# Ladder Assembly at NCU/NTU

WBS : 3.01

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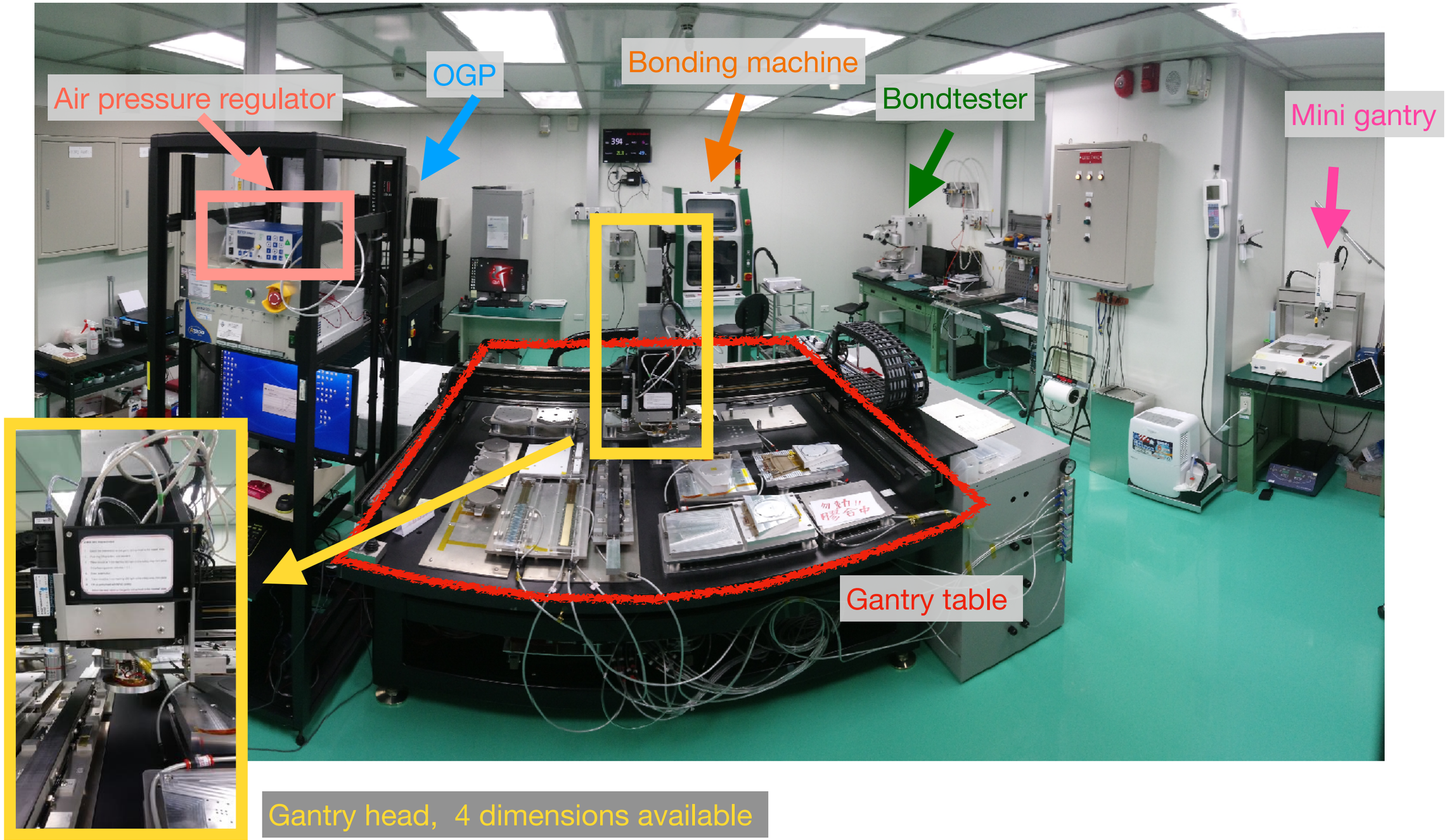
# Content

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

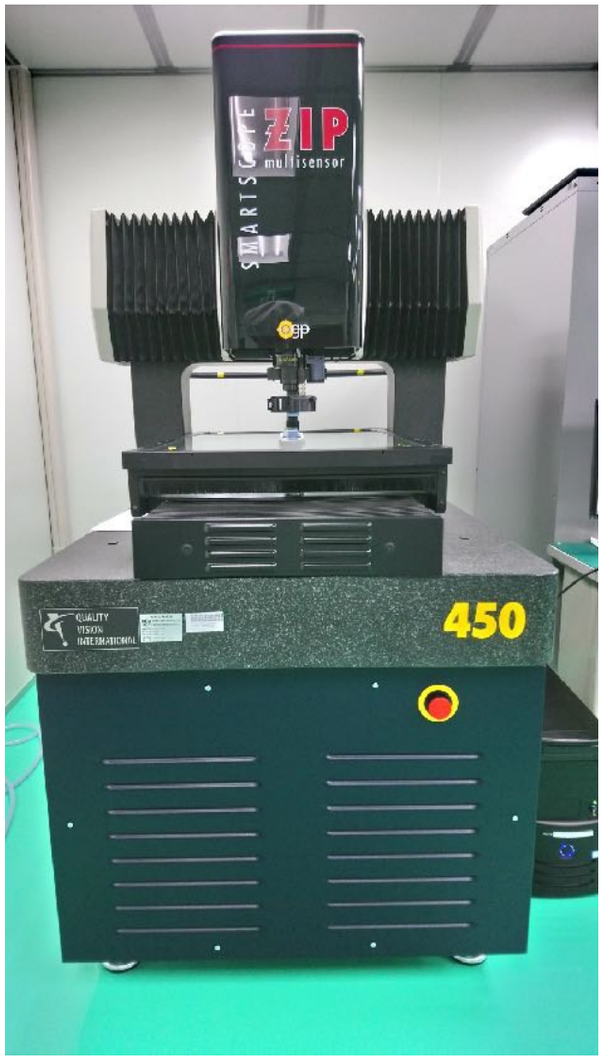
# Taiwan Silicon Detector Facility (TSiDF)



