stave flatness measurement, flow & leakage test




Flow & leakage test is exactly the same with BNL.
Setup is on going.

# Half-ladder assembly : Chip to HDI

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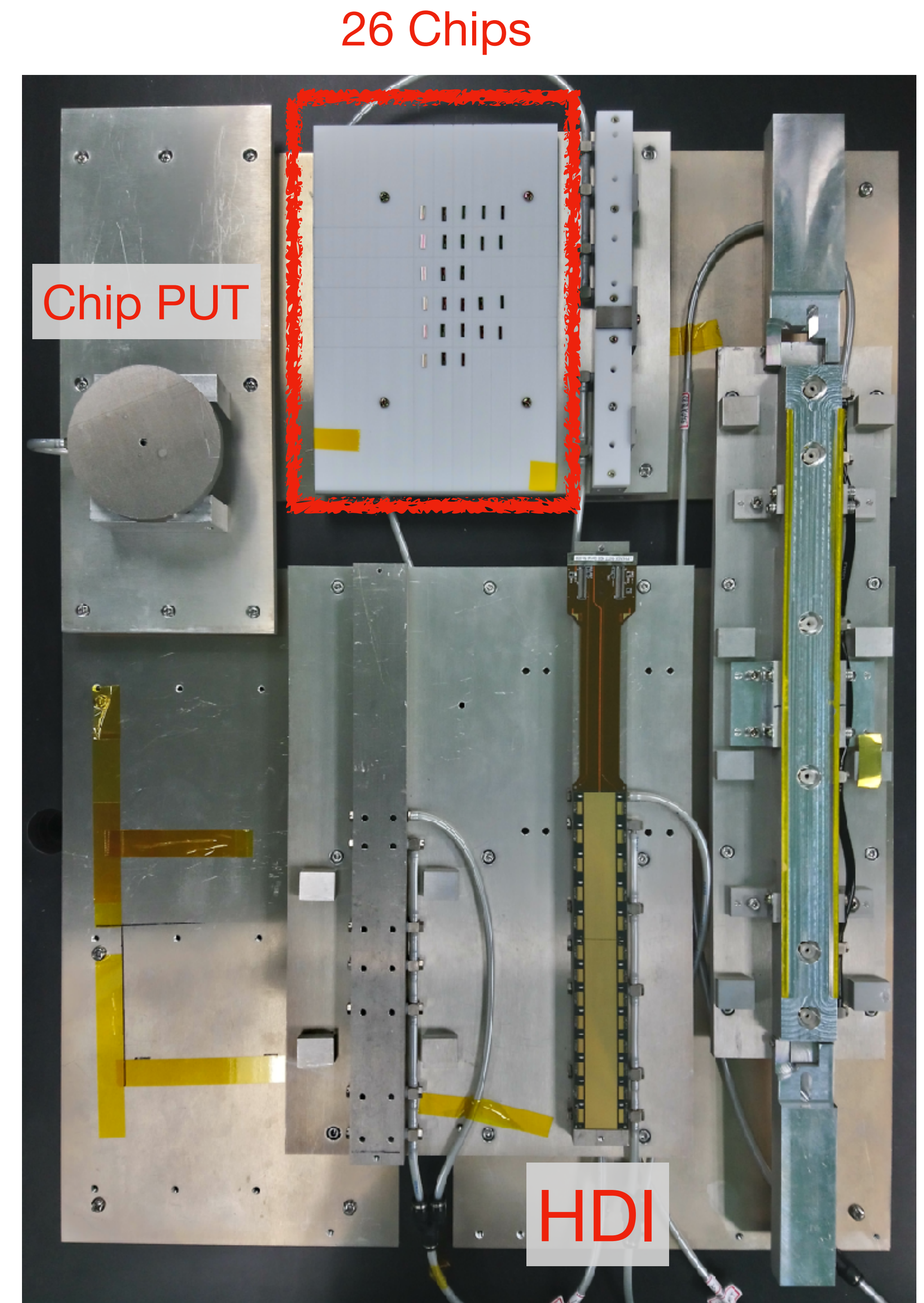
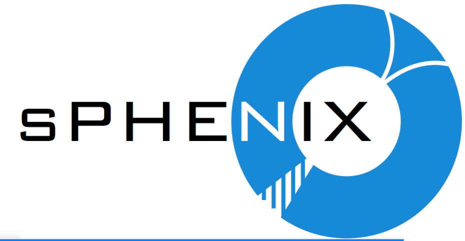
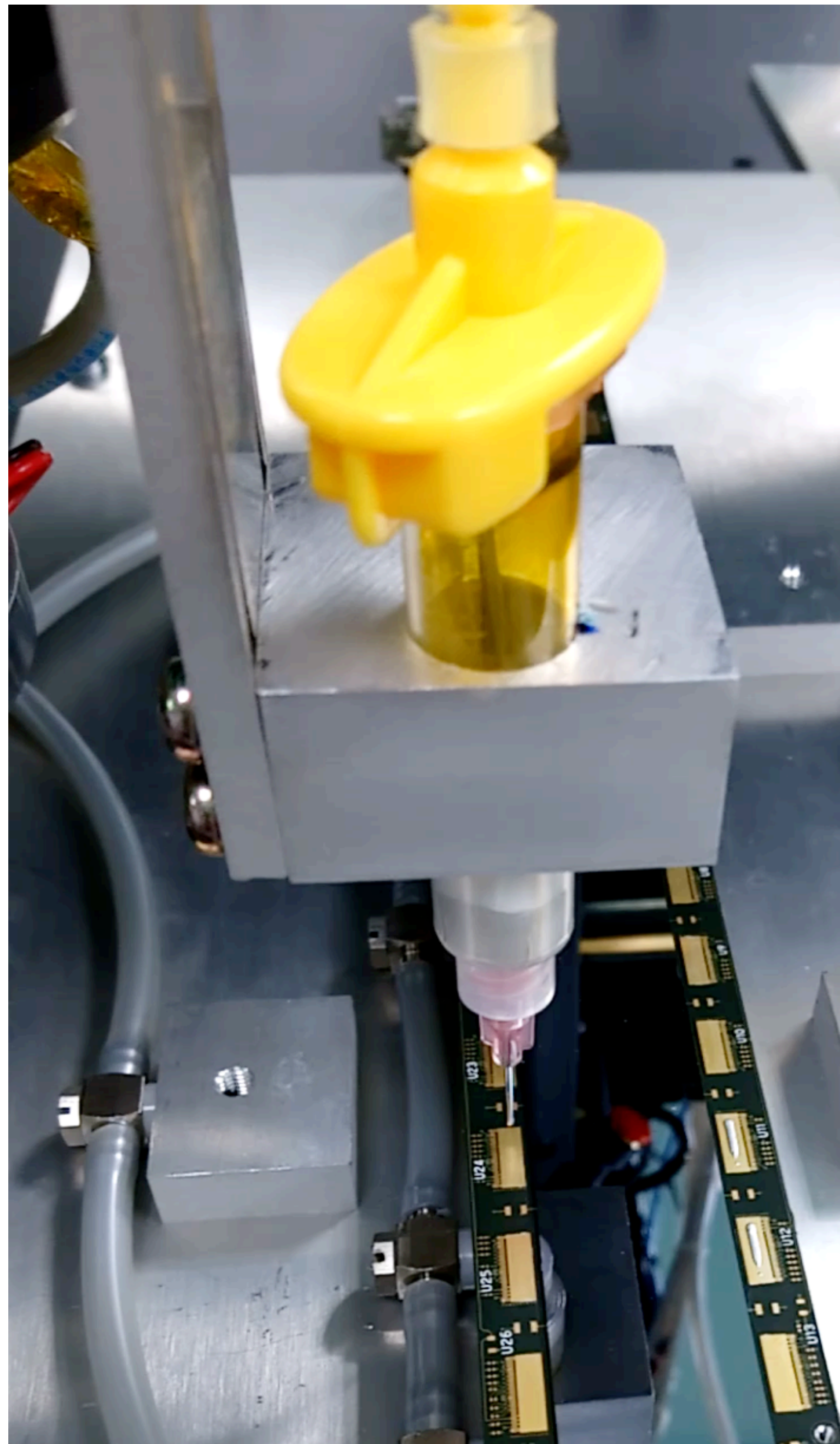
Assembly procedures :
1. Place HDI, 26 chips, chip PUT on tray
2. Measure position & rotation of chips and HDI
3. Glue deposit
4. Measure chip PUT position
5. Chips assembly with chip PUT