# Taiwan Silicon Detector Facility (TSiDF)

Bonding machine
Wire bond

Bondtester
Bonding wire quality test



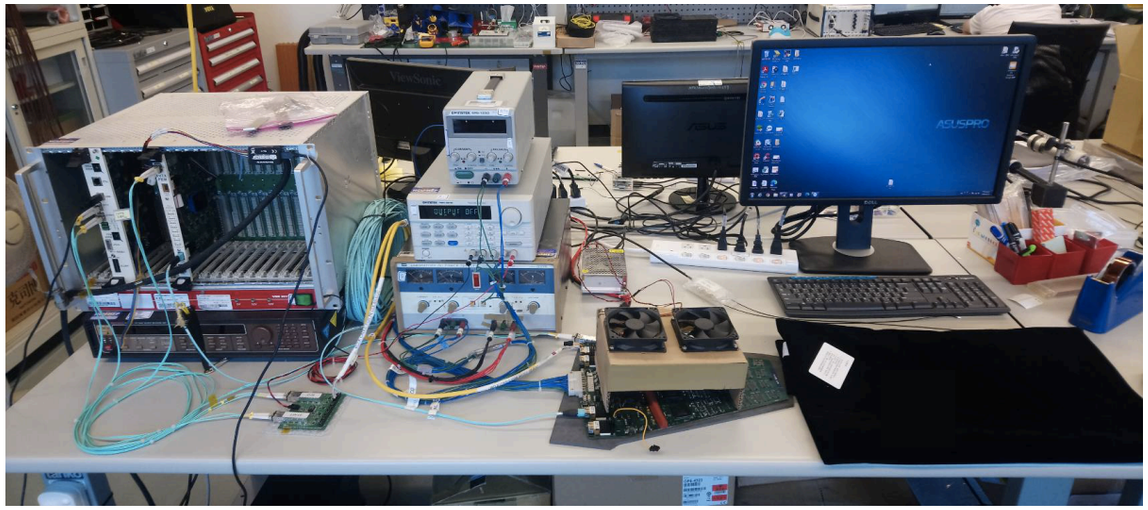

OGP
Flatness & position measurement

Mini gantry
Encapsulation

# Taiwan Silicon Detector Facility (TSiDF)

Testbench

DAQ, Calibration test

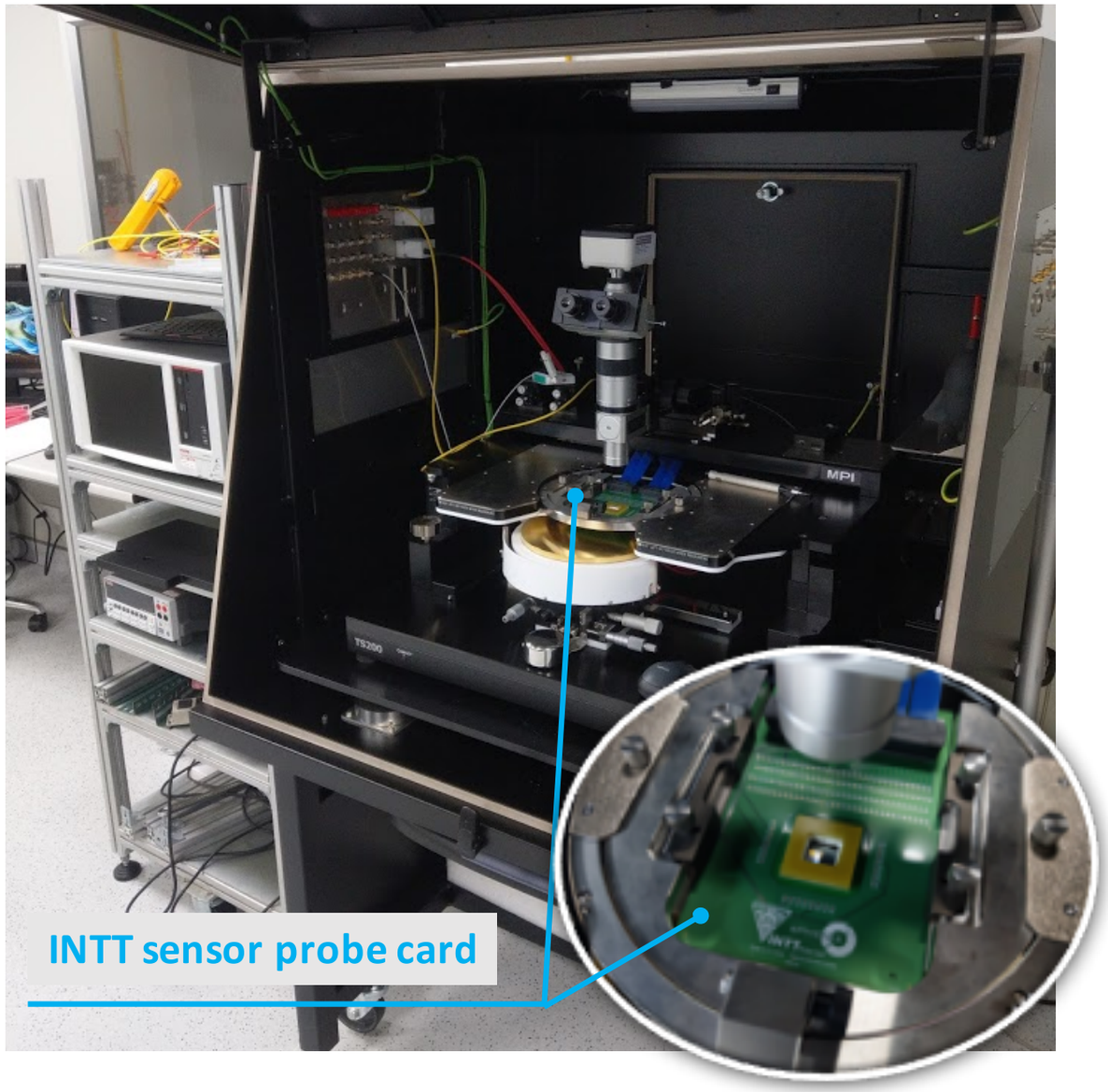


Temperature & humidity chamber

Module/Ladder thermal cycle

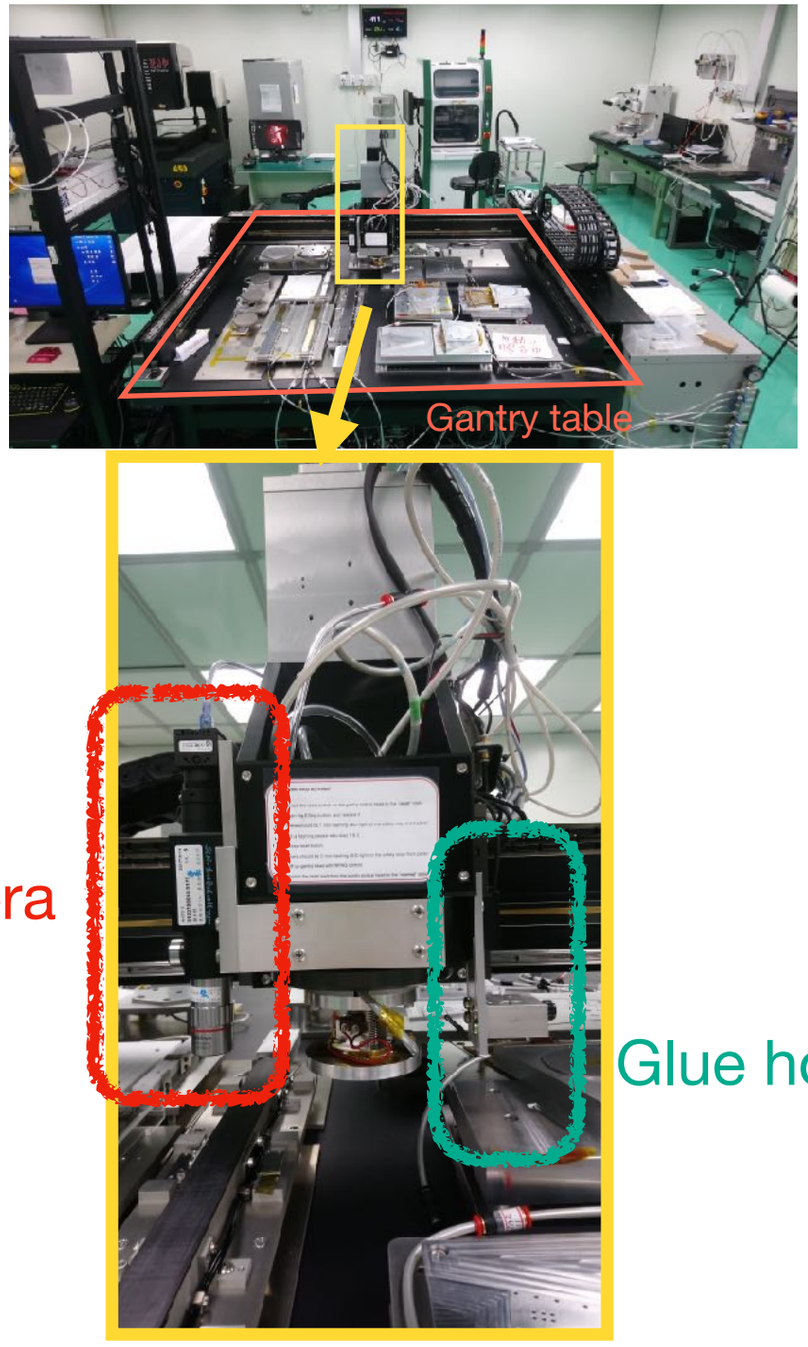
Probe station

INTT sensor characterization



# Ladder assembly equipments

The assembly mainly runs on gantry table

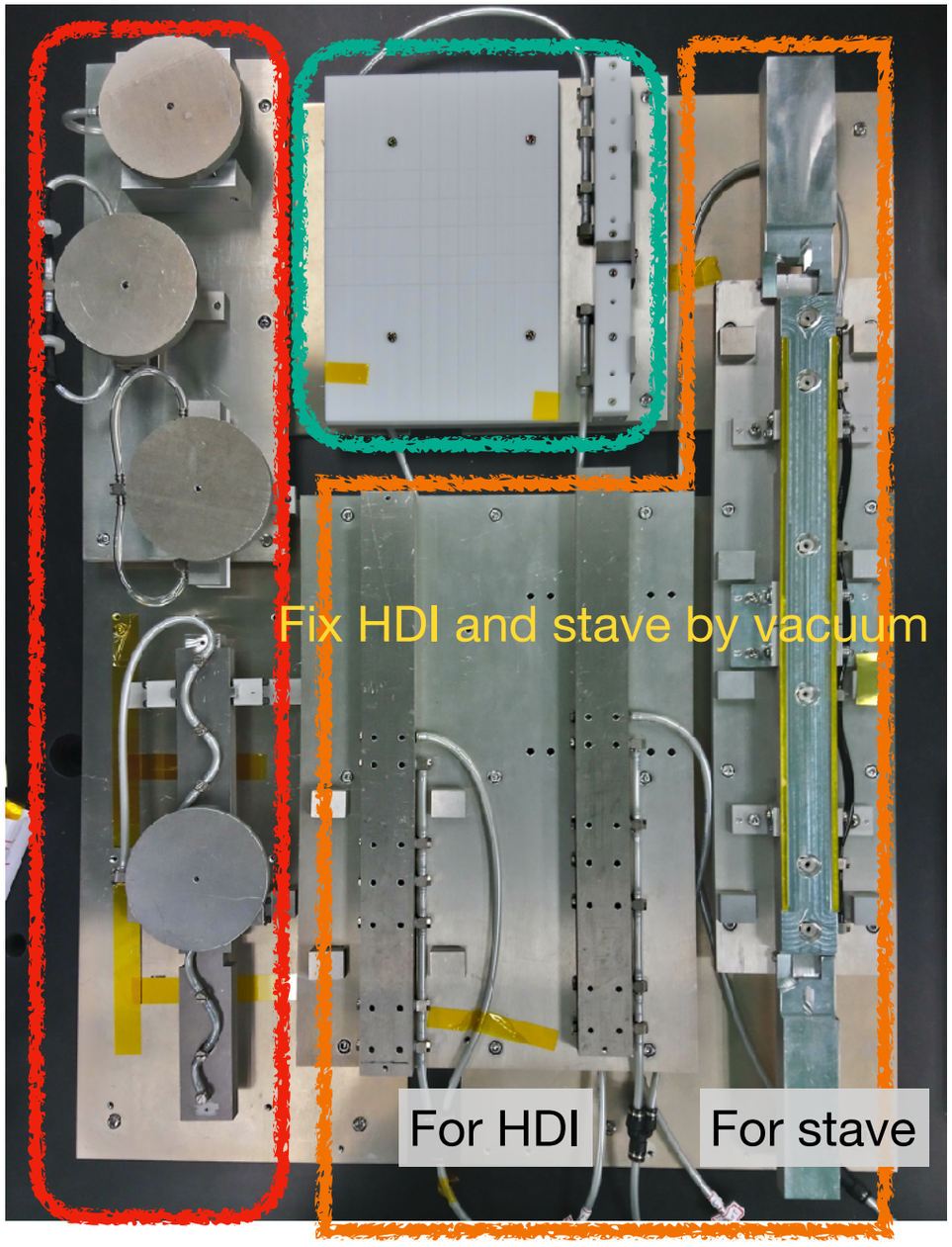



4 dimensional freedom : X, Y, Z & rotation

Gantry head moving accuracy : ~ 5um

Ladder assembly fixtures

Sample tray

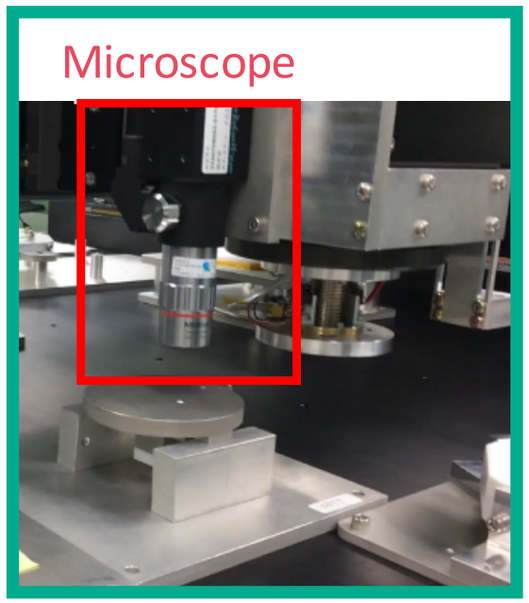


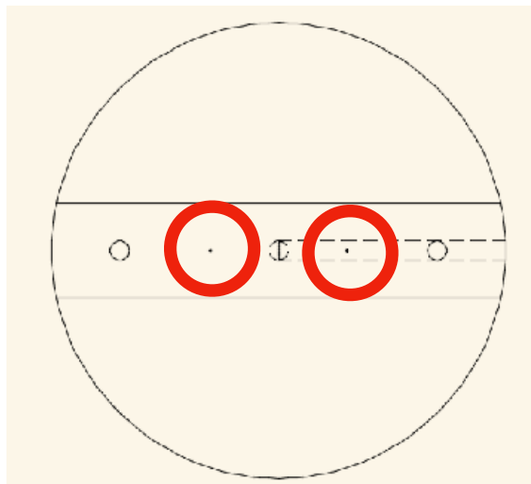

Pick up tools

Assembly tray

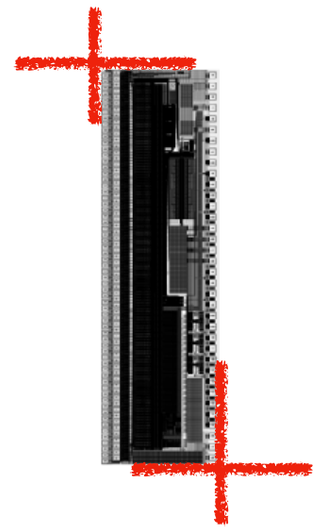
# Component position measurements

The measured positions for each component

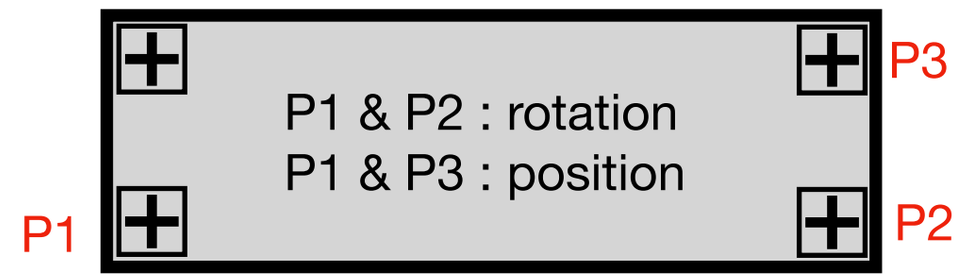


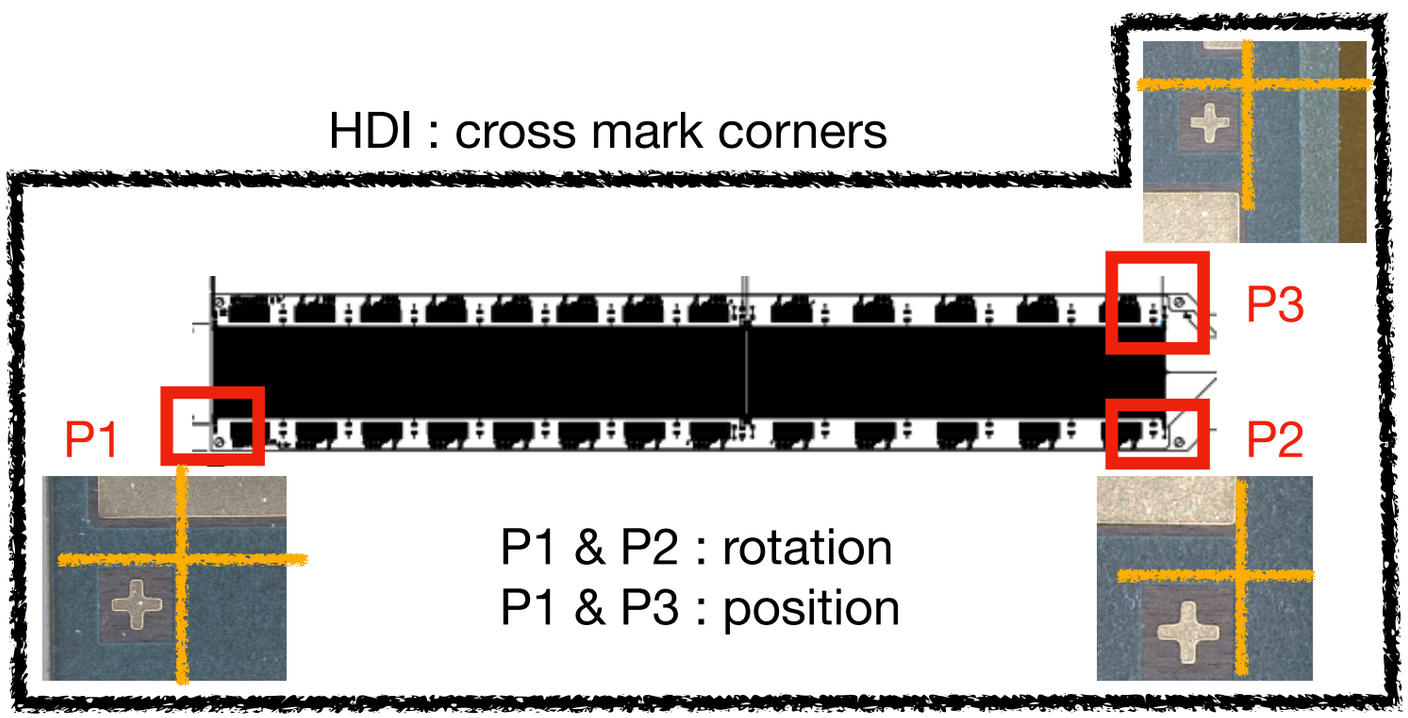
Pick up tools : alignment holes

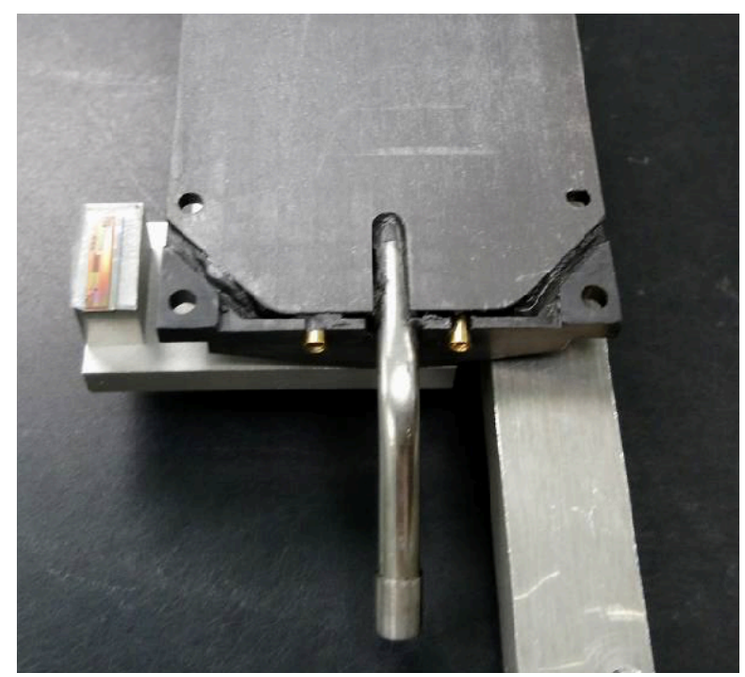


Chip : corners




Sensor : cross marks

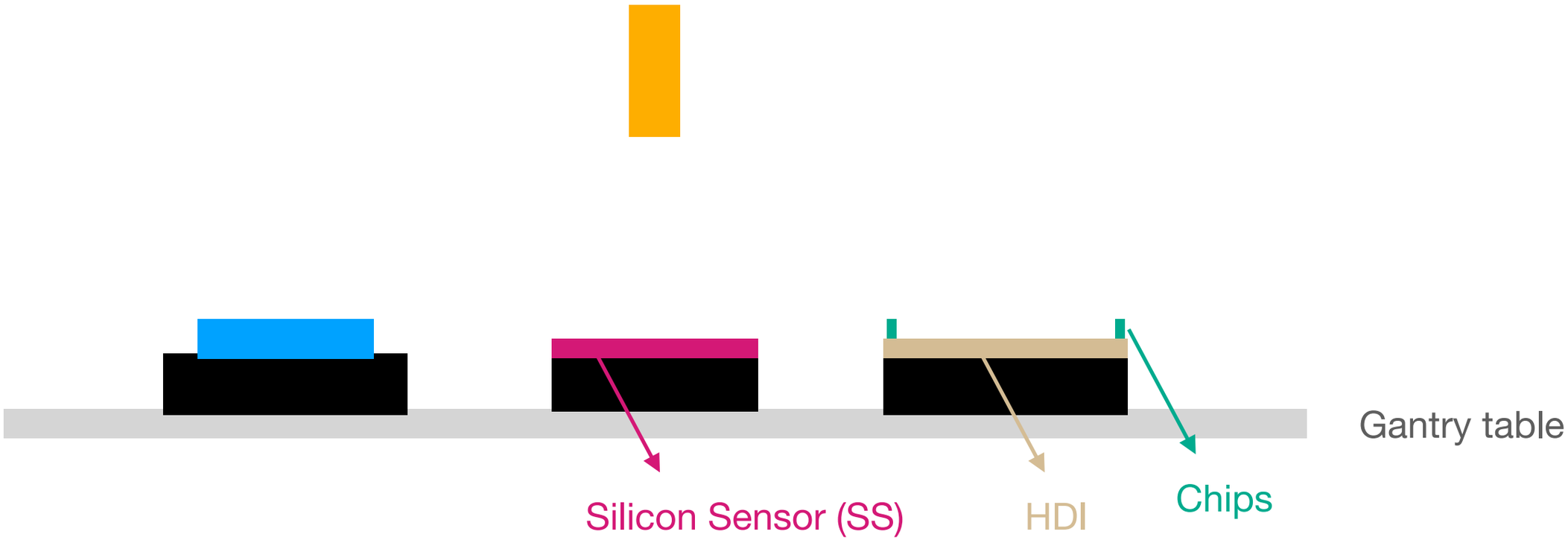


Stave : chip cross mark

# Ladder assembly principle

: Gantry Head (GH)  : Trays for placing components  : Pick Up Tool (PUT)