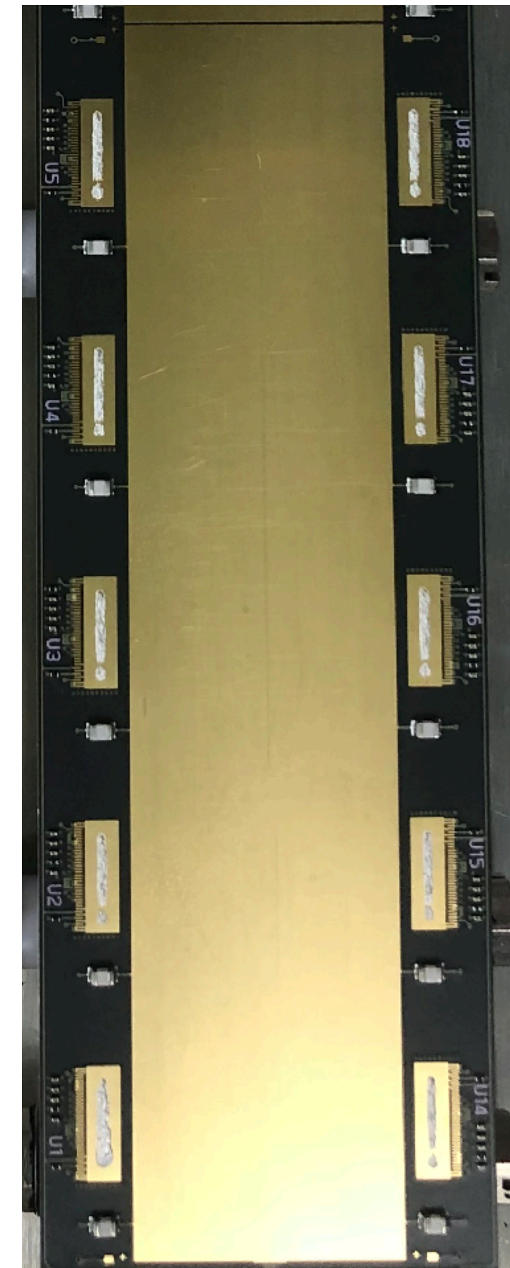
# Half-ladder assembly : Chip to HDI



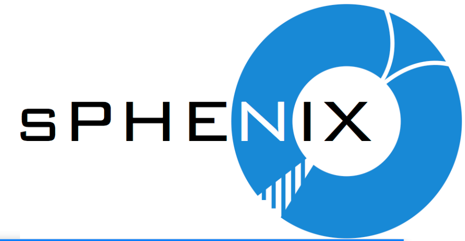

Glue dispensing by air pressure regulator

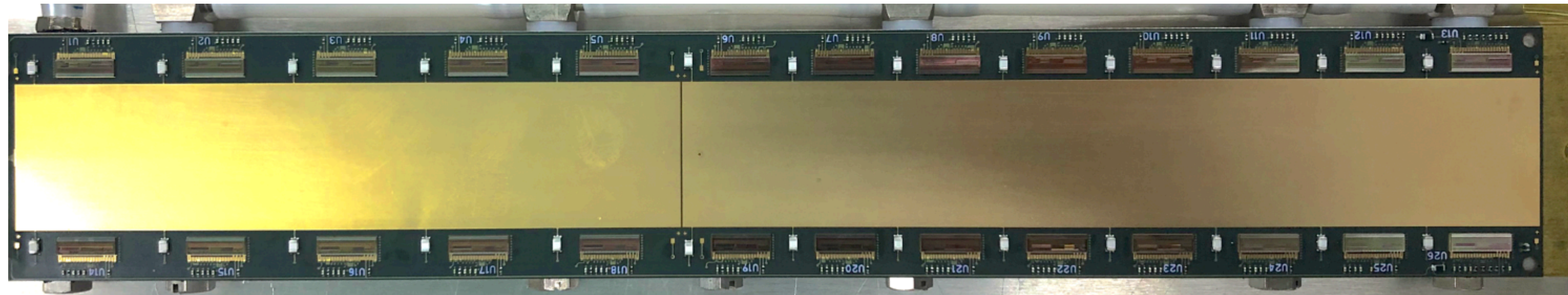


Chip glue pattern

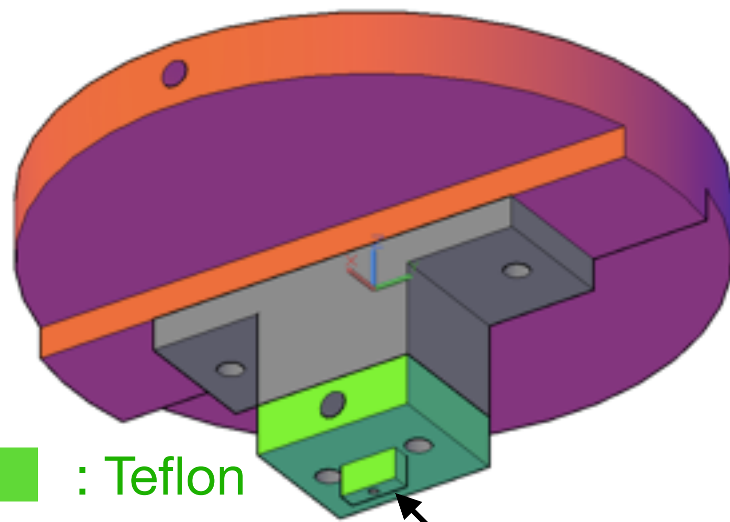


# Half-ladder assembly : Chip to HDI



Chip PUT



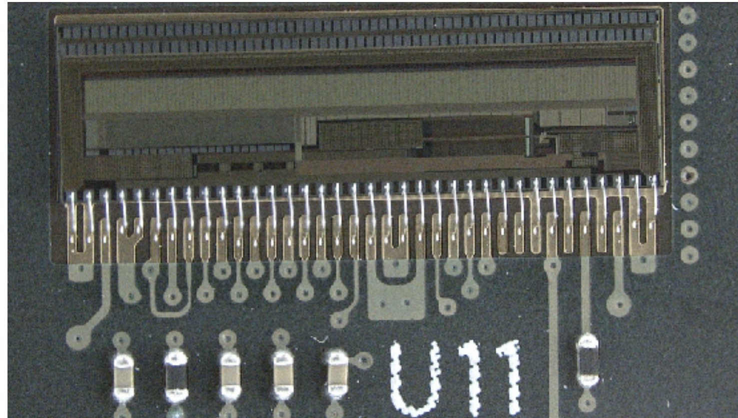
: Teflon

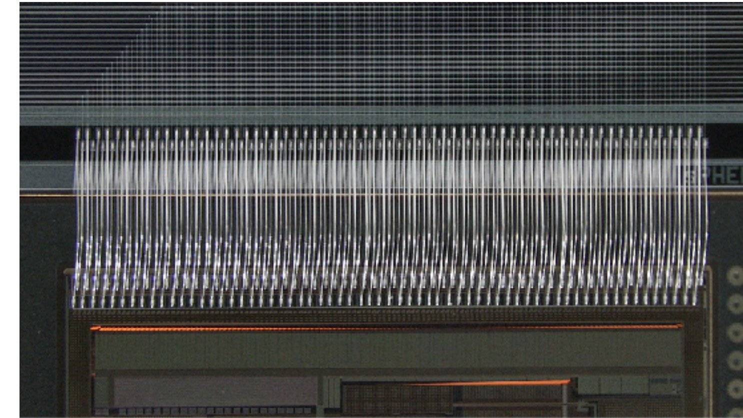
Chip contact surface

# Wire bond



Chip to HDI



Sensor to chip

Sensor to chip bonding

# Half-ladder assembly : Sensor to HDI

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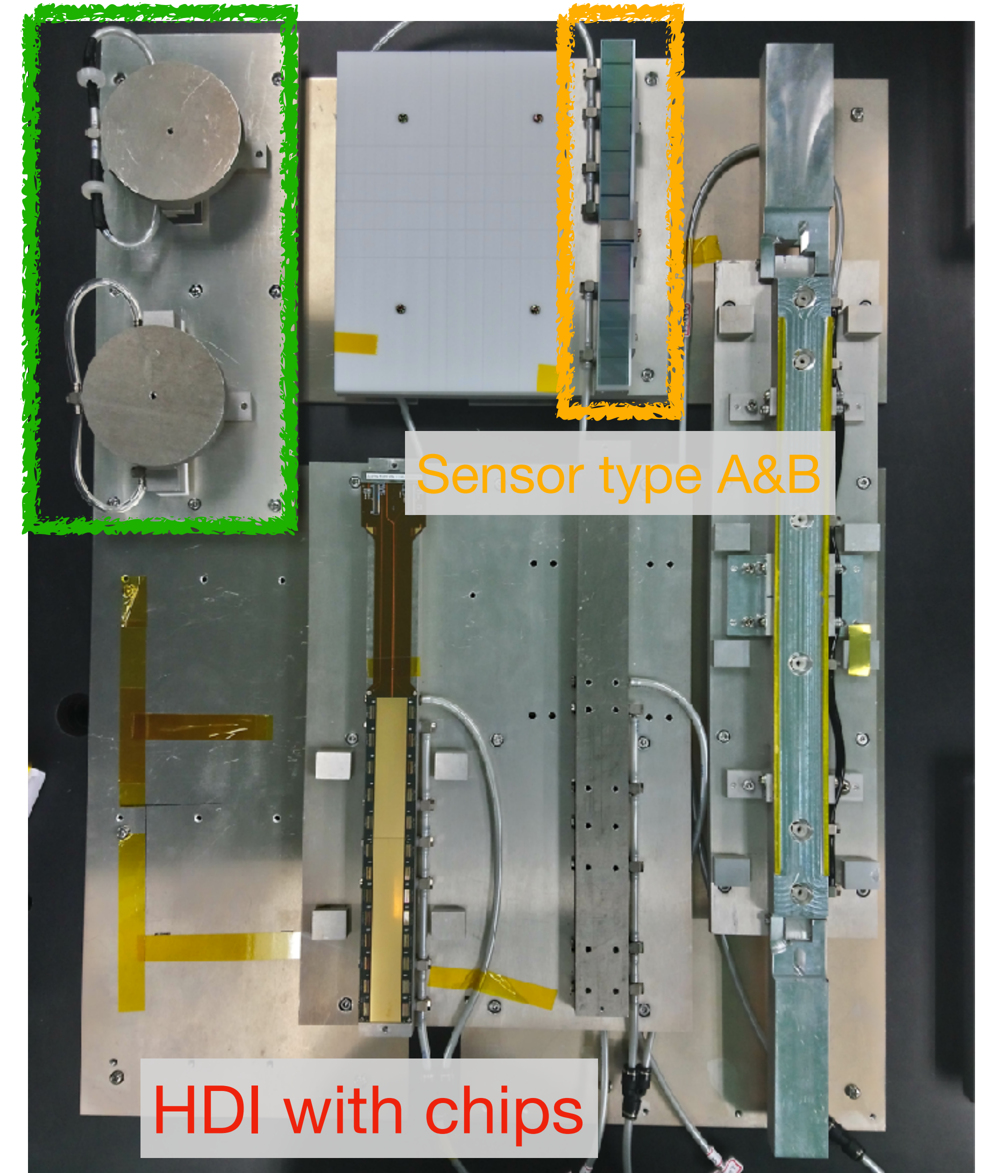
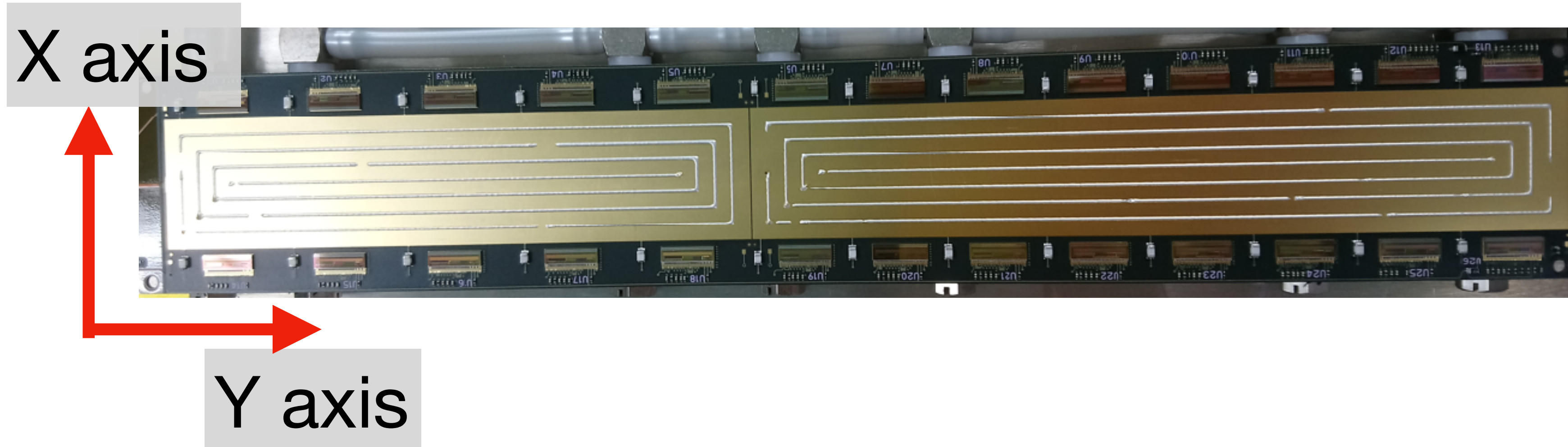
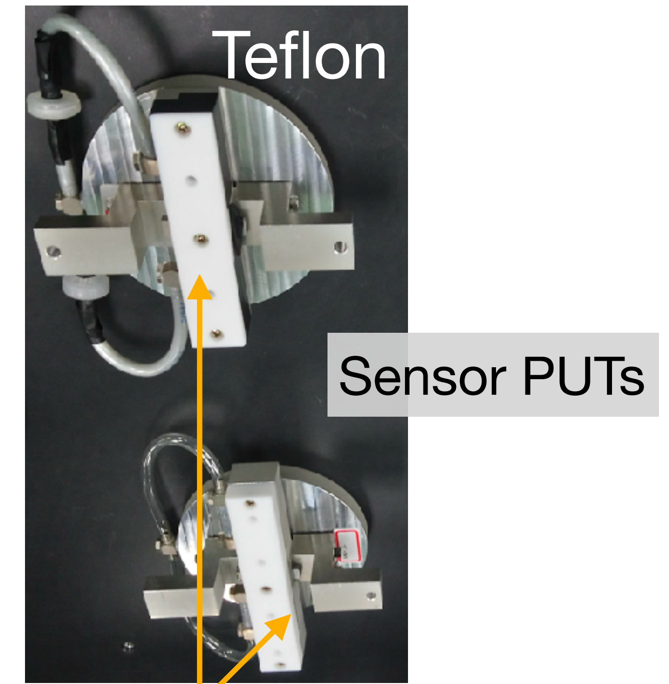
Assembly procedures :

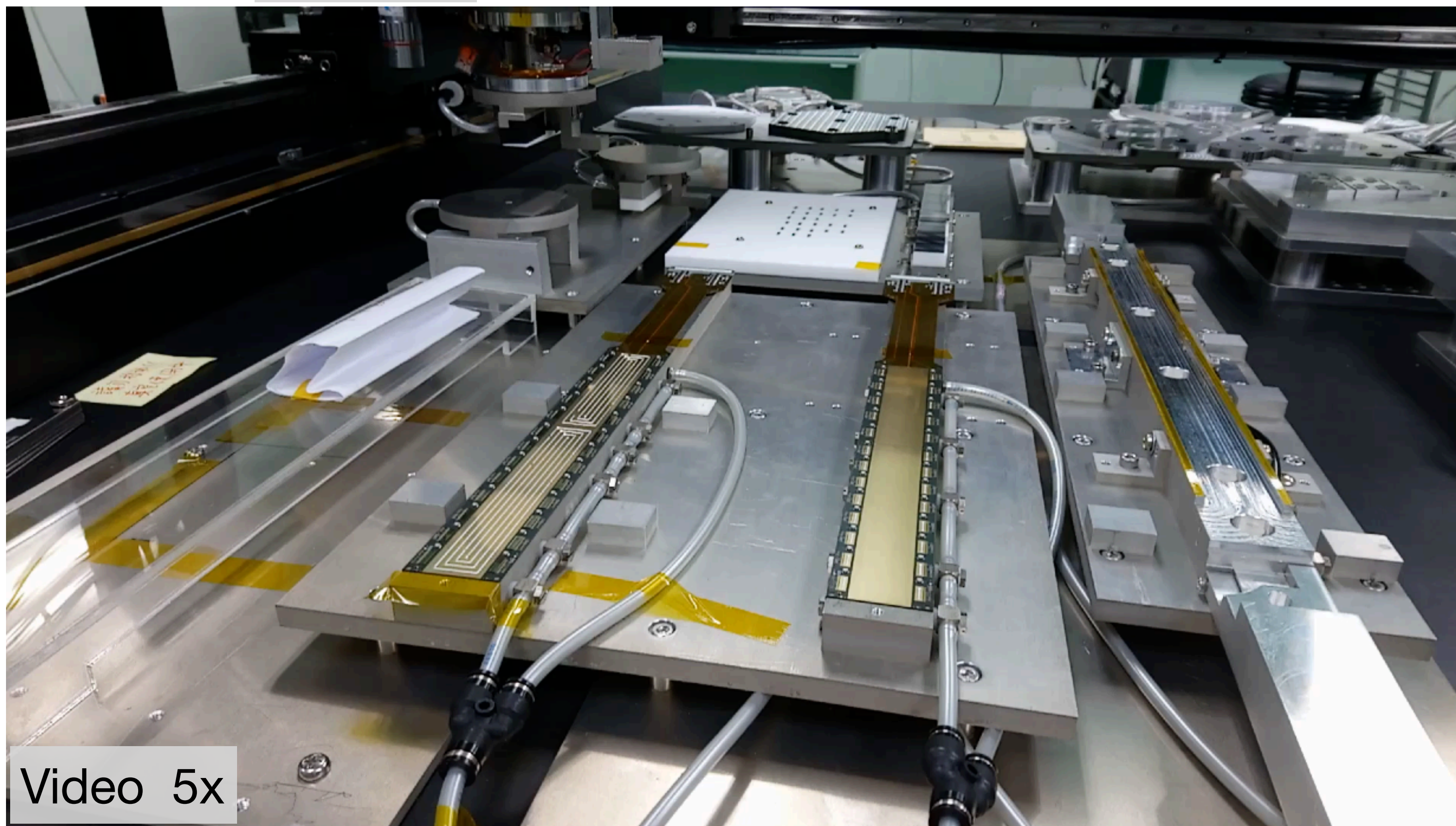
1. Place HDI, sensors and sensor PUTs on tray
2. Measure position & rotation of sensors and HDI
3. Glue deposit
4. Measure sensor PUTs
5. Sensors assembly with sensor PUTs



# Half-ladder assembly : Sensor to HDI




Average sensors placing error
(According to latest 4 half-ladders)

| | Type A | Type B |
|---|---|---|
| **X axis (um)** | -7.6925 | -3.2225 |
| **Y axis (um)** | 14.7925 | -8.715 |
| **Rotation (rad)** | -1.91E-04 | -7.91E-05 |