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

Assembly unit : Module (26 chips + 2 sensors + HDI)

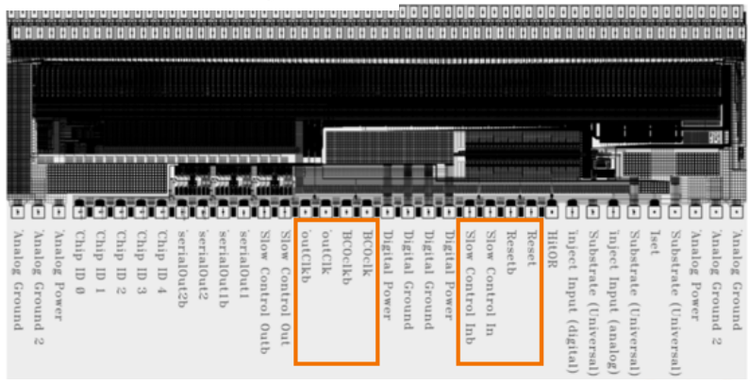
Components test before assembly

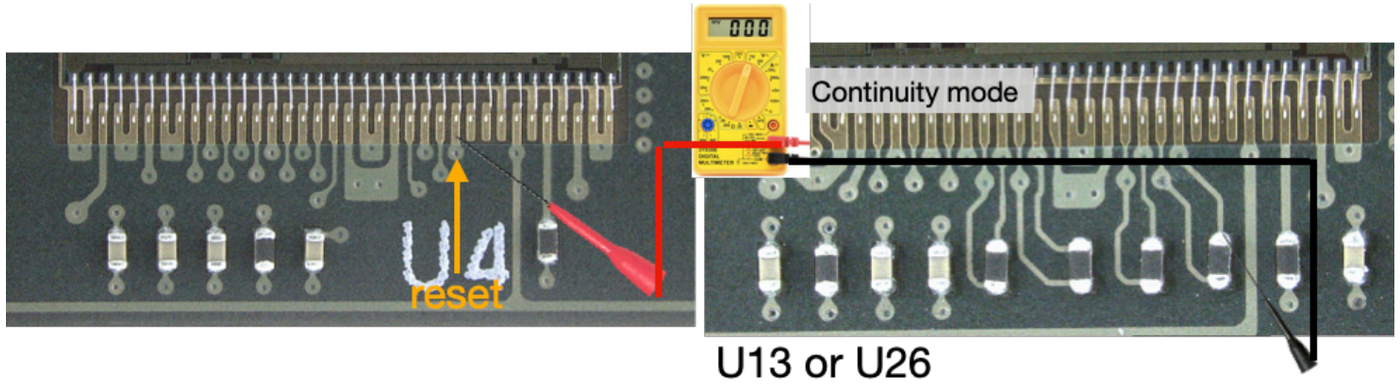
- HDI : pad continuity probing
- Sensor : CV measurement
- Stave : flatness measurement, flow & leakage test

| | Assembly step | | Calibration test |
|---|---|---|---|
| Module | 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 | Module → Stave | V |

# Components test before assembly

## HDI pads continuity test

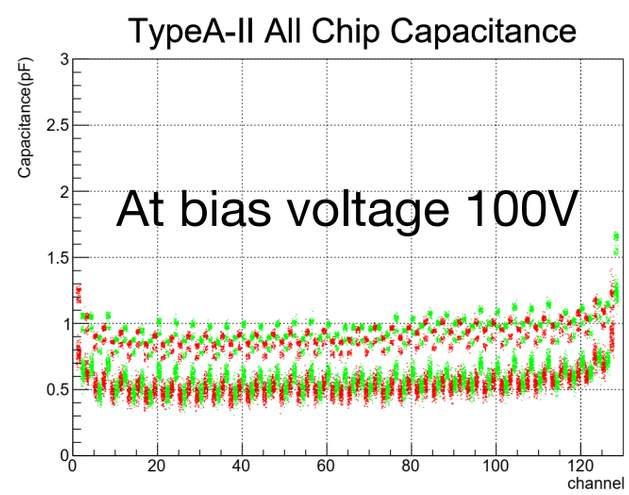


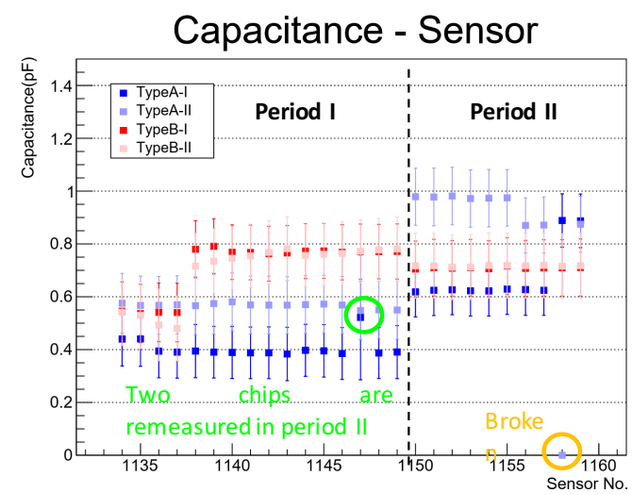




**8 * 26 = 208 receiver pads were tested**

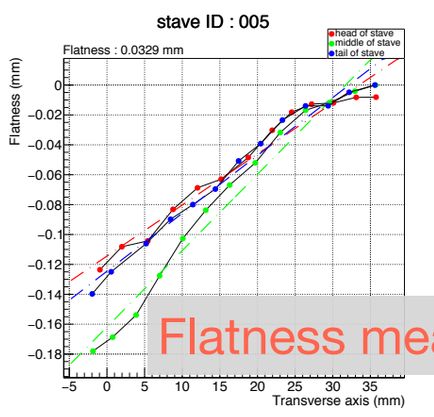
## Sensor CV measurement

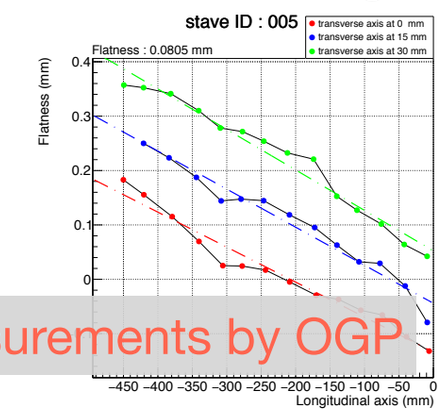
Measurements are on going




## Stave flatness measurement, flow & leakage test



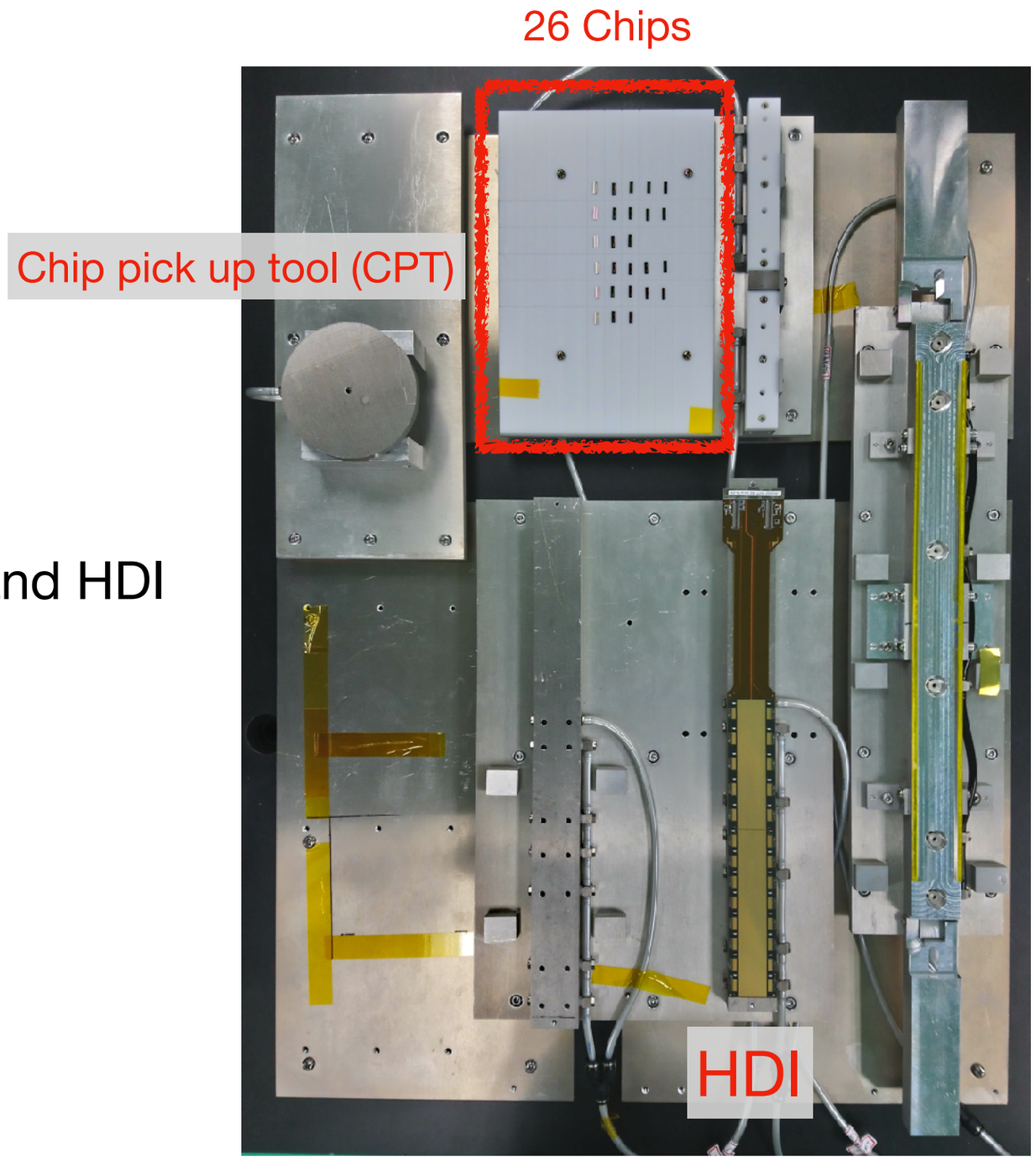

Flatness measurements by OGP

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

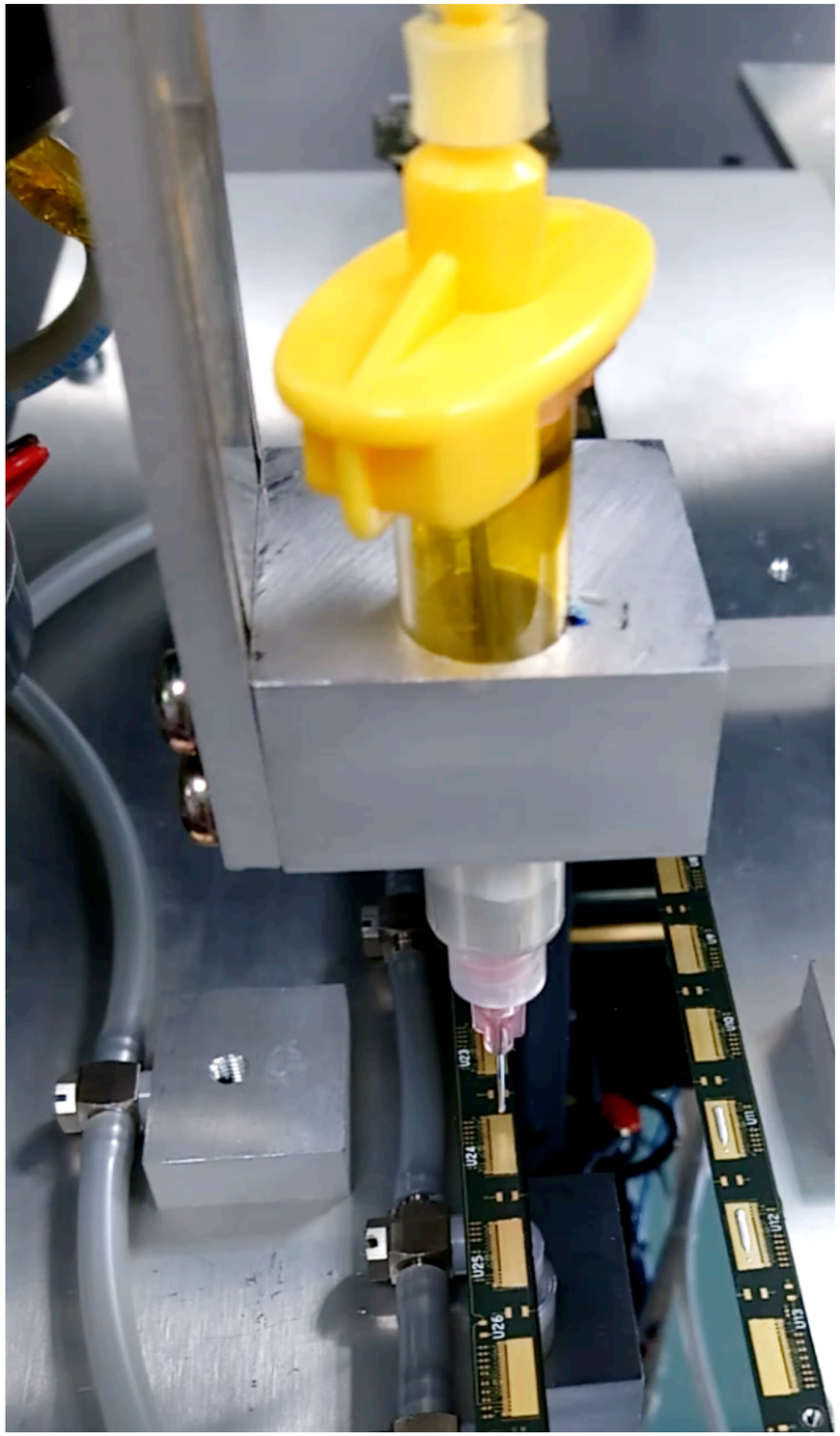
# Module assembly : Chip to HDI

Assembly procedures :