X axis ~-5.46 $\mu m$, Y axis : ~ -11.75 $\mu m$

# Encapsulation

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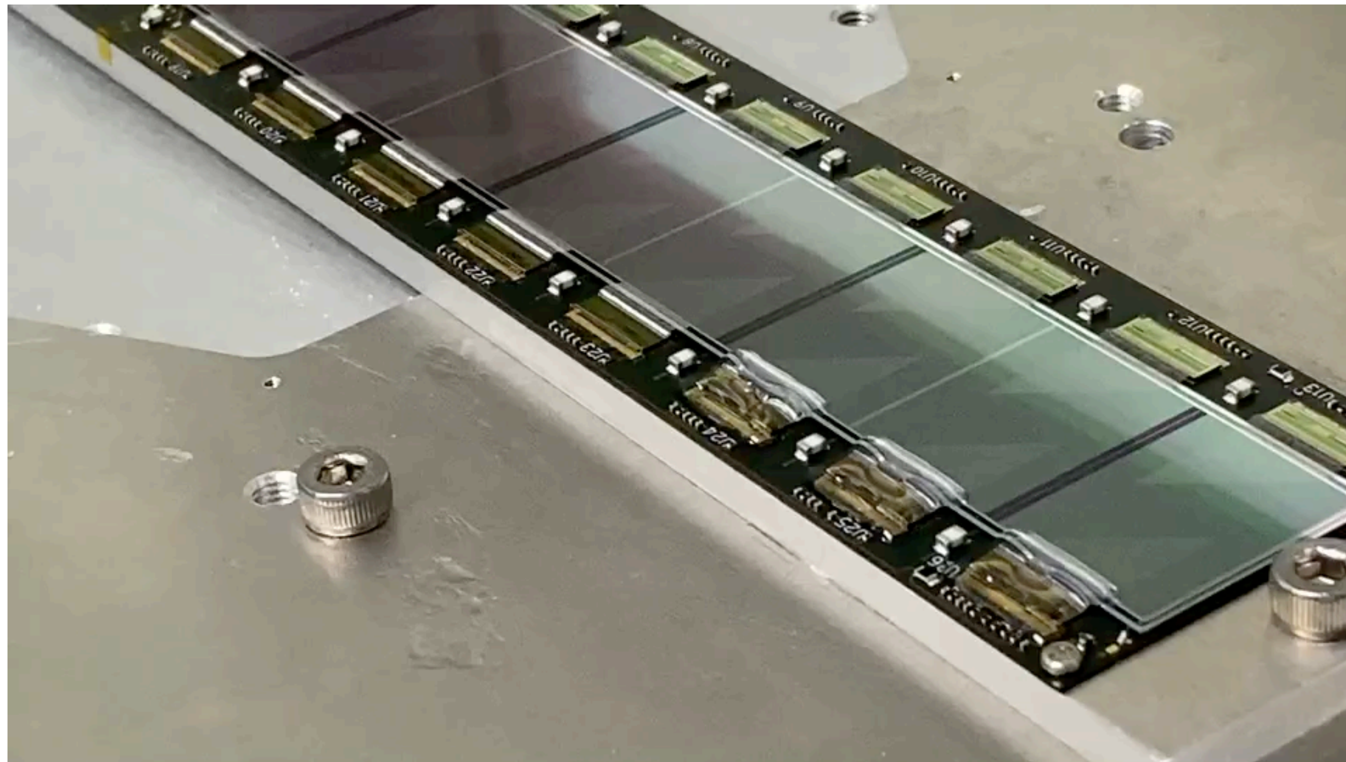
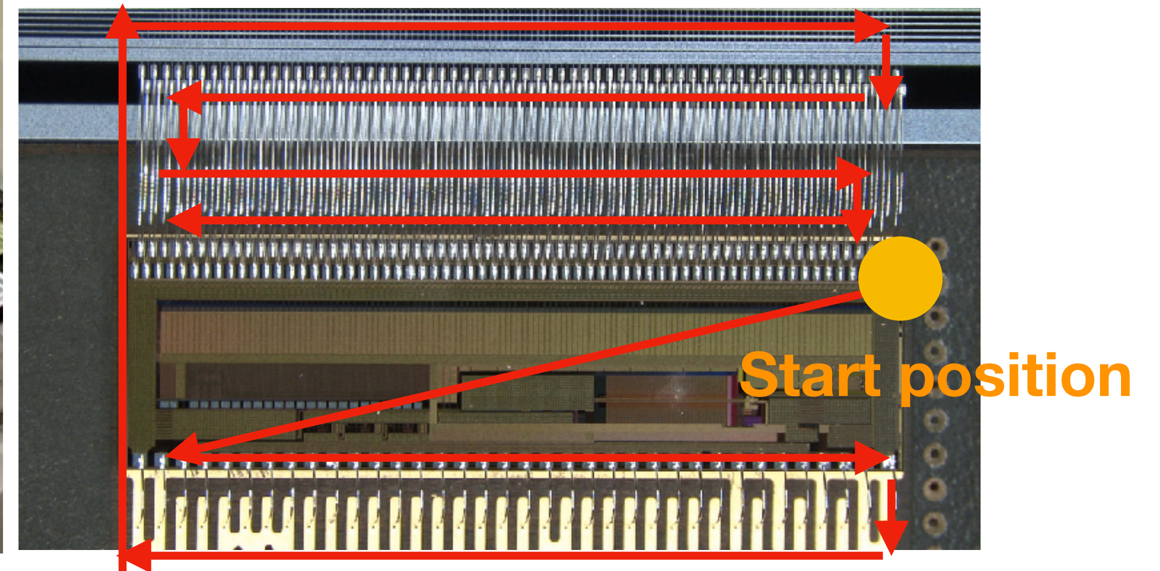
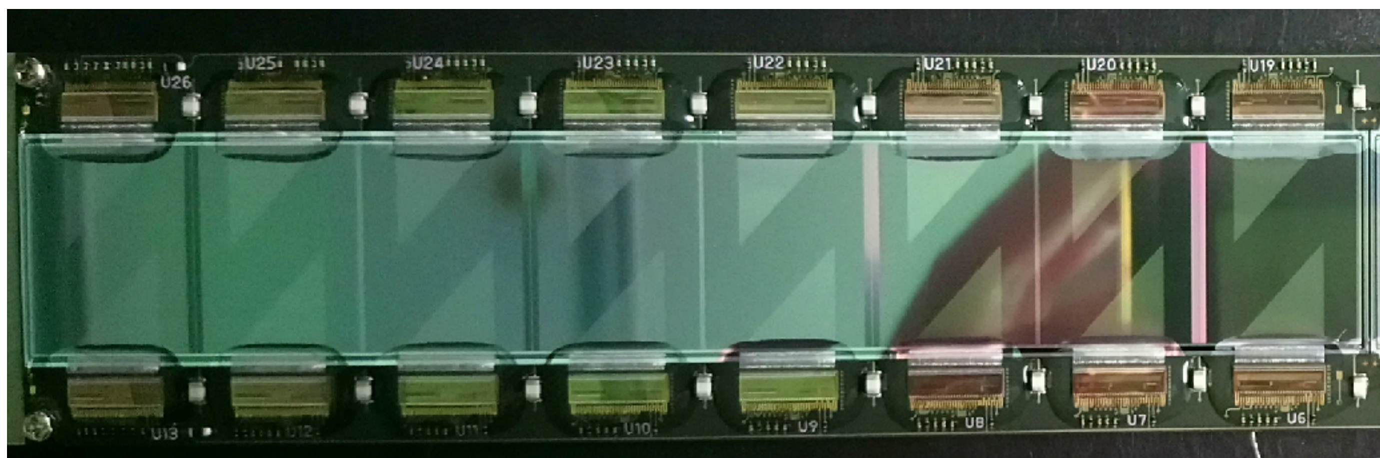


**Sylgard 186 is used**
**Needle size of syringe : 0.6 mm**
**Waiting time : 30 ~ 40 mins after mixing**



Thickness of encapsulation ~ 1.2 mm

# Thermal cycle

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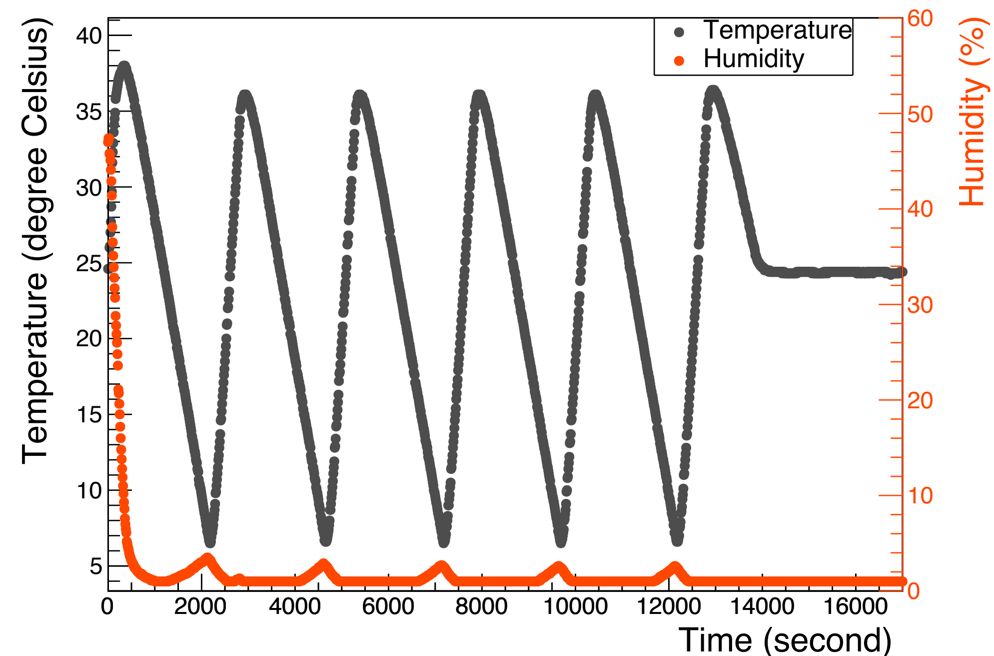
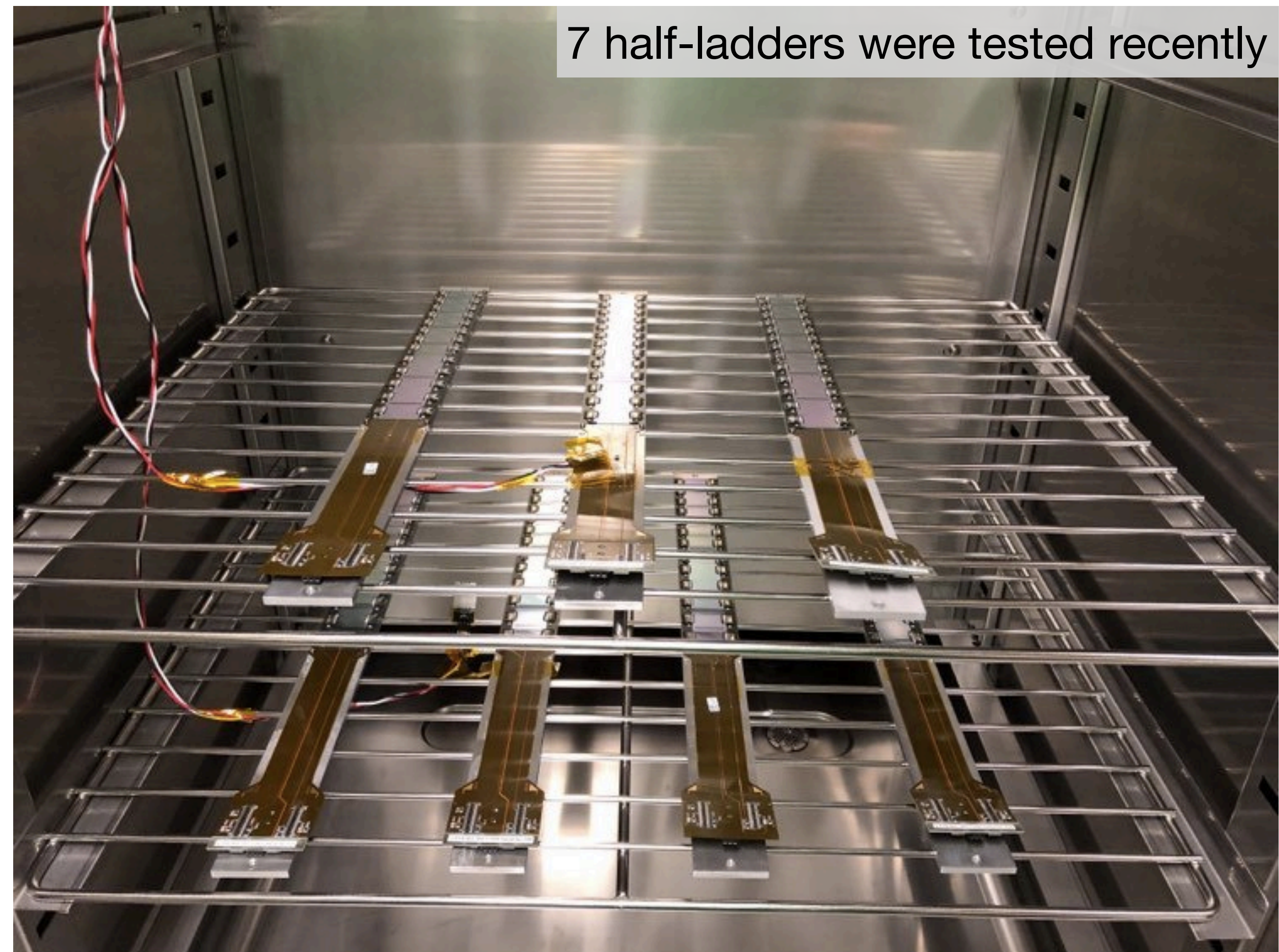
5 $^0C$ ~ 40 $^0C$, for 5 cycles