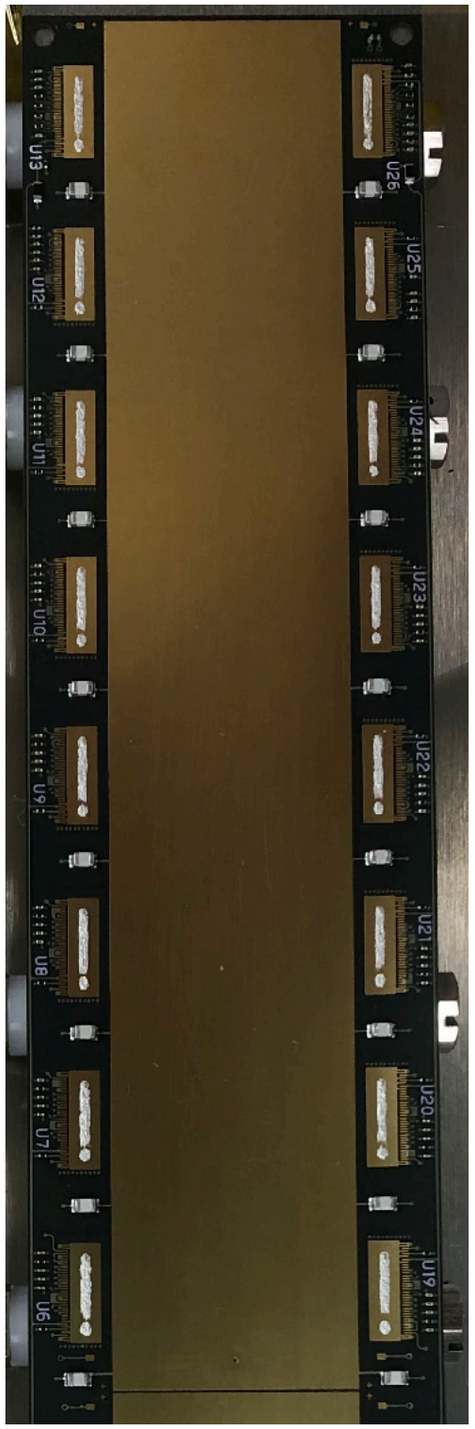
1. Place HDI, 26 chips on tray
2. Measure position & rotation of chips and HDI
3. Glue deposit
4. Measure CPT position
5. Chips assembly with CPT

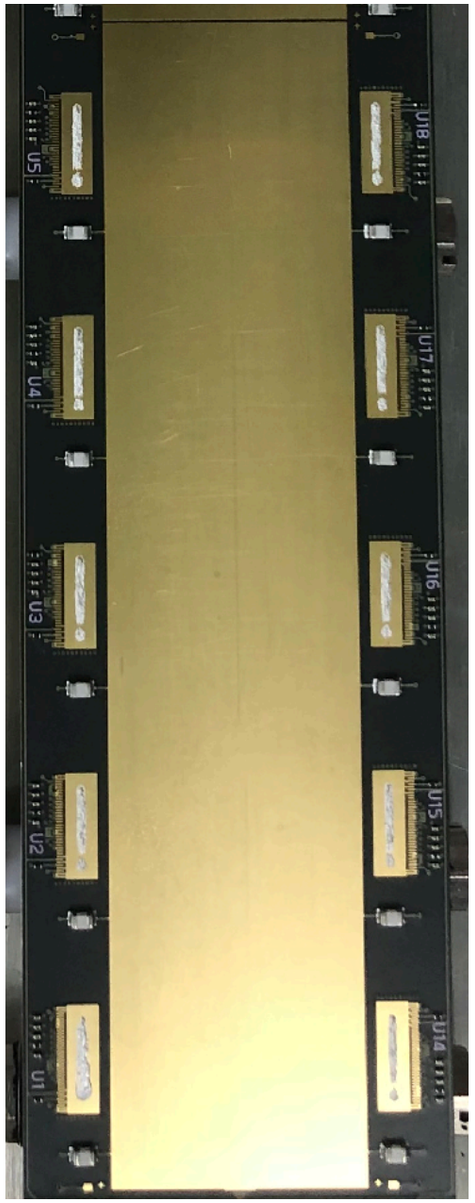


# Module assembly : Chip to HDI

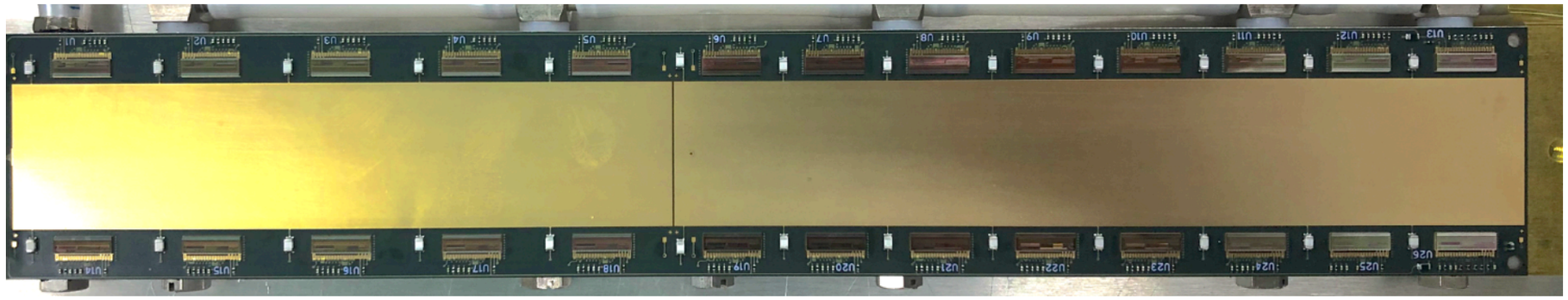


Chip glue pattern

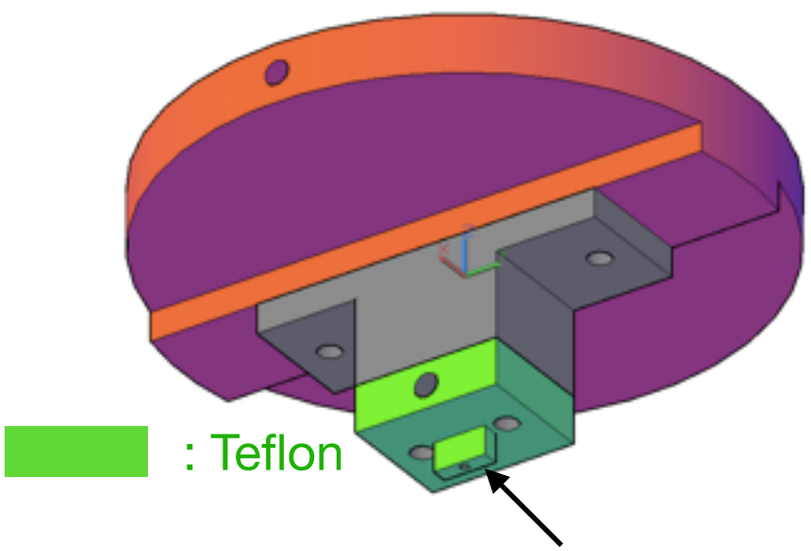




# Module assembly : Chip to HDI

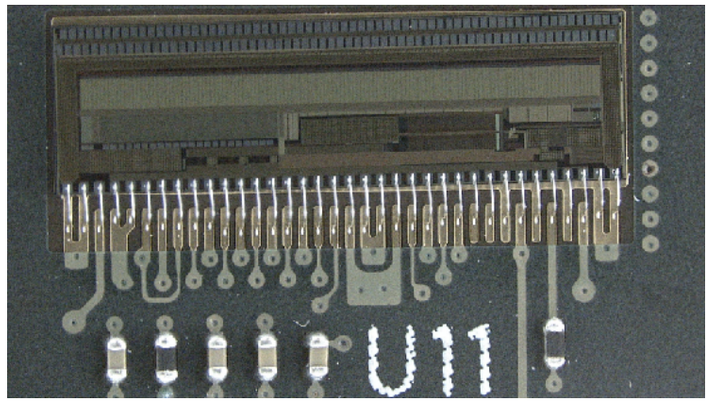


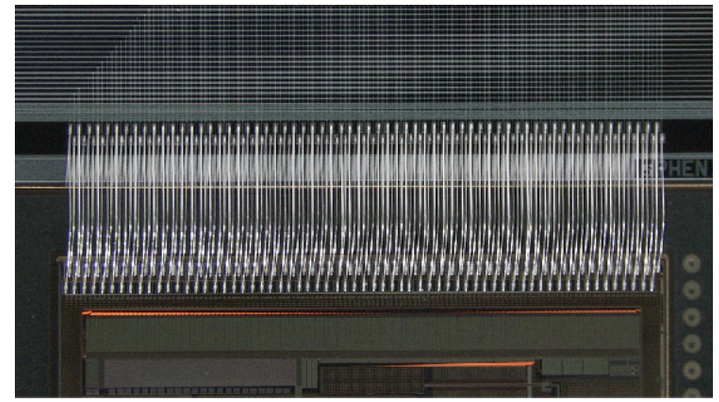
Chip pick up tool



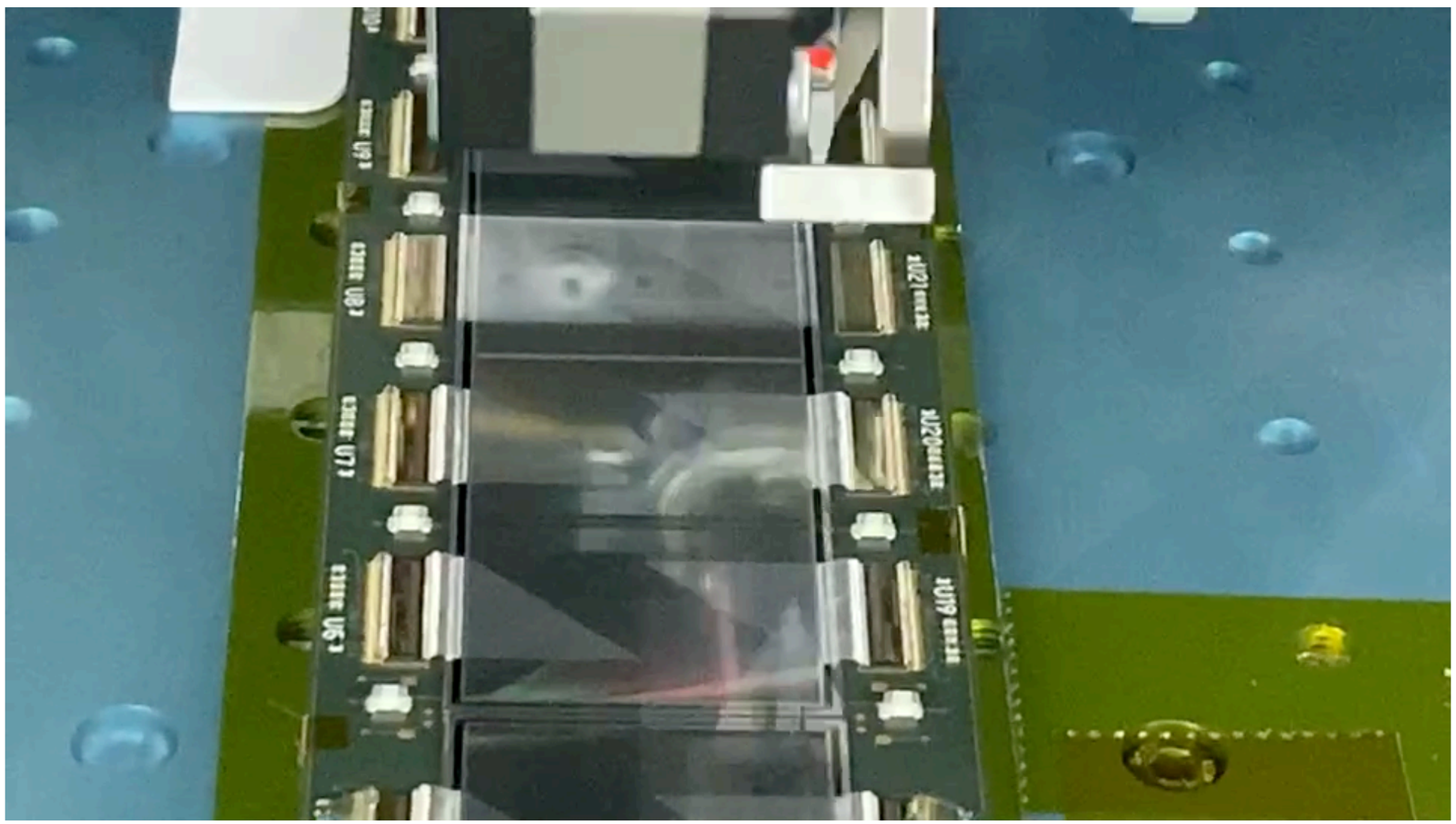
# Wire bond

Chip to HDI



Sensor to chip

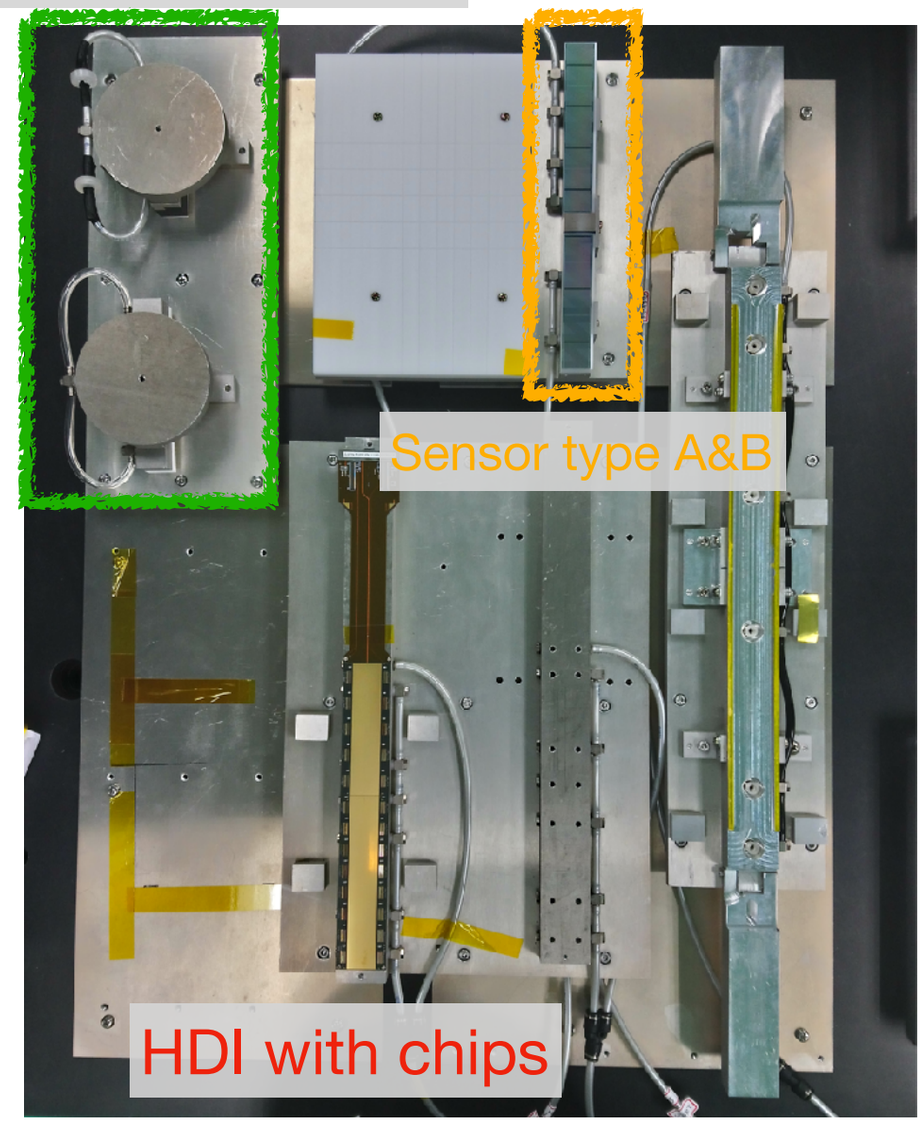


Sensor to chip bonding

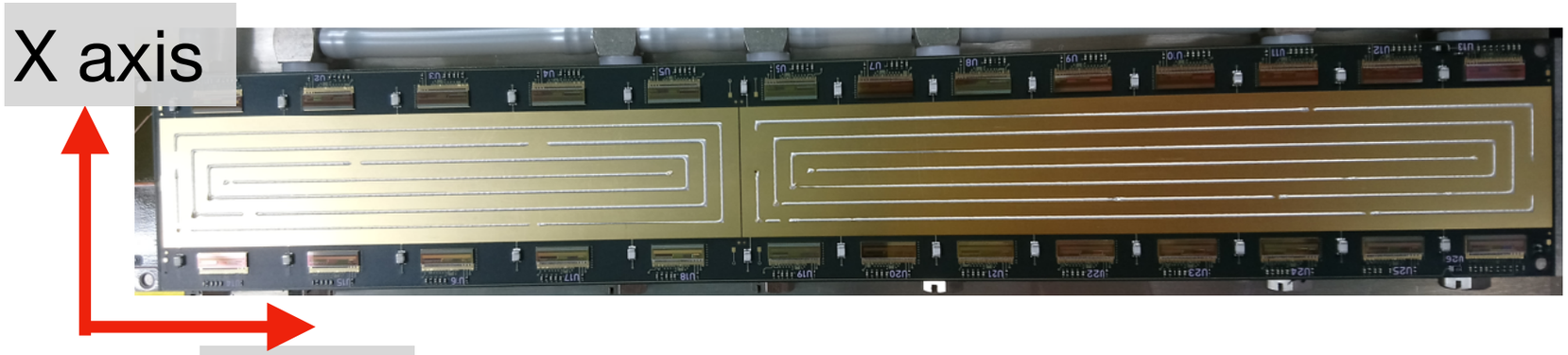
# Module assembly : Sensor to HDI

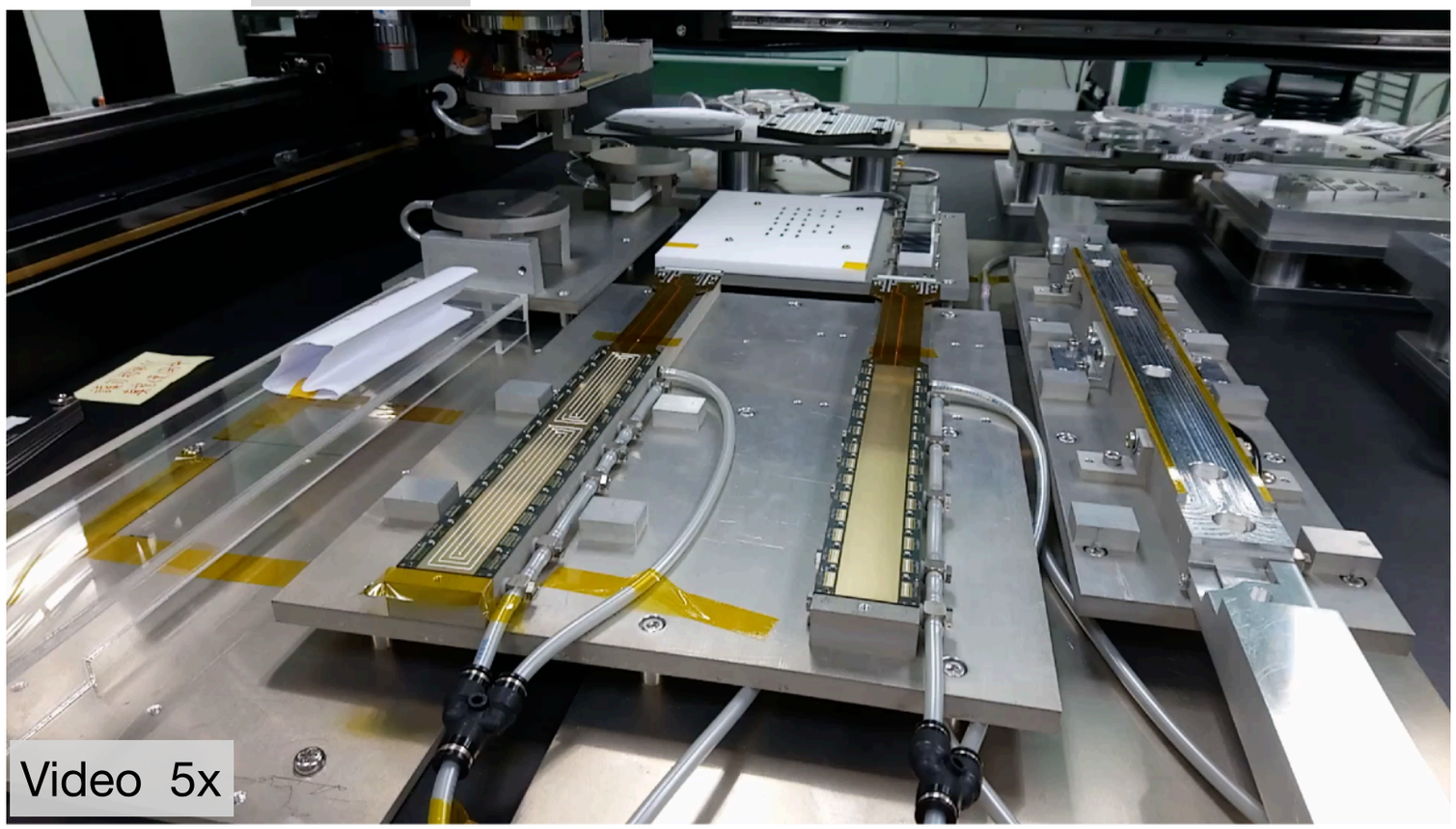
Assembly procedures :

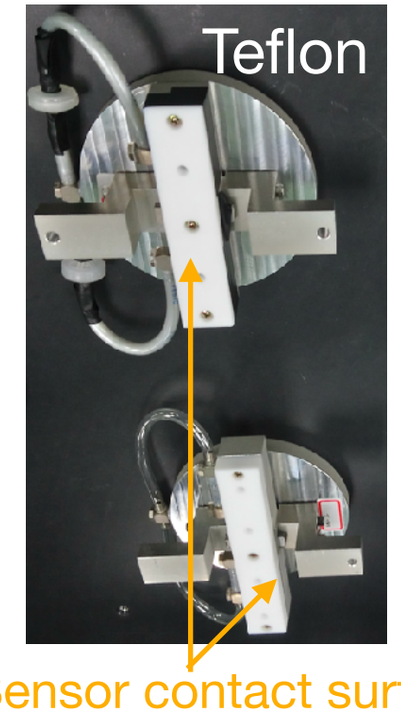
1. Place HDI, sensor type A&B on tray
2. Measure position & rotation of sensors and HDI
3. Glue deposit
4. Measure SPTs
5. Sensors assembly with SPTs



# Module assembly : Sensor to HDI



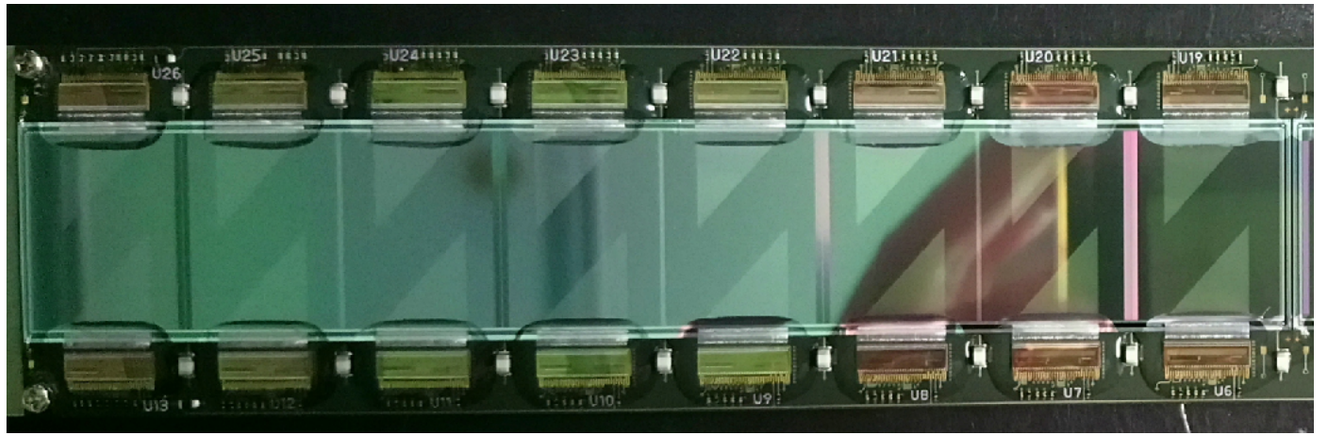



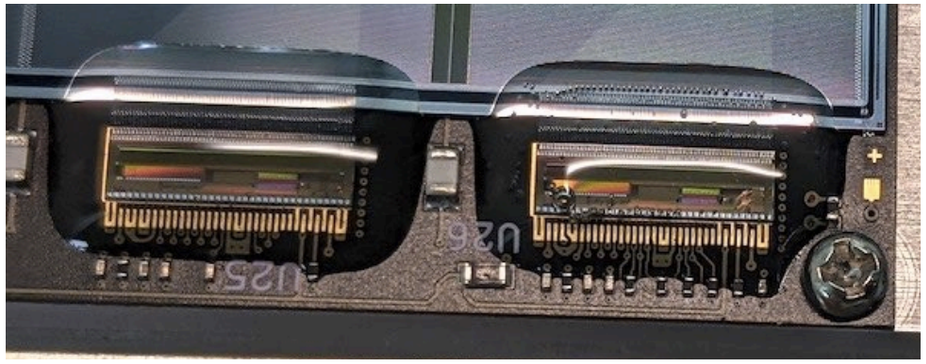

Average sensors placing error
(According to latest 4 modules)

| | 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 |

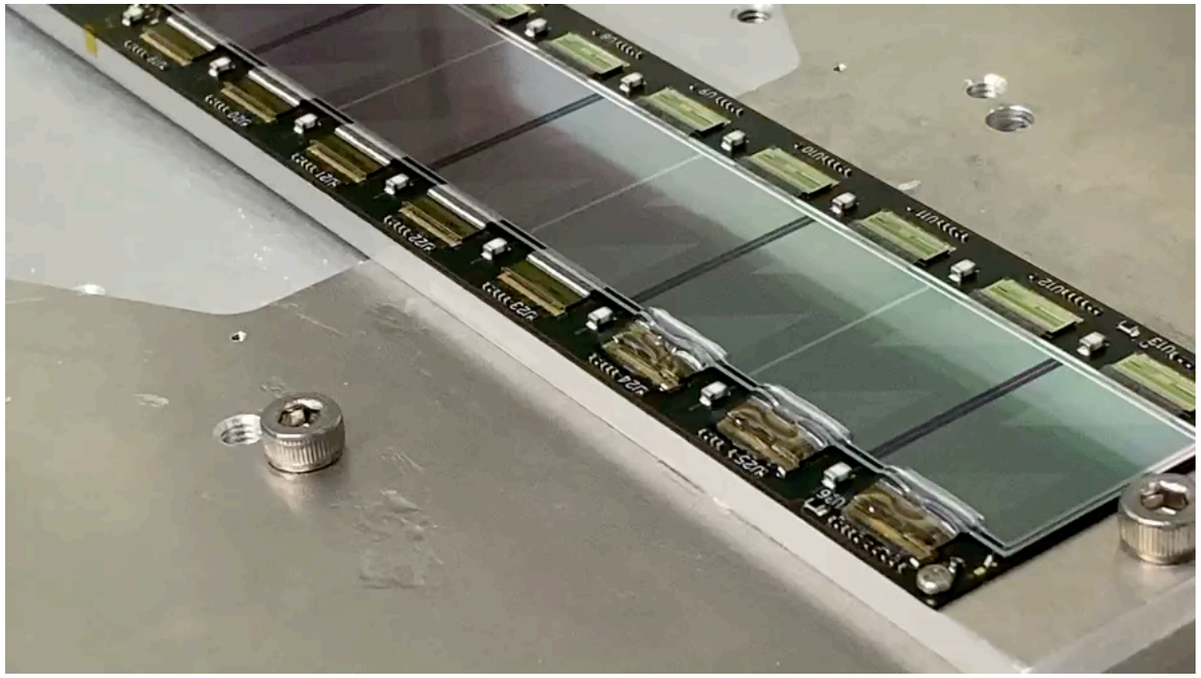
X axis ~-5.46 $\mu m$, Y axis : ~ -11.75 $\mu m$