~ 4 hours operation




Half-ladders function well before and after thermal cycle

# Ladder assembly

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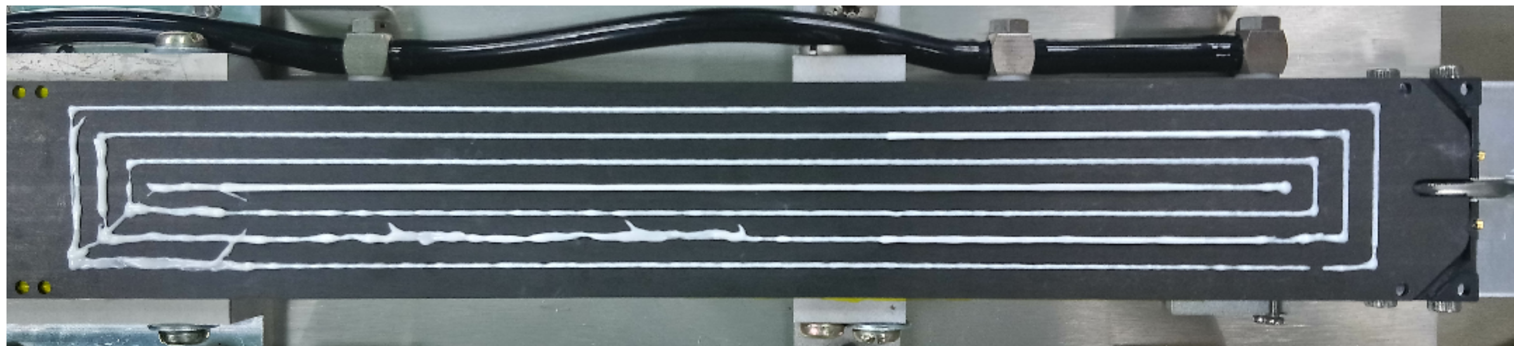
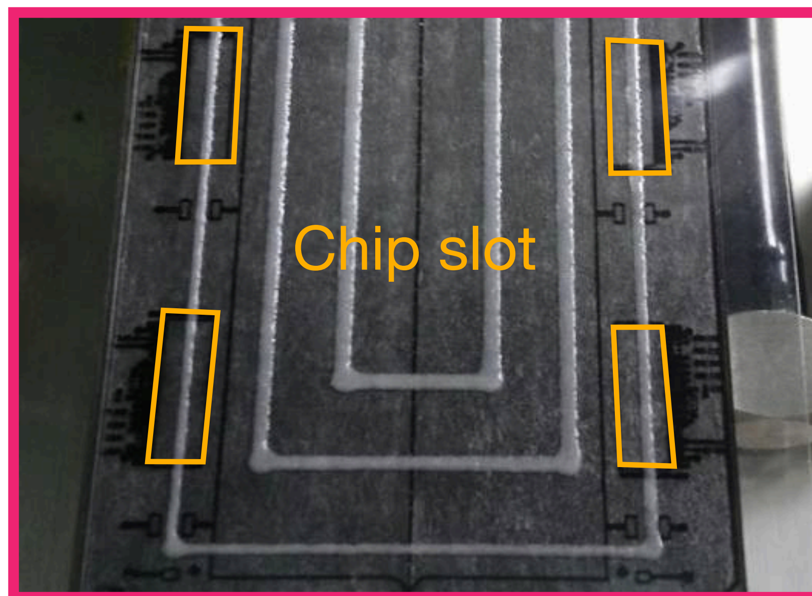
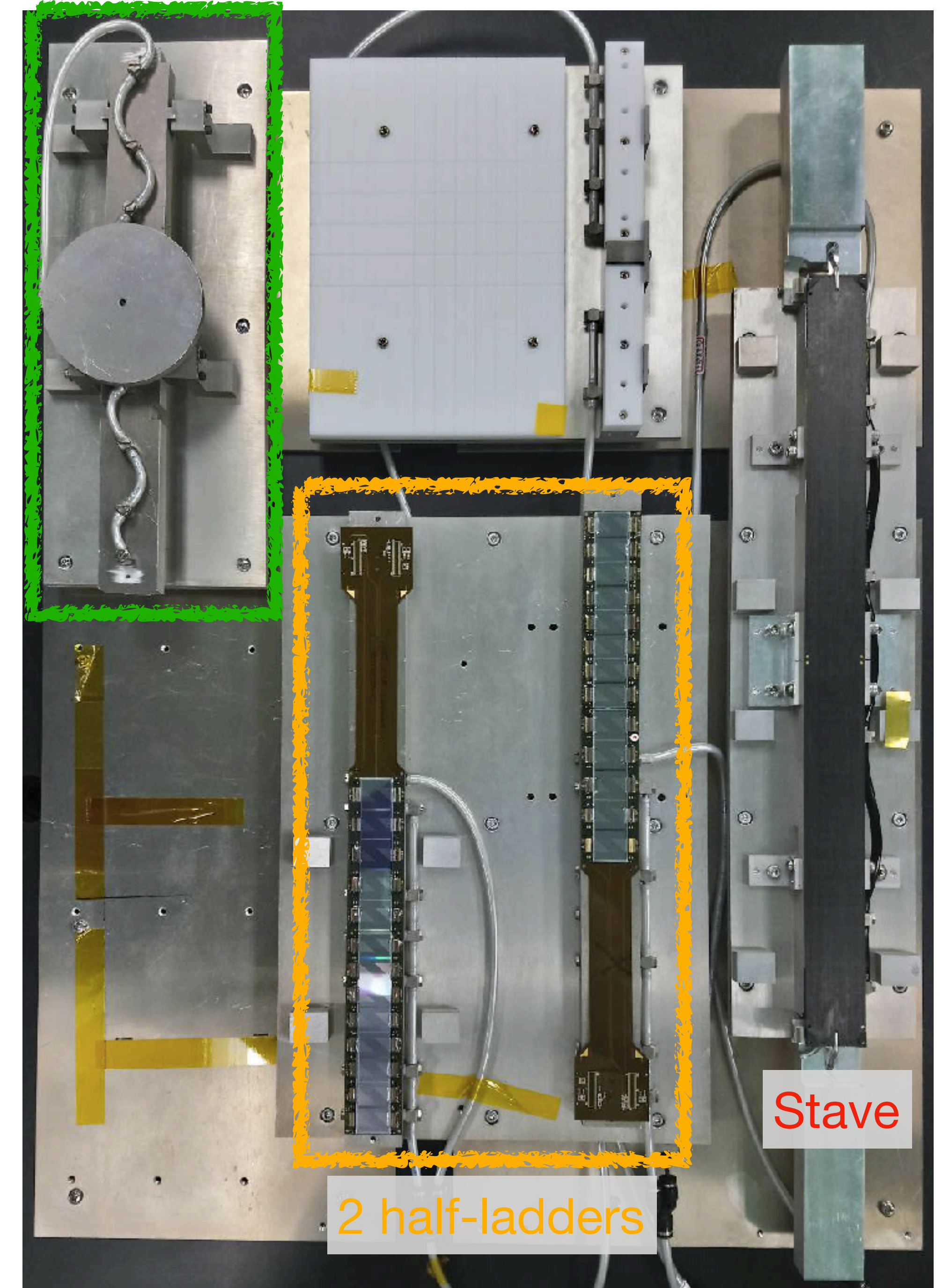
Assembly procedures :

1. Place stave, half-ladders and half-ladder PUT on tray
2. Measure position & rotation of half-ladders and stave
3. Glue deposit
4. Measure half-ladder PUT
5. Half-ladders assembly with half-ladder PUT

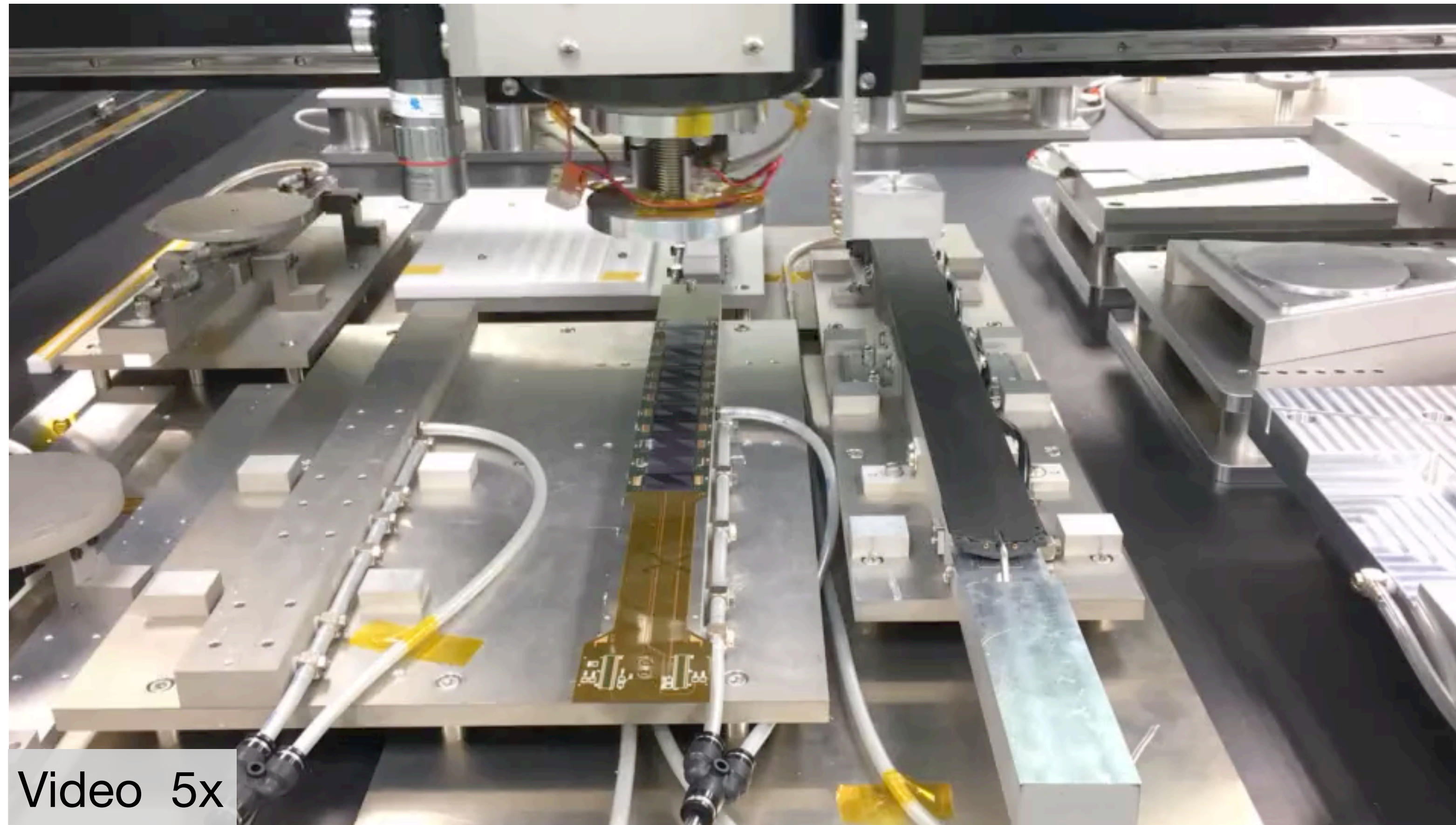




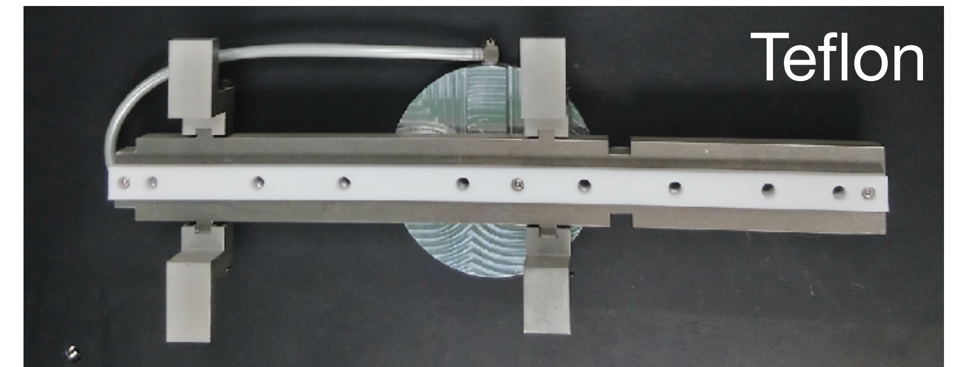

Two glue lines under chip



# Ladder assembly




Back side of half-ladder PUT




Half-ladder placing error on stave

| | |
|---|---|
| **X axis (um)** | < 5 |
| **Y axis (um)** | <10 |
| **Rotation (rad)** | < 1E-4 |

Assembly procedures : verified

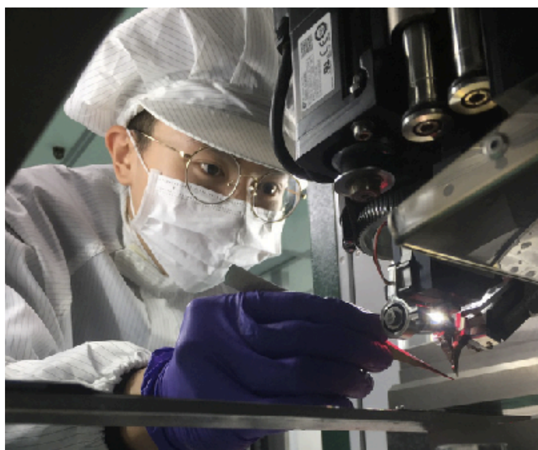
First dummy ladder assembly

# Summary



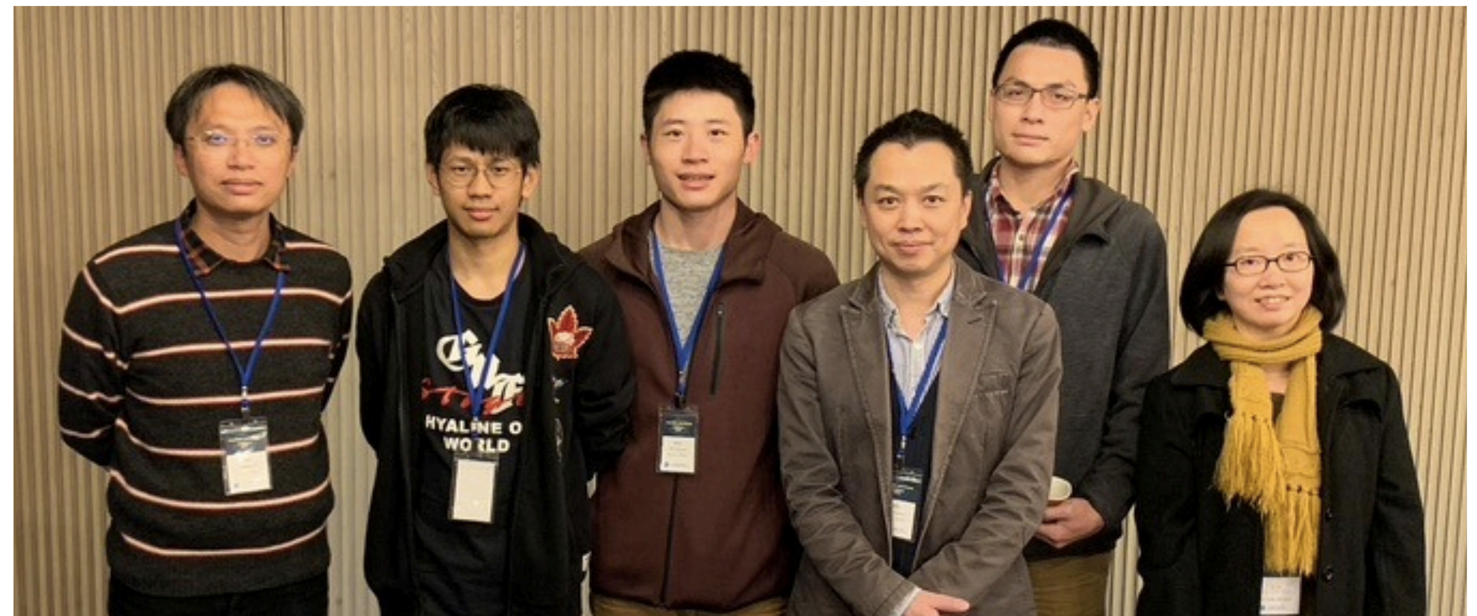
- Assembly fixtures on hand ✓
- Half-ladder assembly ✓
  - Chips and sensors mounted on HDI ✓
  - Wire bond ✓
  - Encapsulation ✓
  - Thermal cycle ✓
- Ladder assembly ✓
  - Half-ladder on stave assembly ✓