# Encapsulation

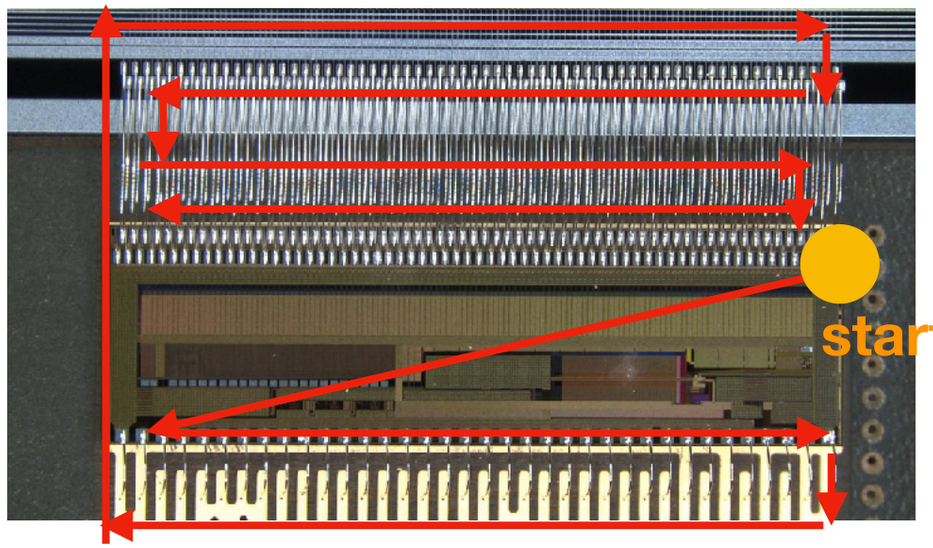




Thickness of encapsulation ~ 1.2 mm

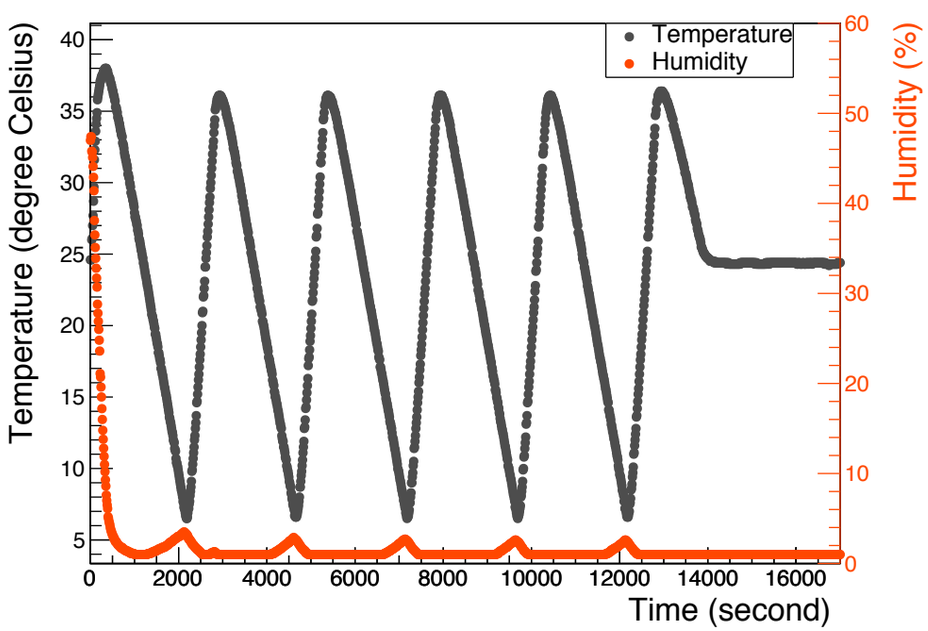


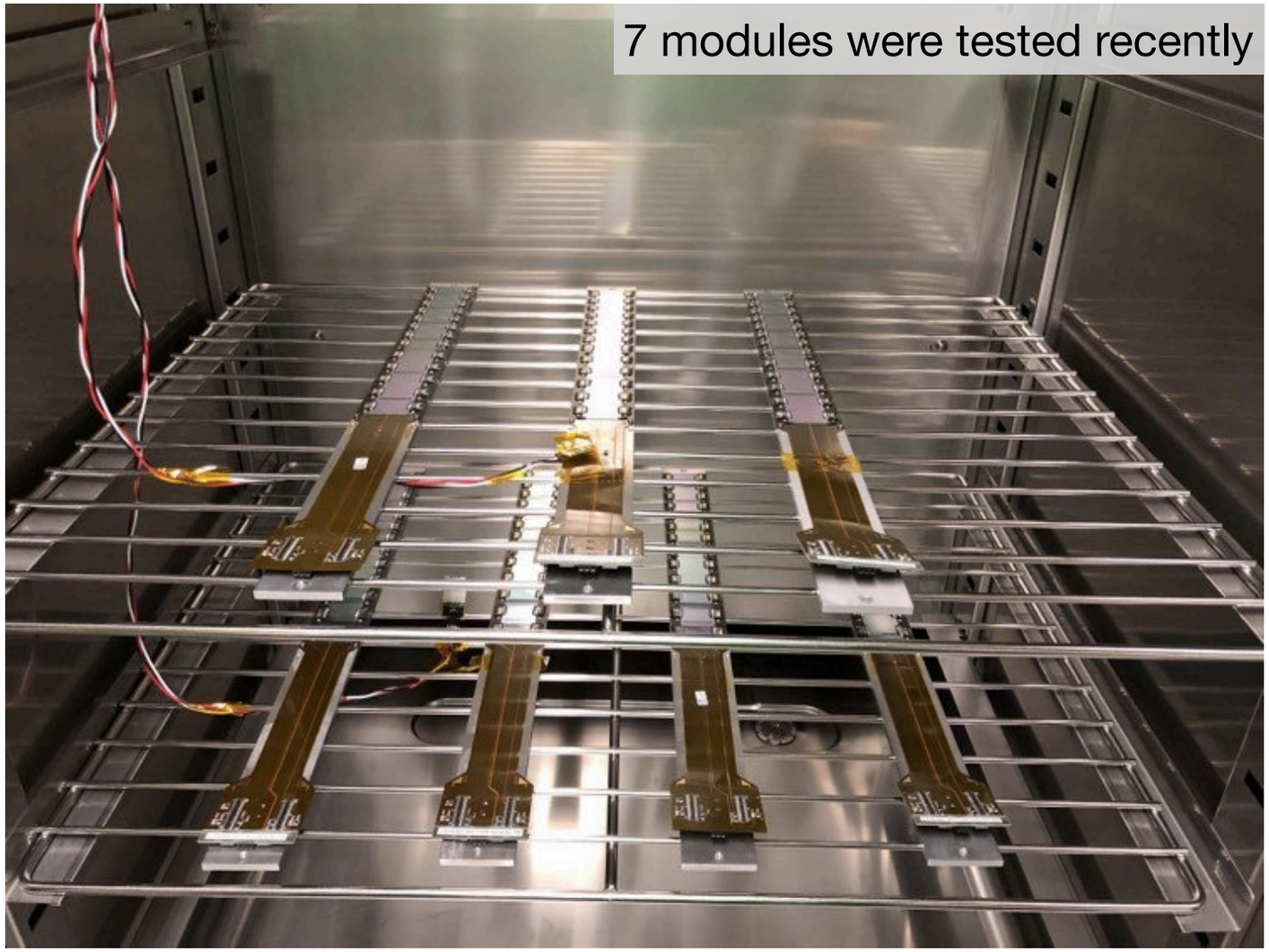
**Sylgard 186 is used**
**Needle size of syringe : 0.6 mm**
**Waiting time : 30 ~ 40 mins after mixing**



# Thermal cycle

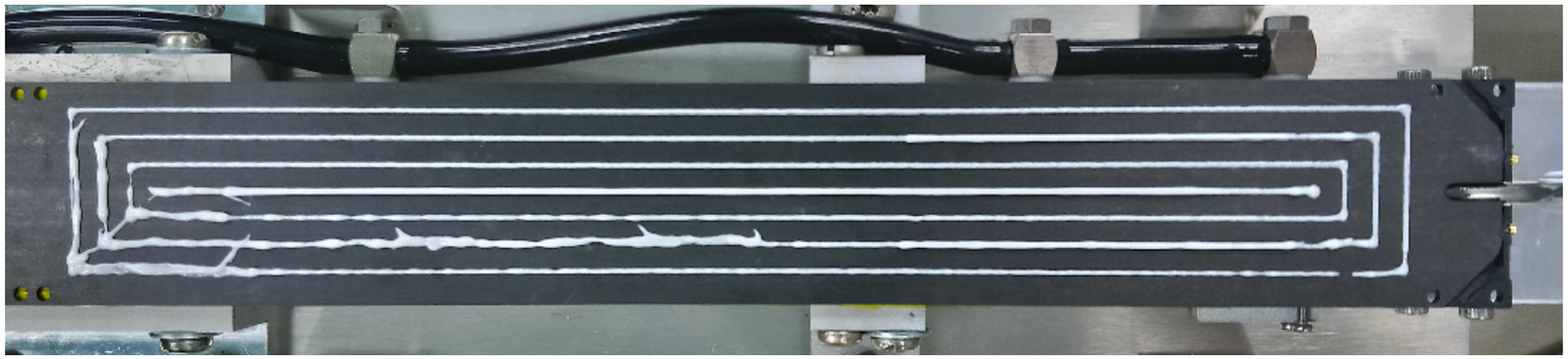
5 $^0C$ ~ 40 $^0C$, for 5 cycles
~ 4 hours operation

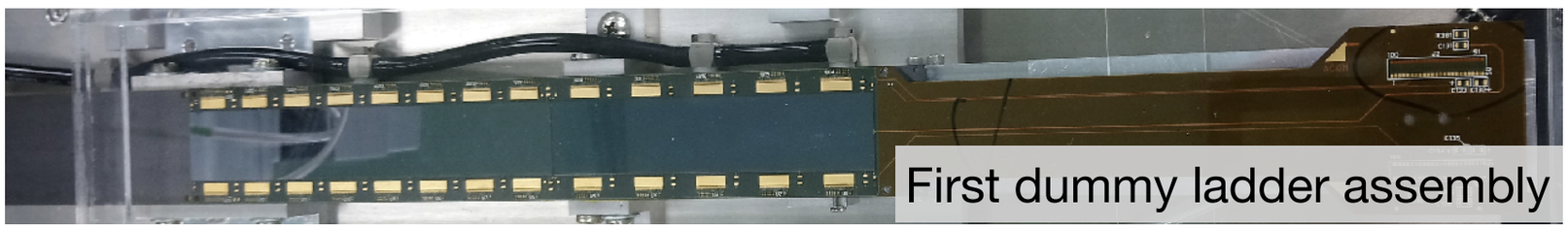


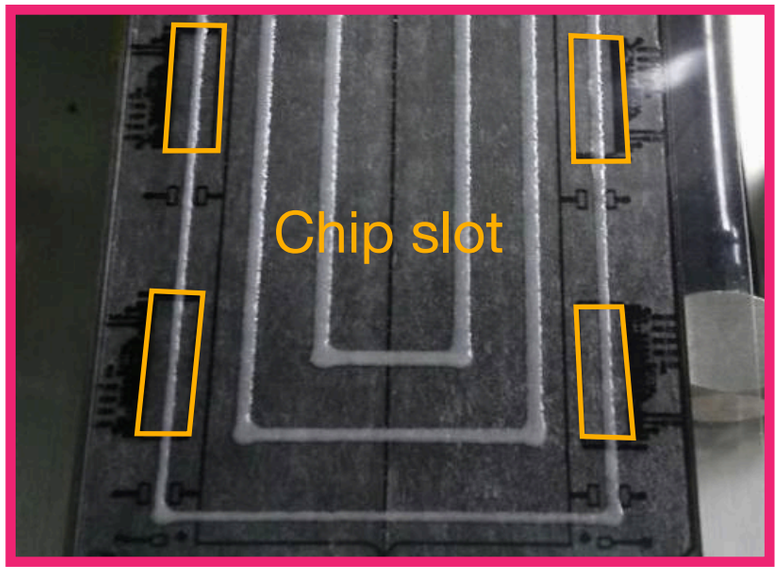




Modules function well before and after thermal cycle

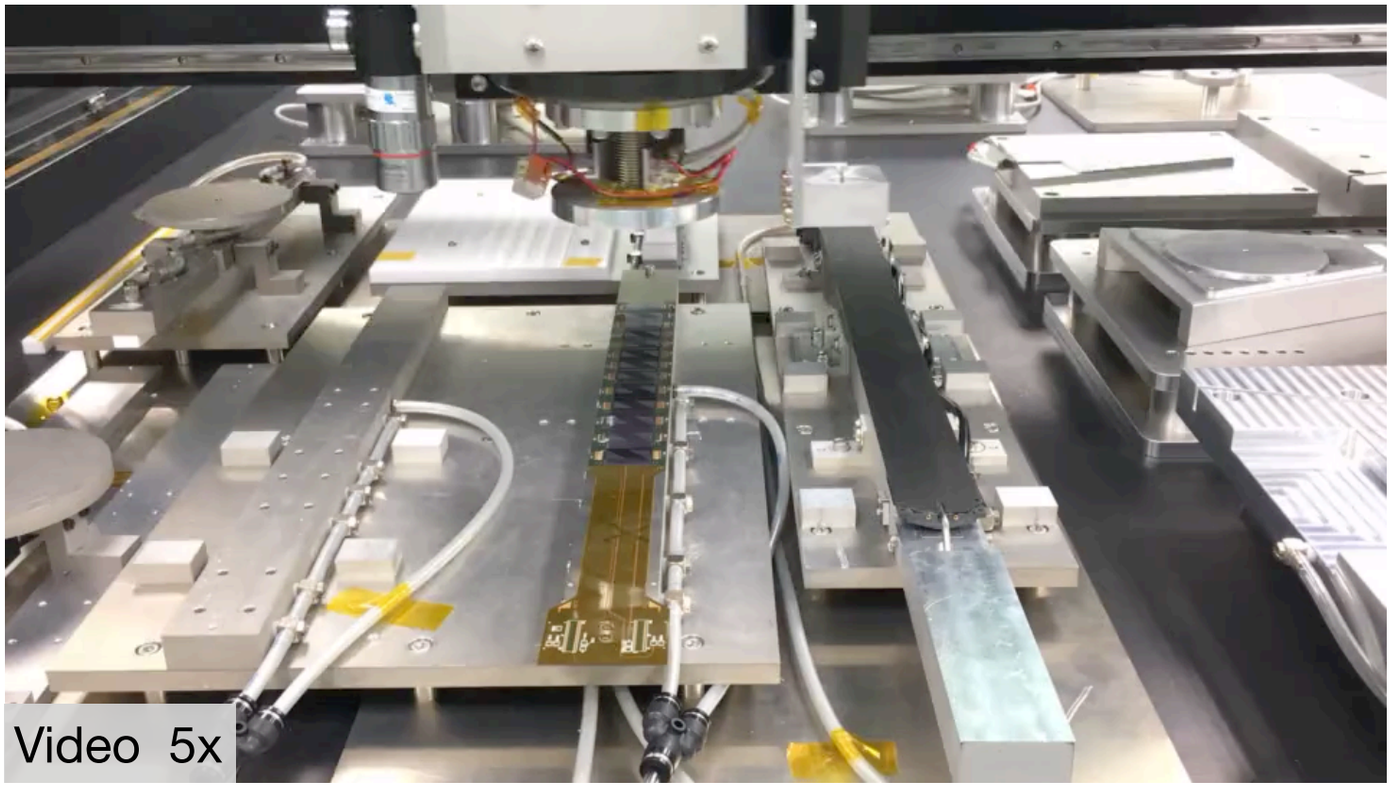
# Ladder assembly






Two glue lines under chip




Module placing error on stave

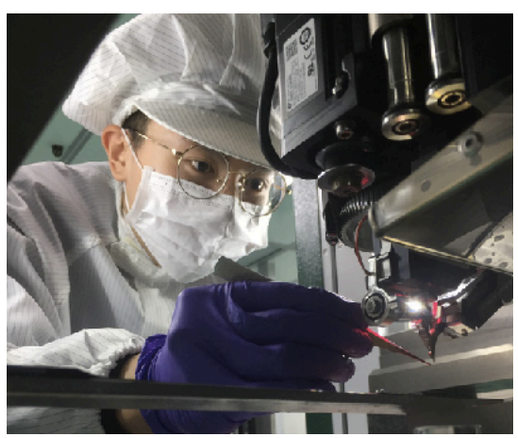
| | |
|---|---|
| **X axis (um)** | < 5 |
| **Y axis (um)** | <10 |
| **Rotation (rad)** | < 1E-4 |

Assembly procedures : verified

# Summary

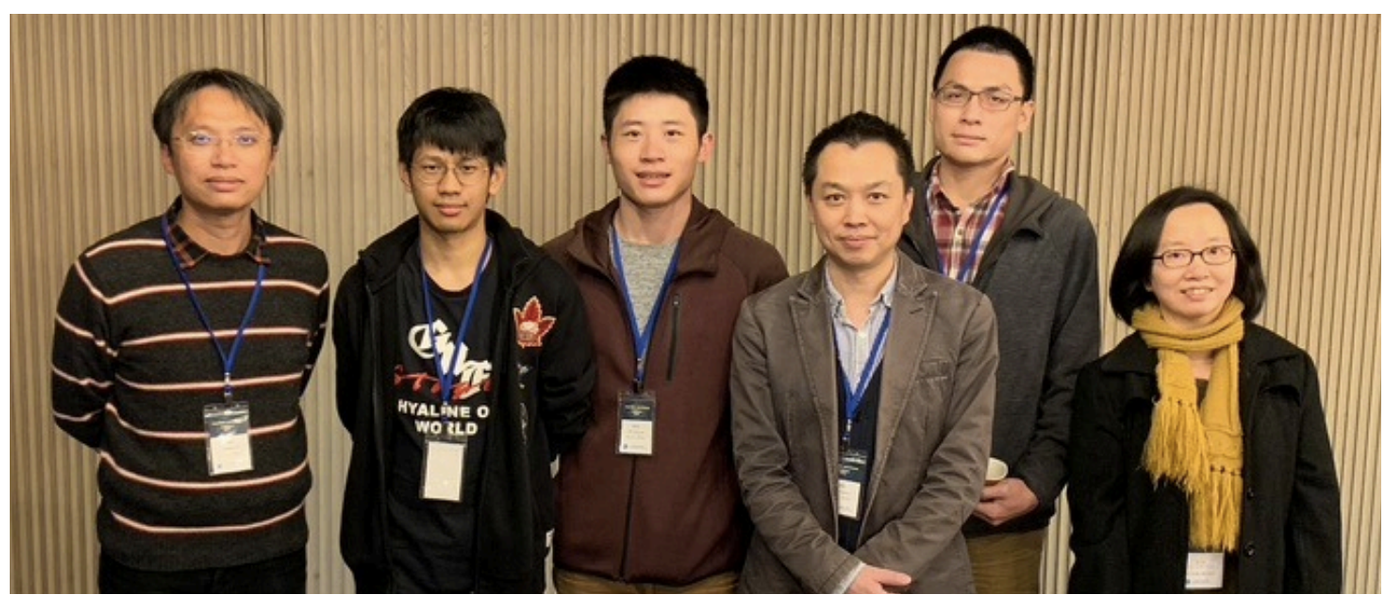
- Assembly fixtures on hand ✓
- Module assembly ✓
  - Chips and sensors mounted on HDI ✓
  - Wire bond ✓
  - Encapsulation ✓
  - Thermal cycle ✓
- Ladder assembly ✓
  - Modules on stave assembly ✓

Ready for full scale production



Ou-Wei Cheng

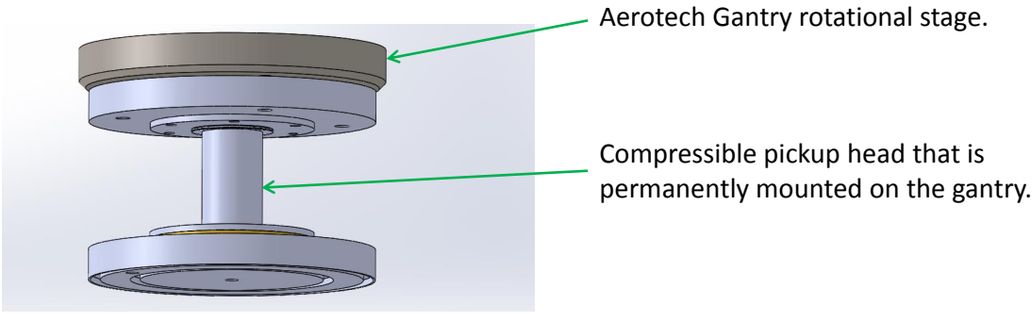
Kai-Yu Cheng



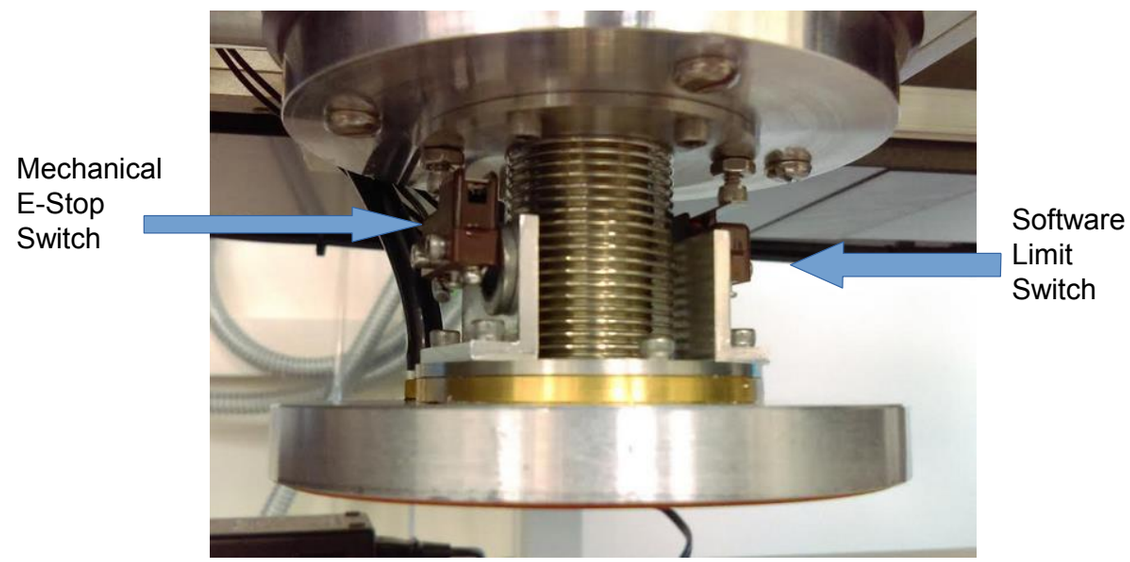
Chia-Ming Kuo Cheng-Wei Shih Lian-Sheng Tsai
Wei-Che Tang Rong-Shyang Lu Janny Huang

# Back up

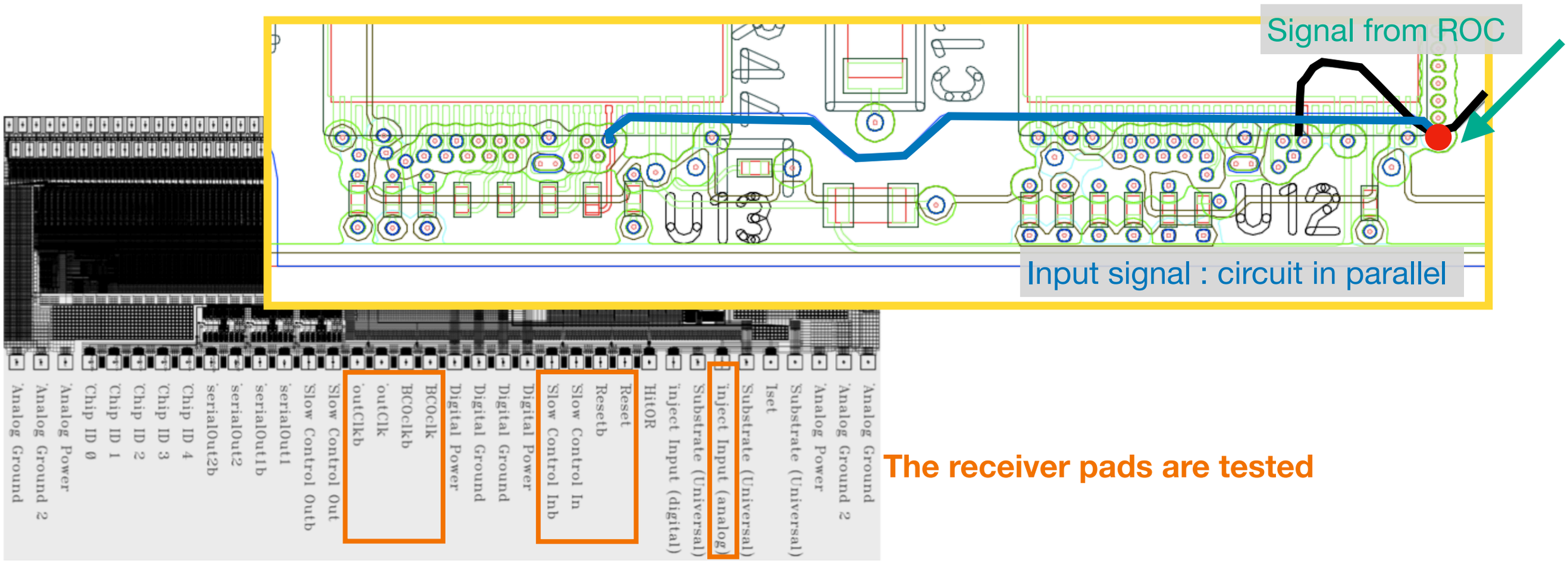
# Gantry Head (GH)