Ready for full scale production



Ou-Wei Cheng

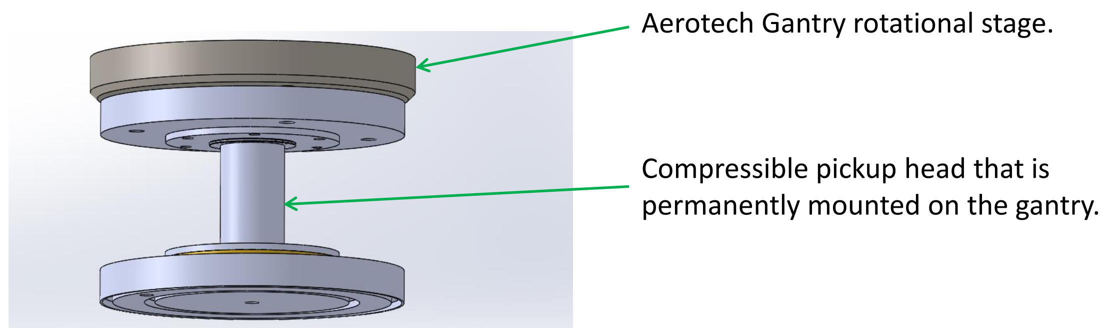
Kai-Yu Cheng



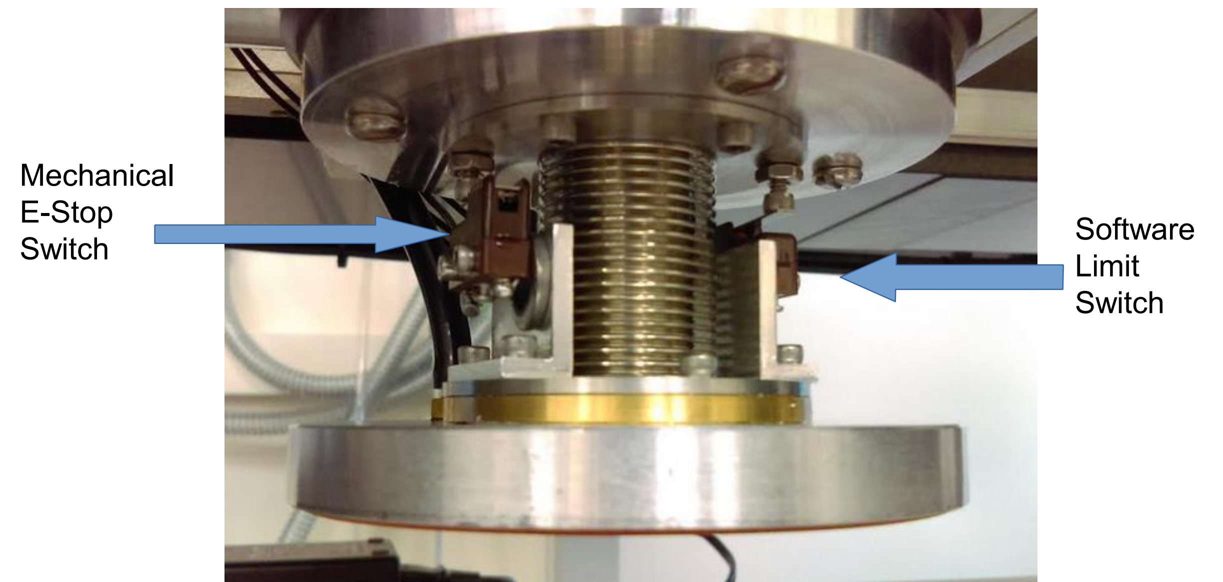
Chia-Ming Kuo Cheng-Wei Shih Lian-Sheng Tsai
Wei-Che Tang Rong-Shyang Lu Janny Huang

# Back up

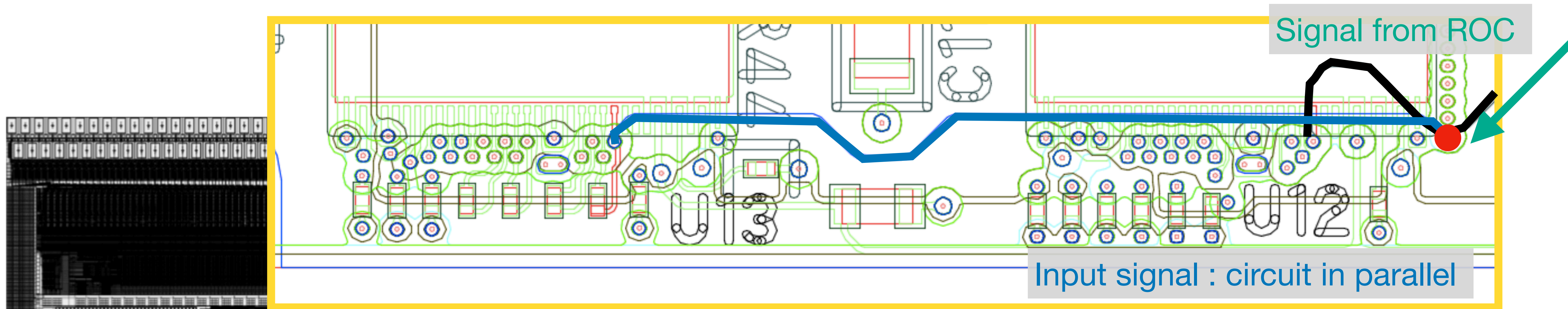
# Gantry Head (GH)



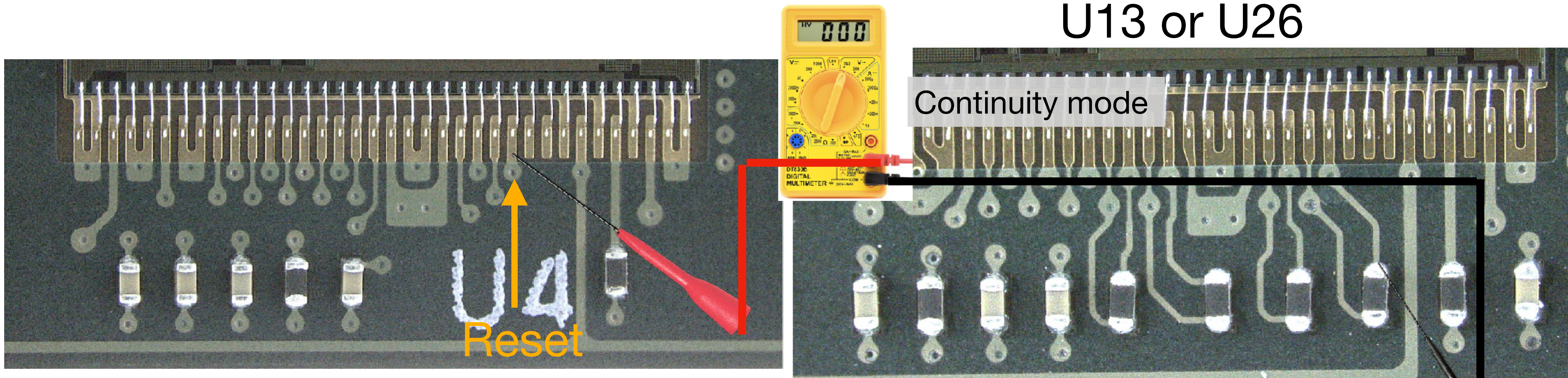

## Compression switches



# HDI pad continuity test




**The receiver pads are tested**



# HDI pad continuity test

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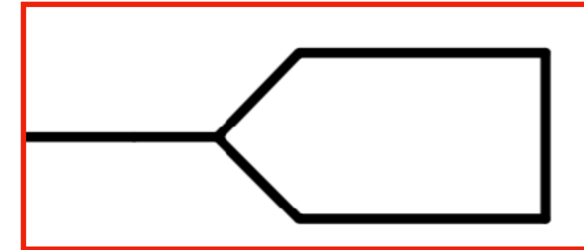
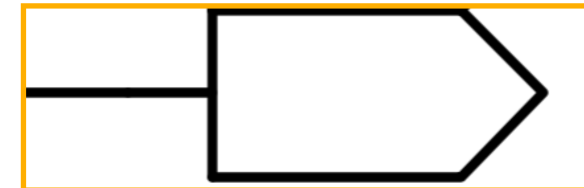
+2.5V-A
+2.5V-D
C64 0.1uF 6.3V
C67 0.1uF 6.3V
C66 0.1uF 6.3V
U17
Analog power
A_GND1 36
A_GND2 35
A_PWR1 34
SUBSTRATE1 33
ISET1 32
SUBSTRATE2 31
INJECT_IN_A 30
SUBSTRATE3 29
INJECT_IN_D 28 NC
HitOR 27 NC
RESET 26
RESETb 25
SLOW_CONTROL_IN 24
SLOW_CONTROL_INb 23
Digital power
D_PWR1 22
DGND1 21
DGND2 20
D_PWR2 19
BCOclk 18
BCOclkb 17
OUTclk 16
OUTclkb 15
SLOW_CONTROL_OUT 14
SLOW_CONTROL_OUTb 13
serialOut1 12
serialOut1b 11
serialOut2 10
serialOut2b 9
Chip ID
chipID4 8
chipID3 7
chipID2 6
chipID1 5
chipID0 4
Analog power
A_PWR2 3
A_GND3 2
A_GND4 1
37 VEE
FPHX_CHIP_2
AGND
DGND
CAL_INJECT2
RESET1
RESET1n
SC_IN1
SC_IN1n
BCO_CLK1
BCO_CLK1n
OUT_CLK1
OUT_CLK1n
SC_OUT1
SC_OUT1n
DATA_SIDE1_CHIP04_OUT0p
DATA_SIDE1_CHIP04_OUT0n
DATA_SIDE1_CHIP04_OUT1p
DATA_SIDE1_CHIP04_OUT1n
R46 40.2K
R222 0
R93 0
R385 0
C69 0.1uF 6.3V
Signal in
Signal out

Signal from ROC to HDI



Signal to ROC from HDI

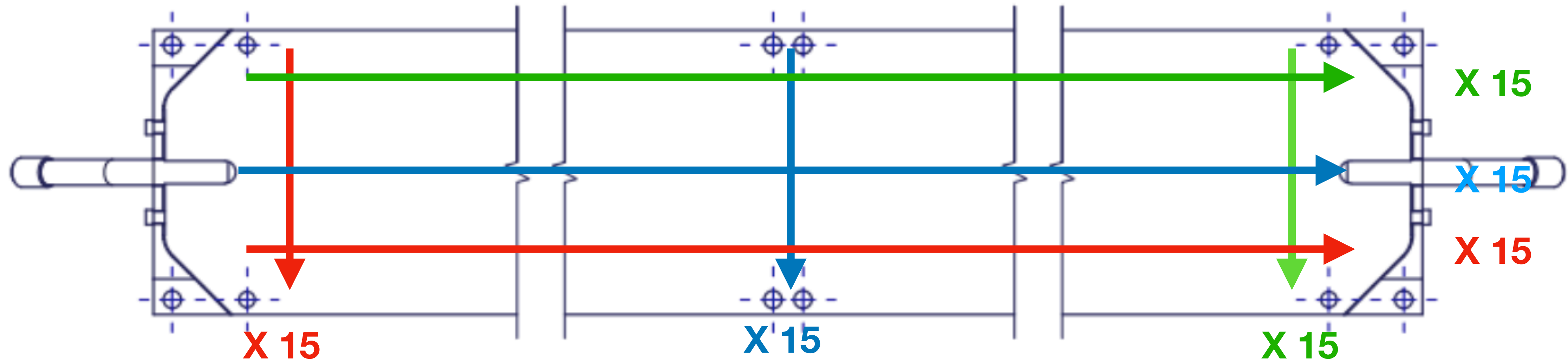


Check the continuity of circuit embedded in HDI

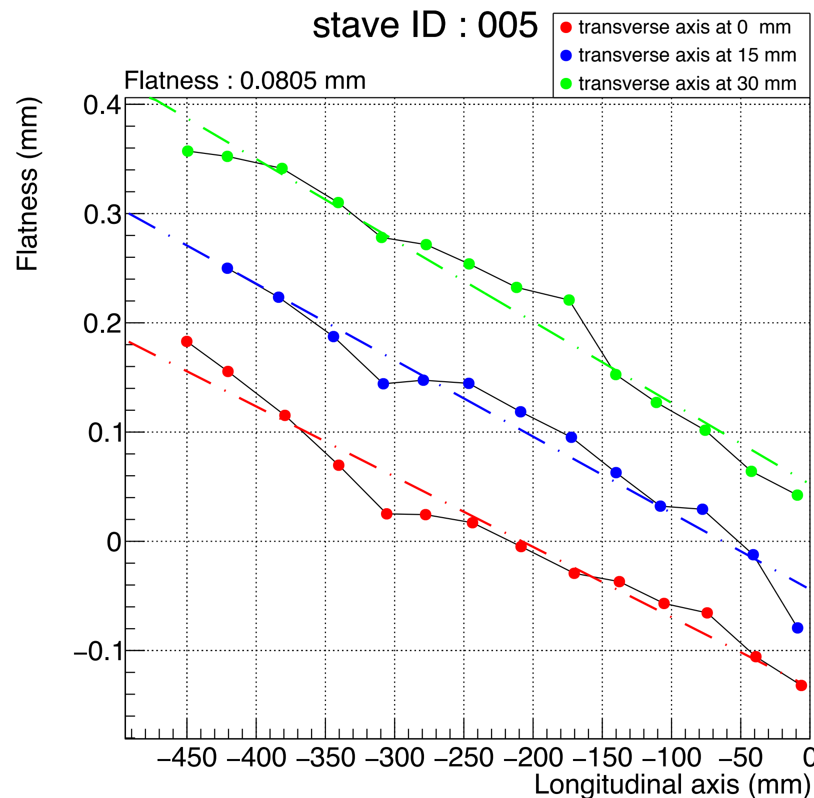
- Analog power
- Digital power
- Signal out
- 9 signal in
- Chip ID

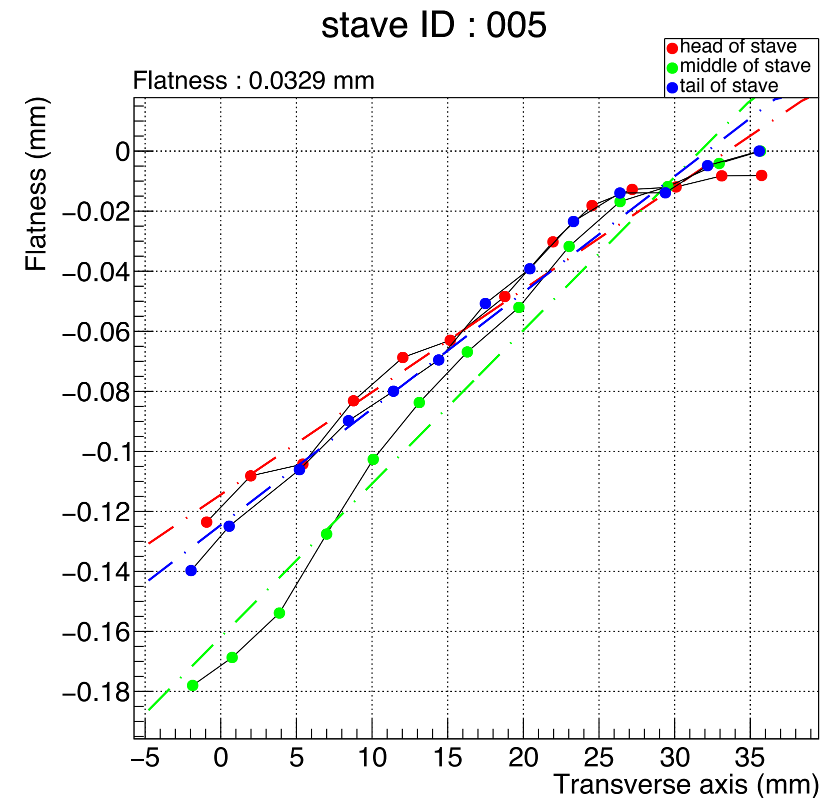
# Stave quality test : flatness measurement

## Measurements done by OGP




**Transverse / Longitudinal directions : 45 measurements data**



# Half-ladder transportation

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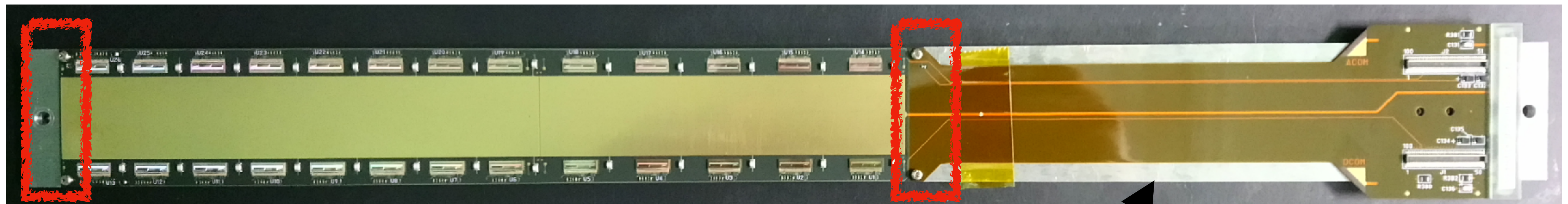
- Gantry table to bonding machine
- Gantry table to min gantry (encapsulation)



HDI is fixed on HDI handle by screws

HDI handle

Half-ladder transportation box : Gantry table to testbench

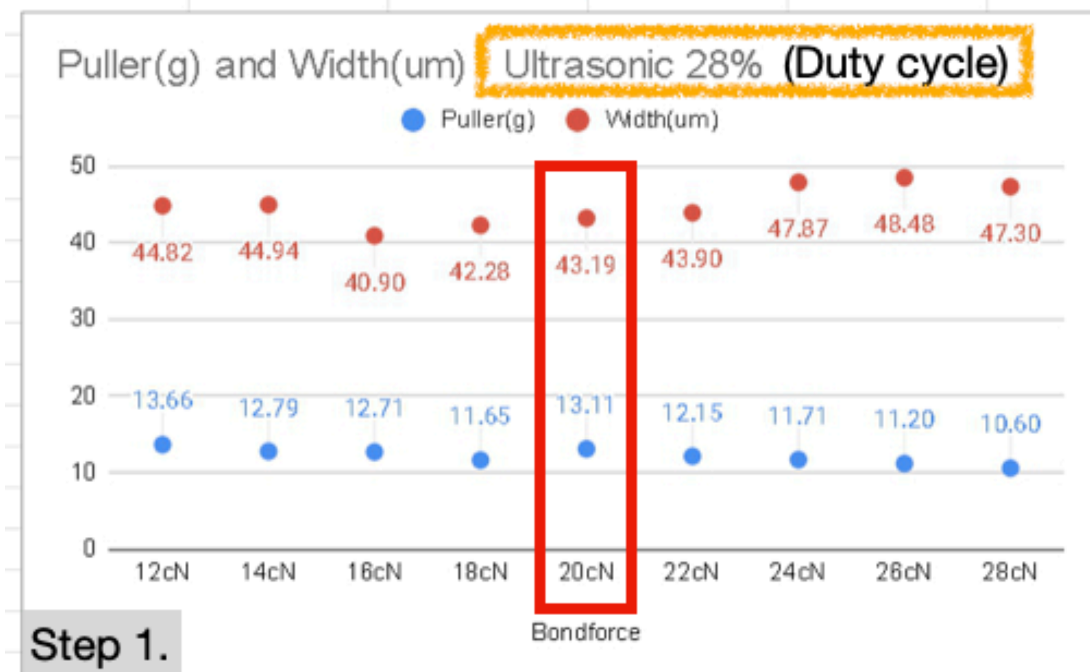
HDI handle

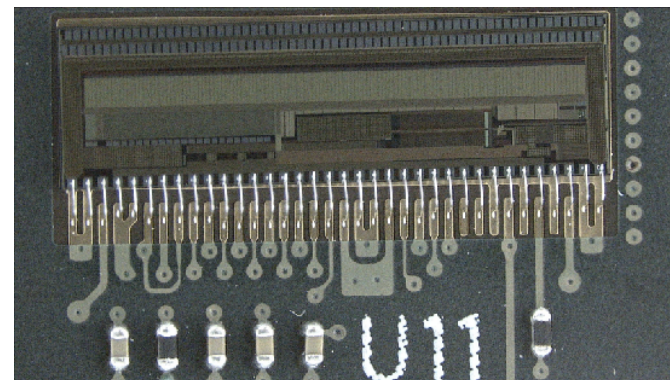
HDI handle is fixed in box by screws

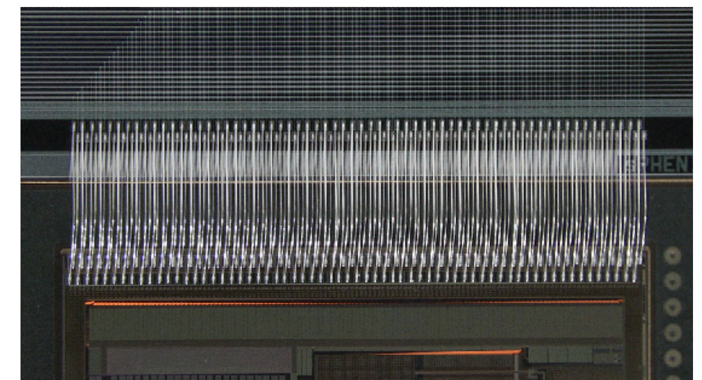
# Wire bond

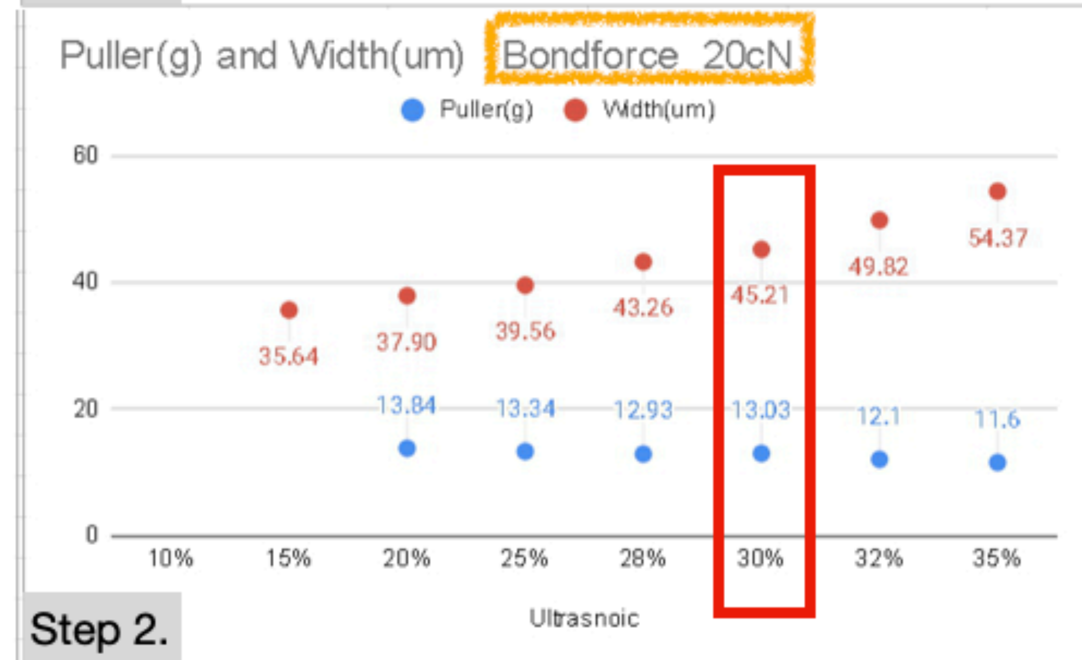


To find the best bond parameters
"Chip to HDI" bonding parameter scan






- Chip to sensor, un-bonded result
  - < 6 channels : 10 half-ladders
  - 33 channels : 1 half-ladder

Chip to HDI parameter

Old -> BF : 28cN, UI 28%
New -> BF : 20cN, UI 30%

# Bonding parameters test

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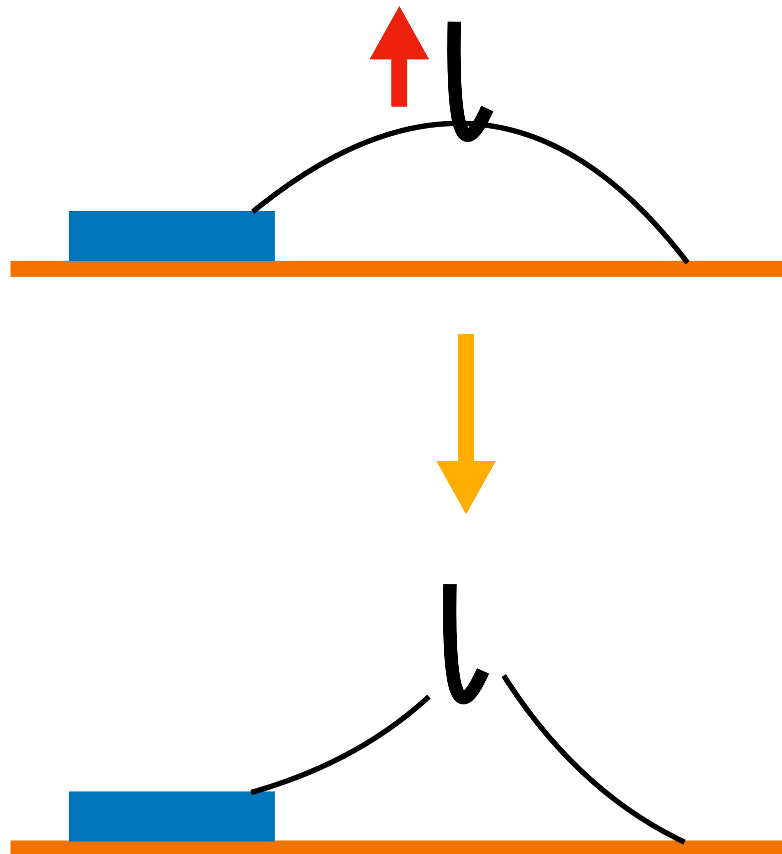


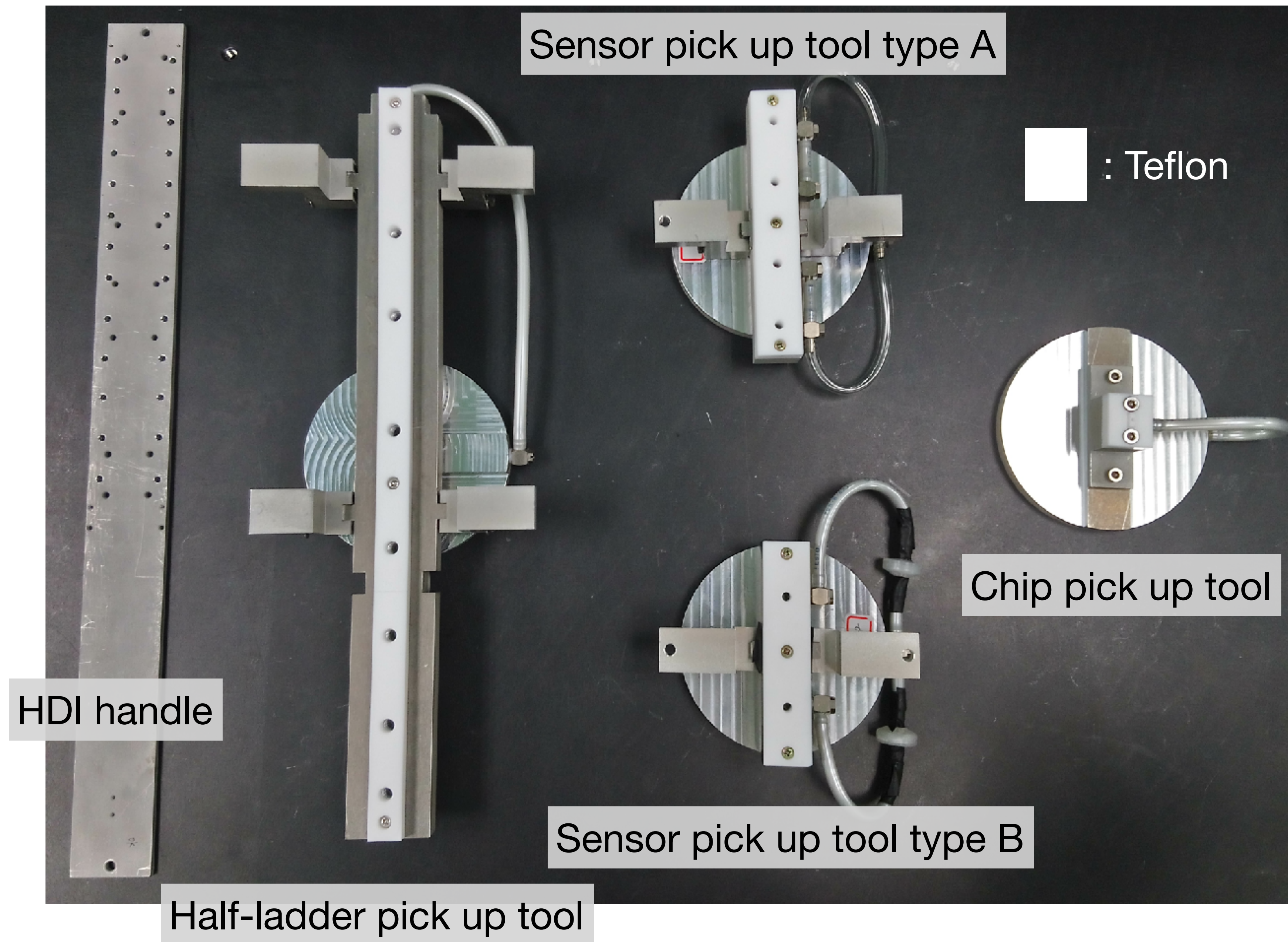

Bonding leg still connects to HDI

Leg width measurement

Leg width

# Assembly tools





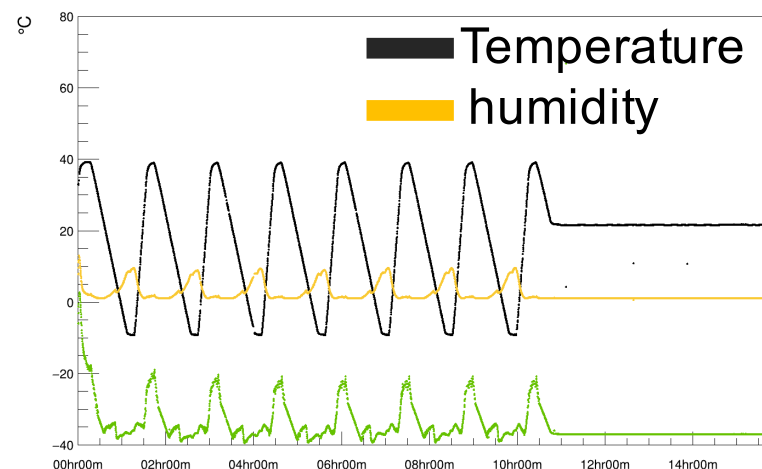
# Thermal cycle

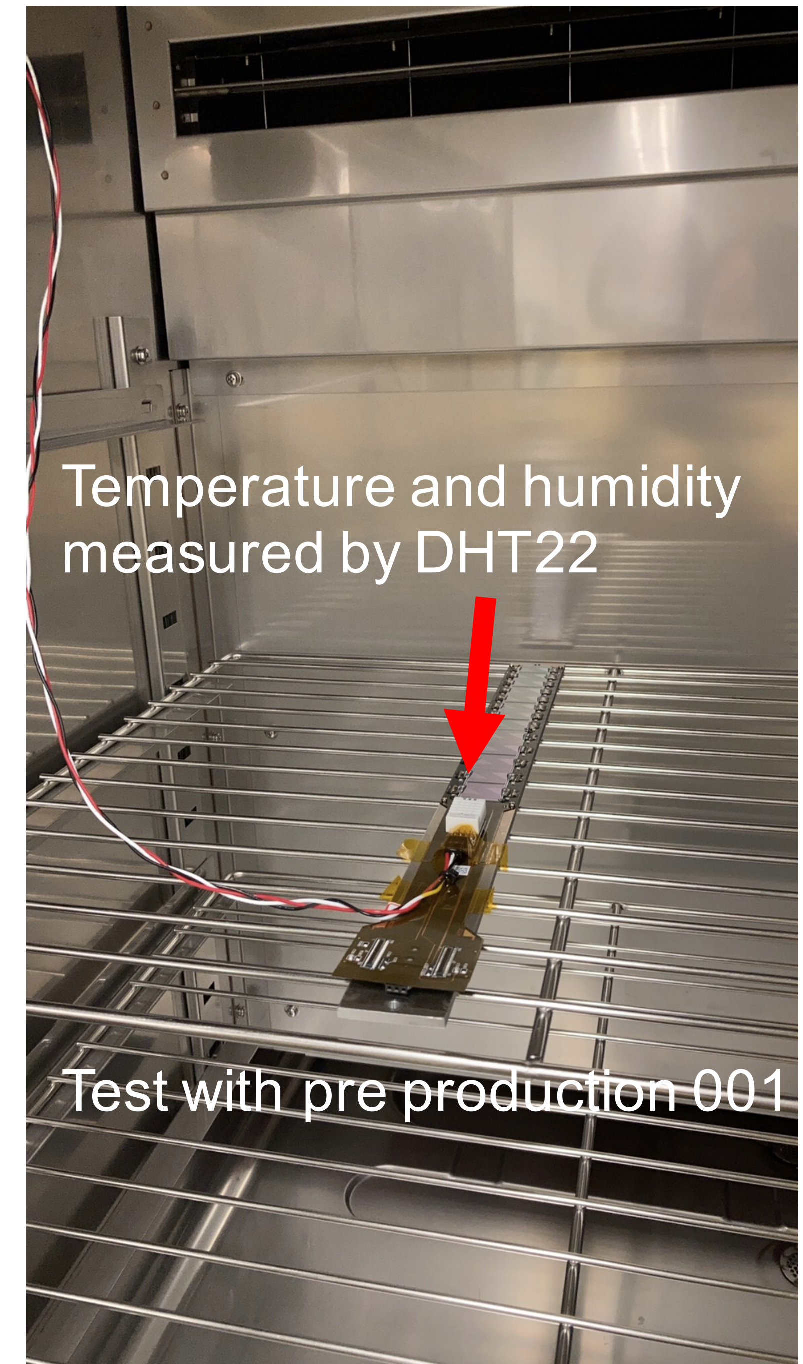
$$\text{AccelerationFactor} = \left(\frac{\Delta T_{test}}{\Delta T_{use}}\right)^{m}, \quad m = 3$$

$$\frac{\text{AF} * \text{cycles}}{\text{cycles/day}} = \text{Lifetime(day)}$$

- $\Delta T_{use}$ = 20°C, assuming detector runs on 5°C and warms up to 25°C
- $\Delta T_{test}$ = 50°C, thermal cycles between -10°C and 40°C
- AF = $(50/20)^3$ = 15.625
- Assuming one cycle for every 10 days, 3 year of lifetime test needs 3*365*0.1/15.625 = 7 cycles

Temperature : -10 $^0C$ ~ 40 $^0C$
Heating time : 17 mins
Cooling time : 50 mins
Repeat : 7 times



# Photo of assembled half-ladders

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# Ladder assembly : method to measure stave

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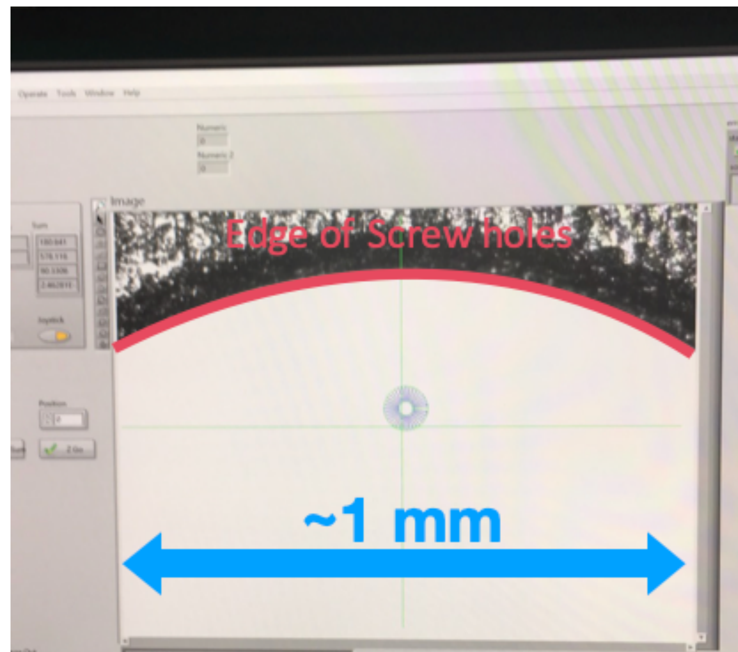
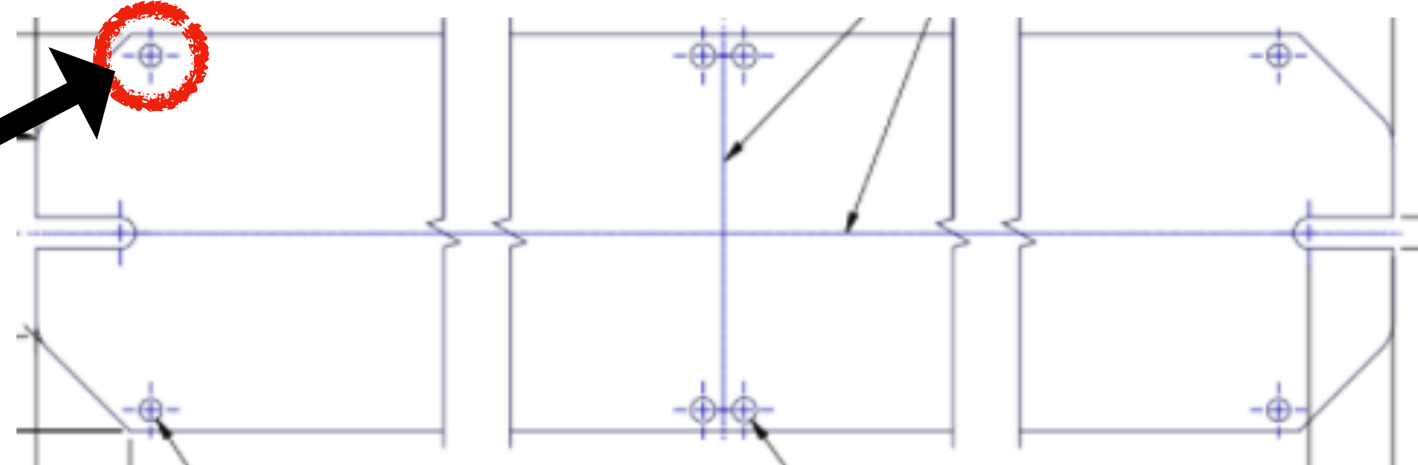
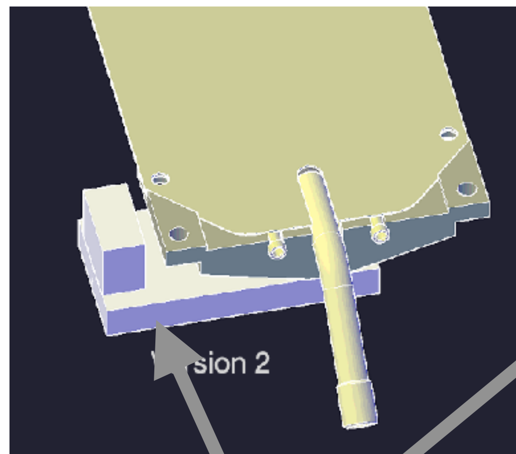
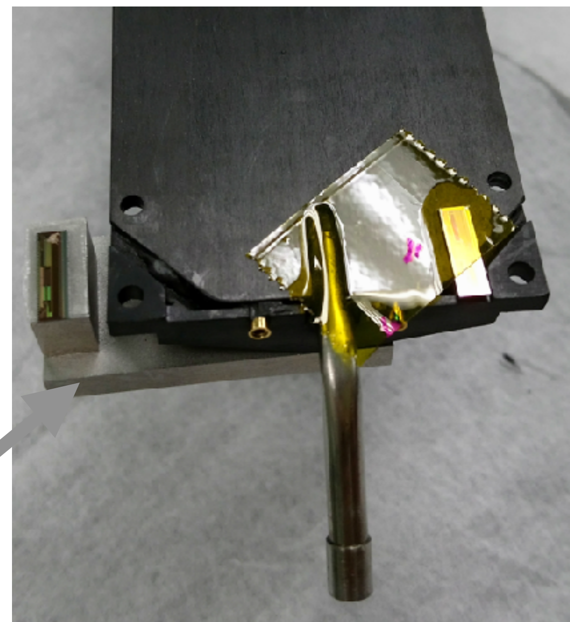



Holes on stave are too big for camera




solution

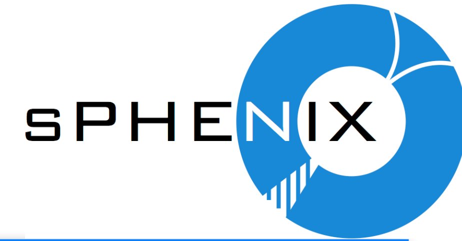



Stave chip holder, fix by screw on back side

1. Assemble "Stave chip holder" on each edge of stave
2. Measure cross marks of chips by OGP
3. Measure the holes of stave by OGP
4. Move stave back to gantry
5. Measure the cross marks of chips by gantry camera
6. By step 2, 3 and 5 -> obtain stave position

**Procedures 1&2 : obtain stave's relative position**

# Production tracking




<table>
<tr><th>Module ID</th><th>status</th><th>sensor ID</th><th>calibration test</th><th>HDI pads test (8 pads)</th><th>X error um (A/B)</th><th>Y error um (A/B)</th><th>rotate error rad (A/B)</th><th>bonding</th></tr>
<tr><td></td><td>0 : pad measurement<br>1 : chip to HDI<br>2 : sesnor to HDI<br>3 : post-encapsulation<br>4 : post - thermal cycle</td><td></td><td>NaN : not yet test<br>G : good<br>G*: good by different set up (in note)<br>B : bad</td><td>G : all good<br>serial out 1/1b 2/2b : not test</td><td>Placing error = HDI-sensor, unit : micrometer</td><td></td><td></td><td>All : All channels are bounded</td></tr>
<tr><td>Pre 001</td><td>4</td><td>S14629-01, 1131</td><td>G</td><td></td><td></td><td></td><td></td><td>39 channels unbounded</td></tr>
<tr><td>Pre 002</td><td>3</td><td>S14629-01, 1132</td><td>G</td><td></td><td></td><td></td><td></td><td>All</td></tr>
<tr><td>Pre 003</td><td>4</td><td>S14629-01, 1139</td><td>G</td><td></td><td>47.8/-41.66</td><td>18.60/15.33</td><td>5.13E-5/-3.21E-5</td><td>All</td></tr>
<tr><td>Pre 004</td><td>4</td><td>S14629-01, 1142</td><td>G*</td><td>G</td><td>-17.5/-12.04</td><td>-42.32/-37.76</td><td>-1.2e-4/6.7e-5</td><td>2 : number of unbounded channels<br>chip : channel<br>8 : 124<br>20 : 6</td></tr>
<tr><td>first batch</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Module 041</td><td>4</td><td>S14629-01, 1134</td><td>G</td><td></td><td>84.86/89.53</td><td>-11.40/-27.38</td><td>4.19E-4/2.91E-4</td><td>All</td></tr>
<tr><td>Module 042</td><td>4</td><td>S14629-01, 1135</td><td>G</td><td></td><td>44.17/12.76</td><td>-0.72/-9.63</td><td>8.9E-5/2.16E-4</td><td>All</td></tr>
<tr><td>Module 044</td><td>4</td><td>S14629-01, 1136</td><td>G</td><td></td><td>77.91/32.73</td><td>-21.87/-11.73</td><td>6.77E-4/8.6E-4</td><td>All</td></tr>
<tr><td>Module 071</td><td>4</td><td>S14629-01, 1137</td><td>G</td><td>G</td><td>5.35/-7.83</td><td>-21.56/-39.9</td><td>-6.43e-5/3.09e-4</td><td>All</td></tr>
<tr><td>Module 073</td><td>3</td><td>S14629-01, 1141</td><td>G*</td><td>G</td><td>8.66/-2.4</td><td>19.2/-9.68</td><td>-7.82E-5/2.5E-5</td><td>5 unbound channels<br>4:90, 7:3, 8:100, 18:33, 22:79</td></tr>
<tr><td>Module 074</td><td>2</td><td>S14629-01, 1148</td><td>G*</td><td>G</td><td>-3.04/-2.34</td><td>17.18/-2.01</td><td>1.68E-4/-1.17E-4</td><td>33 unbond channels :<br>7 : 116,| 8 : 24,| 8 : 26|, 10 : 6|. 12 : 122<br>17 : 106|, 17 : 108|, 17 : 110|, 18 : 113<br>19 : 18, |19 : 24, |19 : 26, |19 : 28<br>19 : 106,| 19 : 108,| 19 : 126,| 20 : 10<br>20 : 19,| 20 : 104,| 20 : 108,| 21 : 104<br>21 : 106,| 21 : 108,| 21 : 110|, 22 : 16<br>24 : 18, |24 : 20,| 24 : 22,| 25 : 16<br>25 : 22, |25 : 23|, 25 : 24, |26 : 14</td></tr>
<tr><td>Module 076</td><td>2</td><td>S14629-01, 1138</td><td>NaN</td><td>G</td><td>7.35/1.1</td><td>12.62/13.41</td><td>-1.6E-4/-5.73E-5</td><td></td></tr>
<tr><td>Module 077</td><td>2</td><td>S14629-01, 1147</td><td>NaN</td><td>G</td><td>-11.72/-7.05</td><td>10.17/9.76</td><td>-3.58E-4/-1.17E-4</td><td></td></tr>
<tr><td>Module 078</td><td>2</td><td>S14629-01, 1146</td><td>NaN</td><td>G</td><td>12.151/6.872</td><td>-9.175/-0.578</td><td>-2.80E-4/-1.52E-4</td><td></td></tr>
<tr><td>Module 079</td><td>1</td><td></td><td>G</td><td>G</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Module 024</td><td>1</td><td></td><td>G</td><td>G</td><td></td><td></td><td></td><td></td></tr>
</table>

# Half-ladder storage in Taiwan

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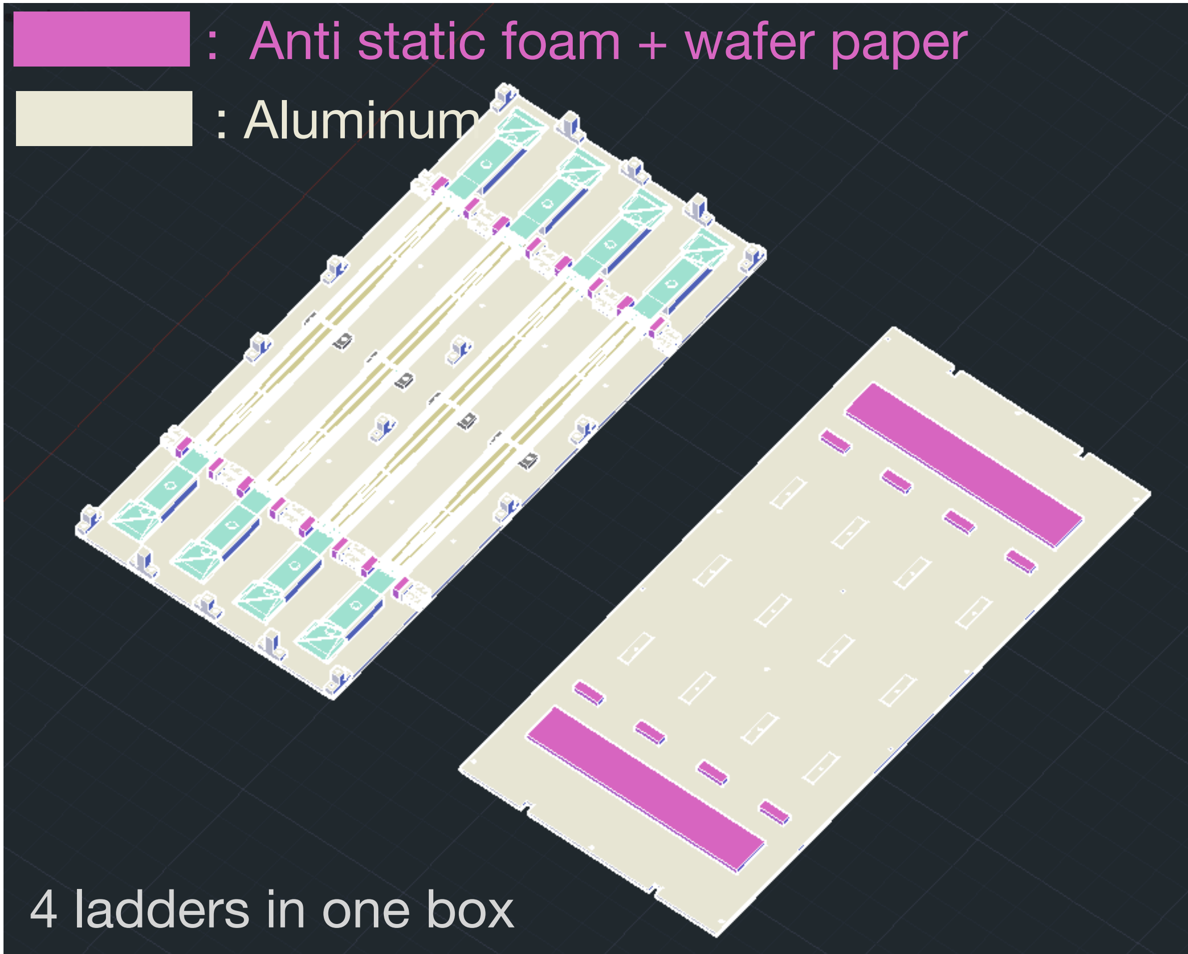
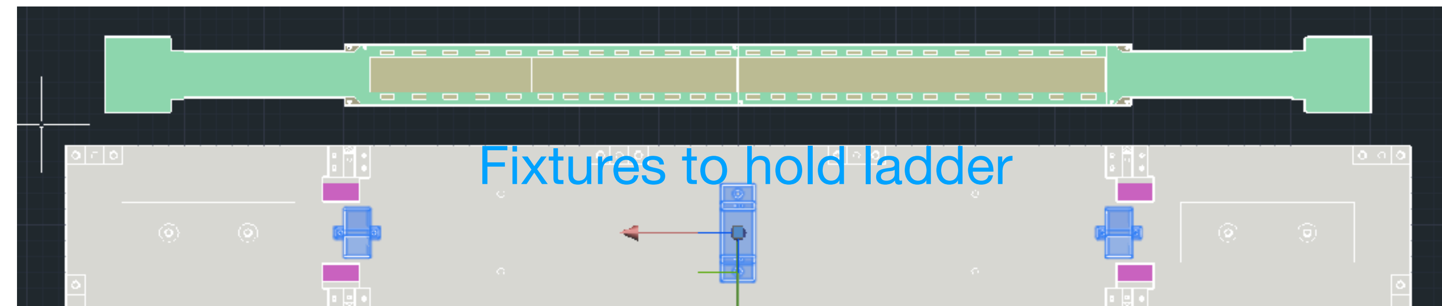
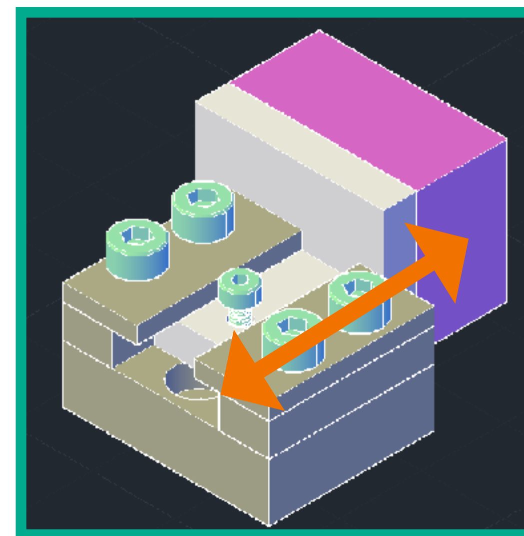
Half-ladders are stored in clean room

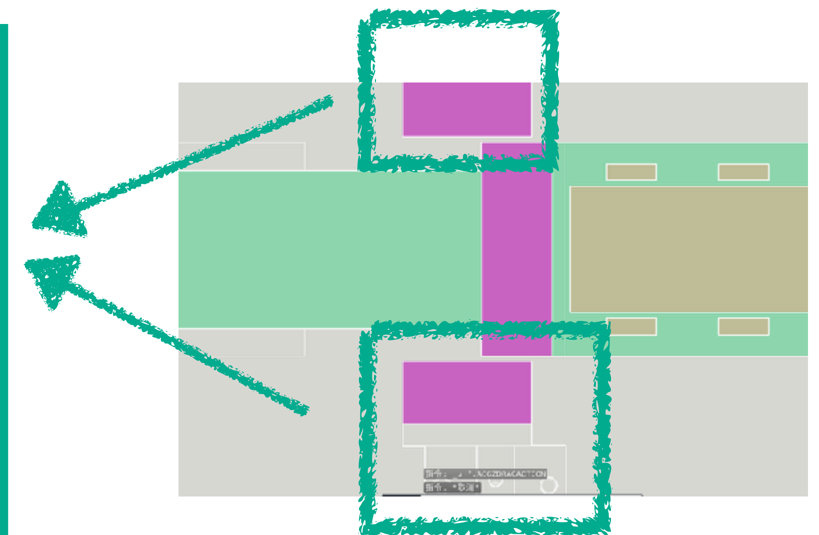
# Ladder transportation & storage

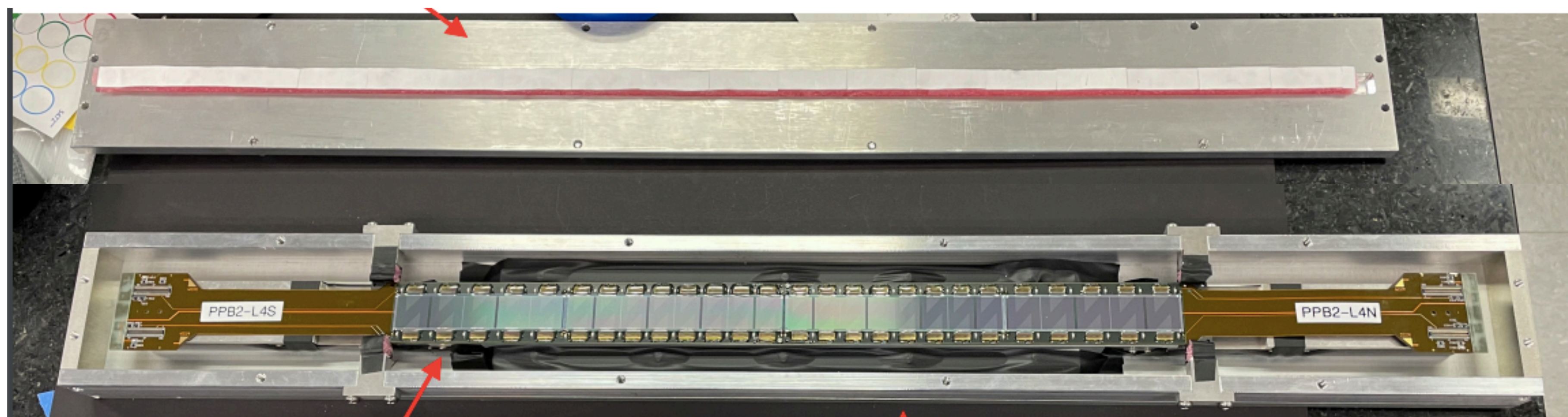



The box is capable for ladder transportation and storage








Prototype box is produced, shipping 1 ladder from BNL to NWU

# INTermediate Tracker (INTT)

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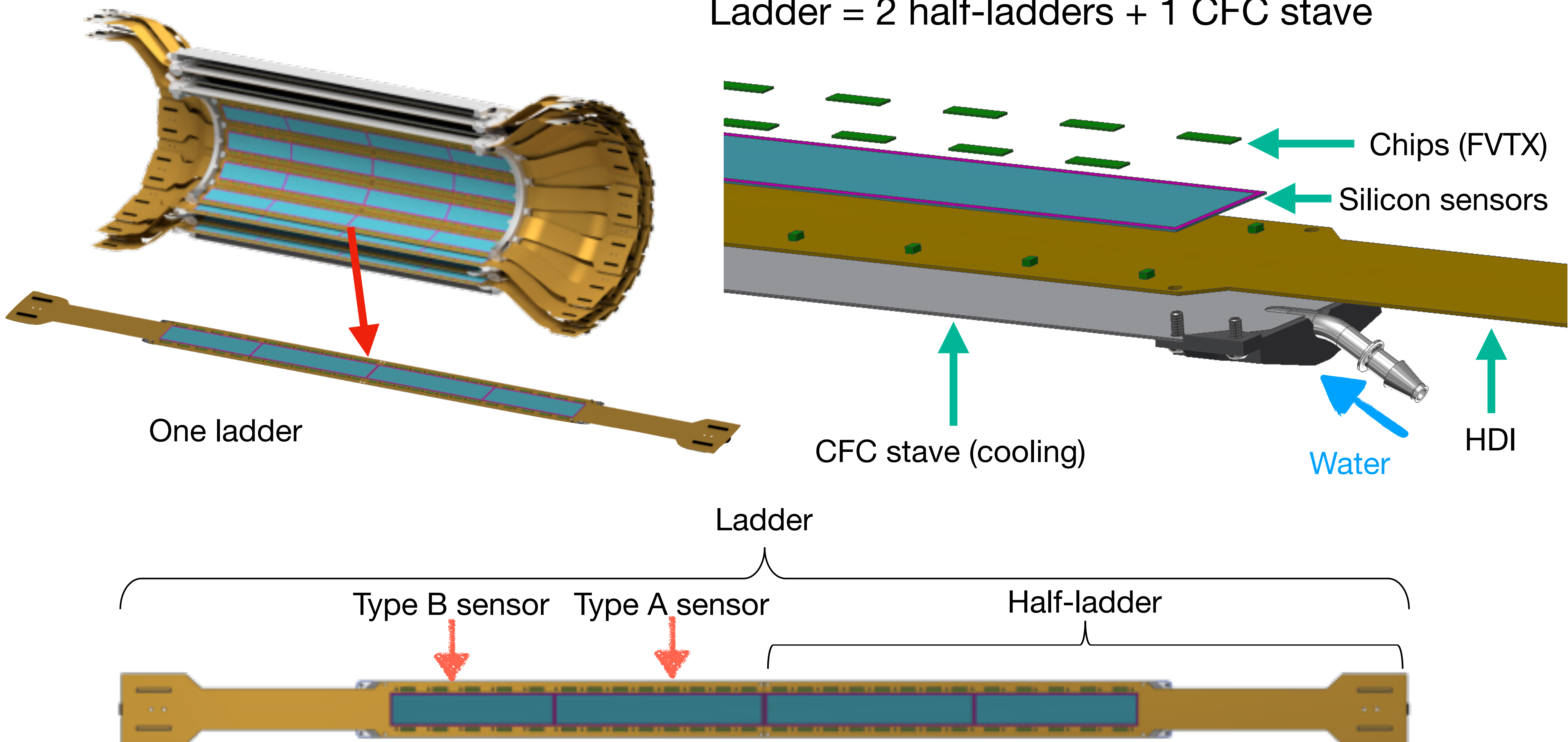
2 layers of silicon strip detector

Half-ladder = 1 HDI + 26 chips + 2 silicon sensors
Ladder = 2 half-ladders + 1 CFC stave




INTT : 56 ladders + 64 spares = 120 ladders -> 40 ladders in Taiwan