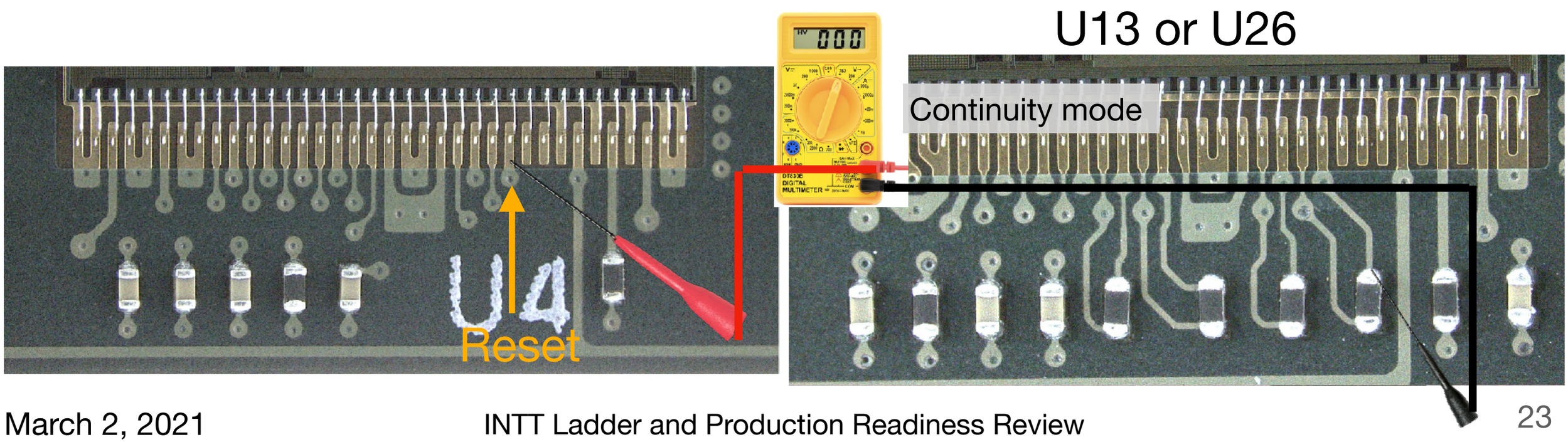

## Compression switches



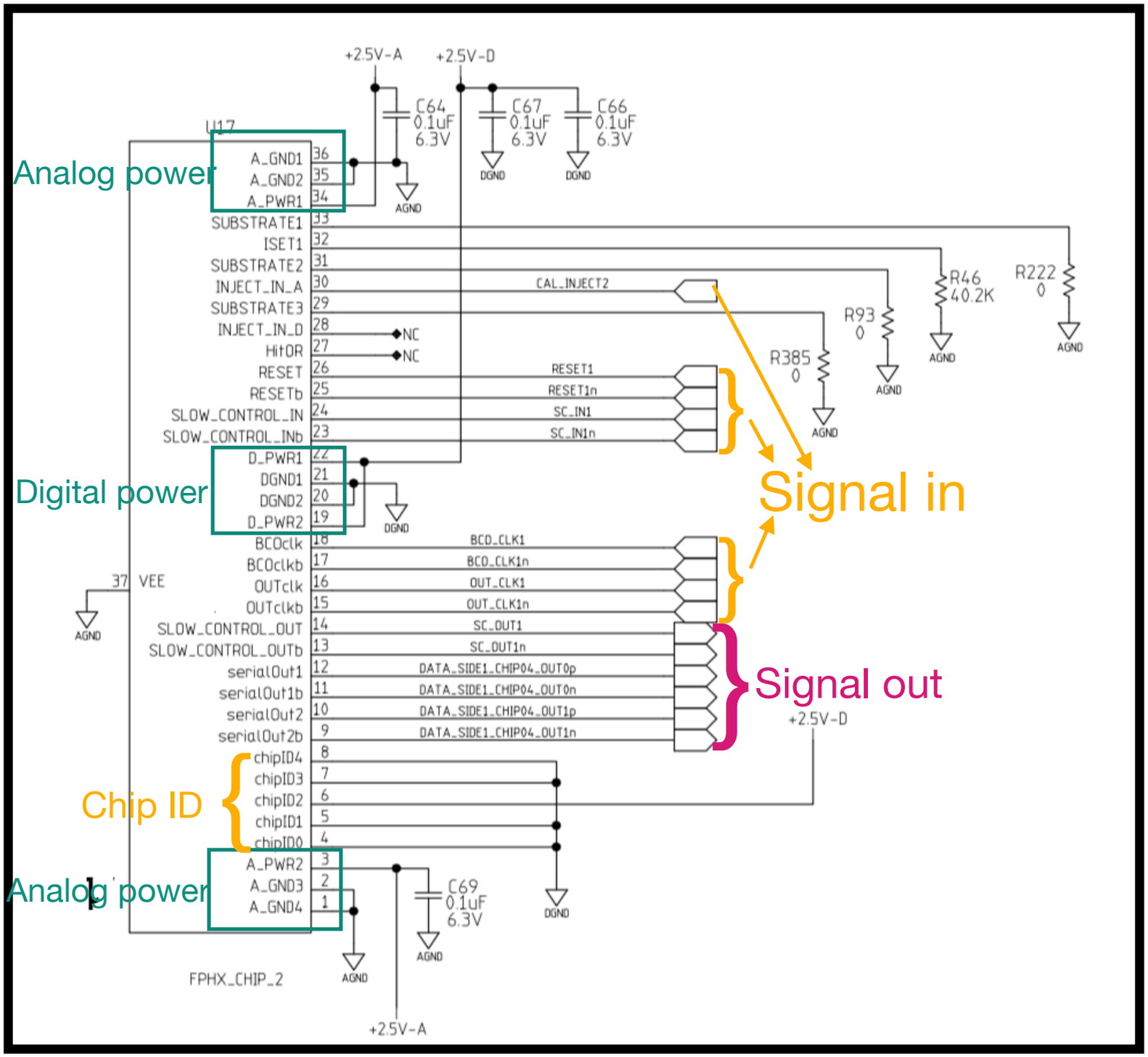
# HDI pad continuity test



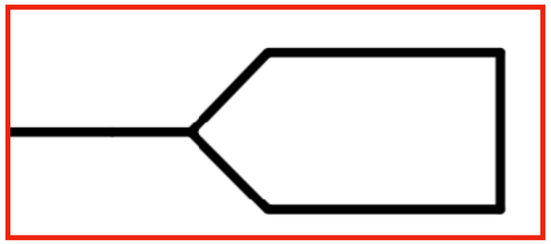

**The receiver pads are tested**



# HDI pad continuity test




Signal from ROC to HDI



Signal to ROC from HDI

Check the continuity of circuit embedded HDI

Analog power

Digital power

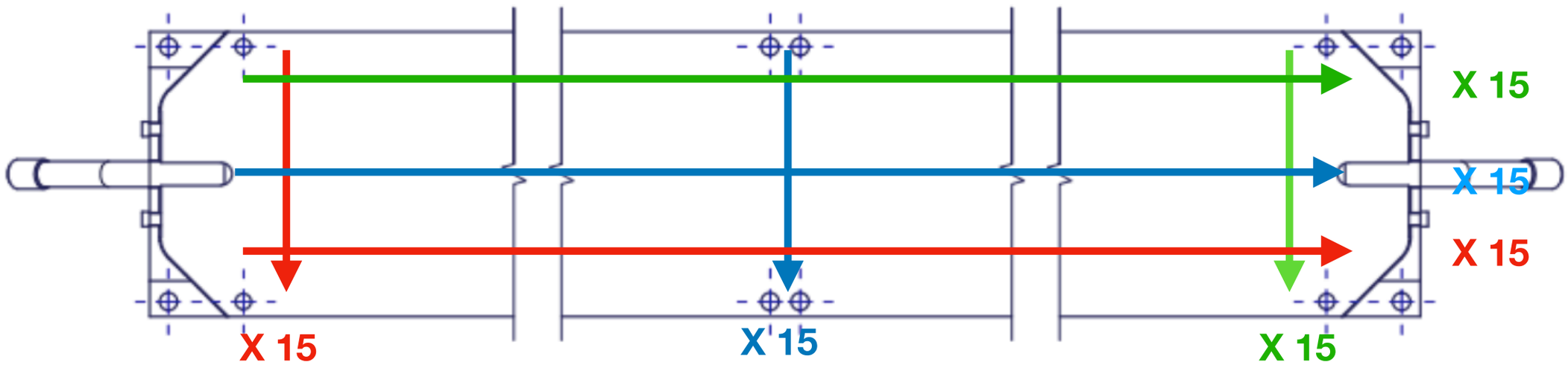
Signal out

9 signal in

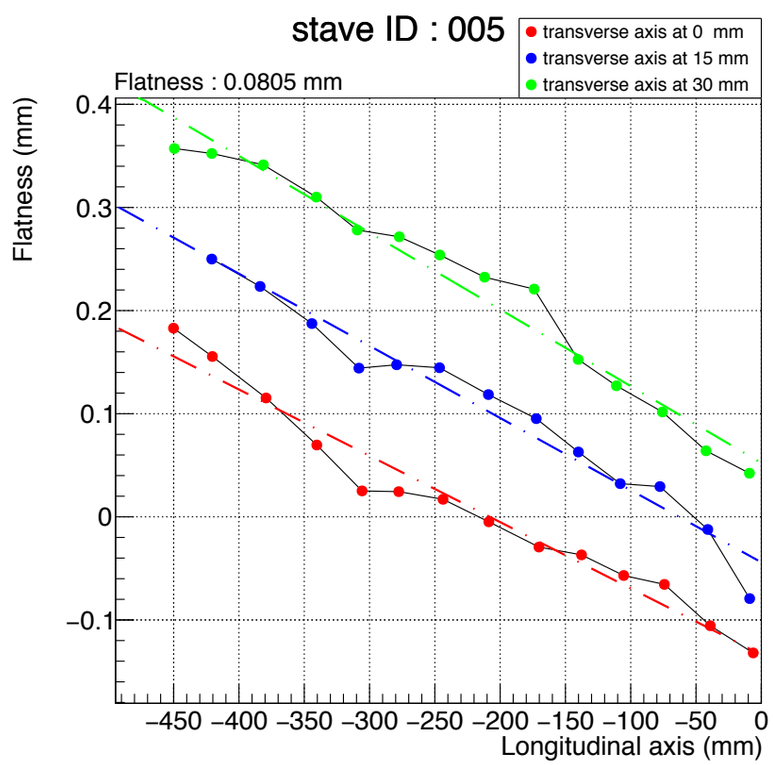
Chip ID

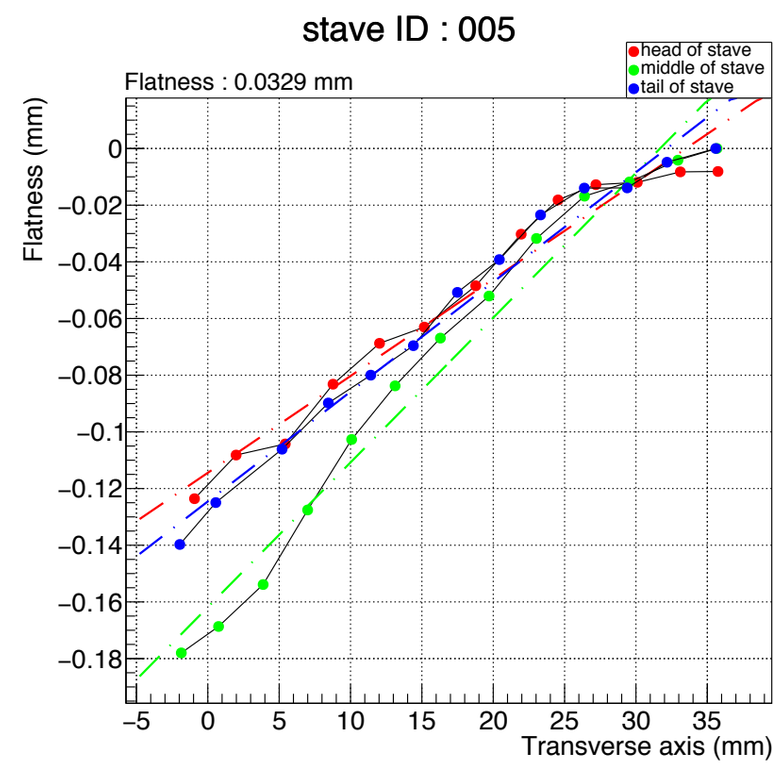
# Stave quality test : flatness measurement

**Measurements done by OGP**



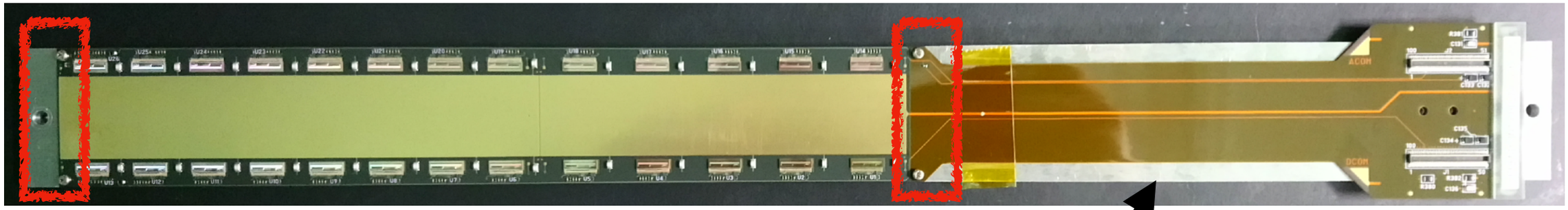

**Transverse / Longitudinal directions : 45 measurements data**



# Module transportation

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



HDI is fixed on HDI handle by screws

HDI handle

Module transportation box : Gantry table to testbench

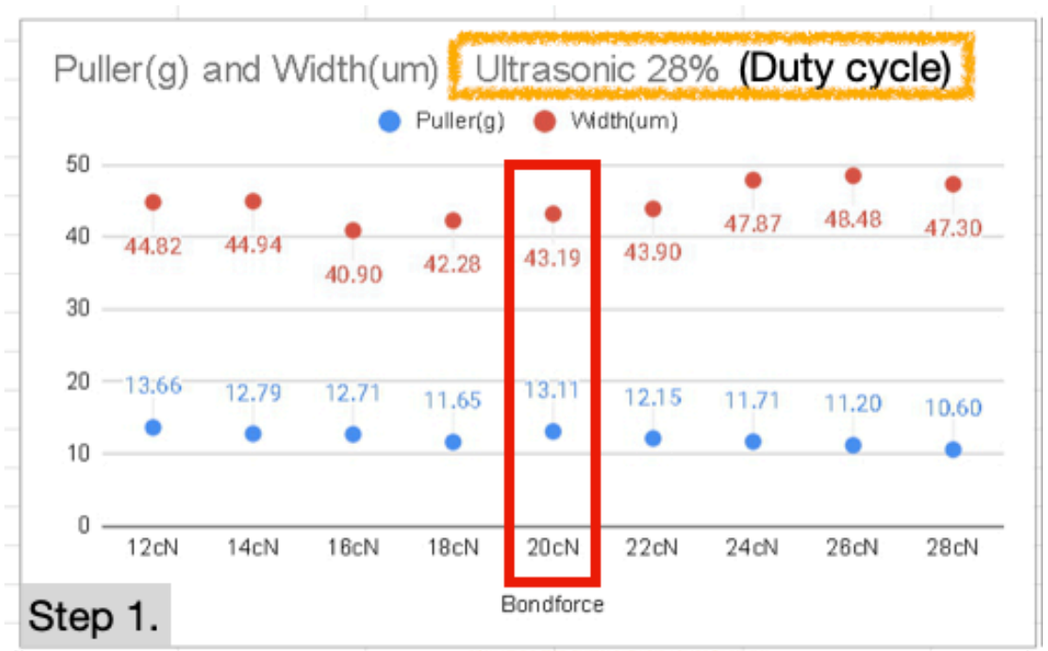
HDI handle

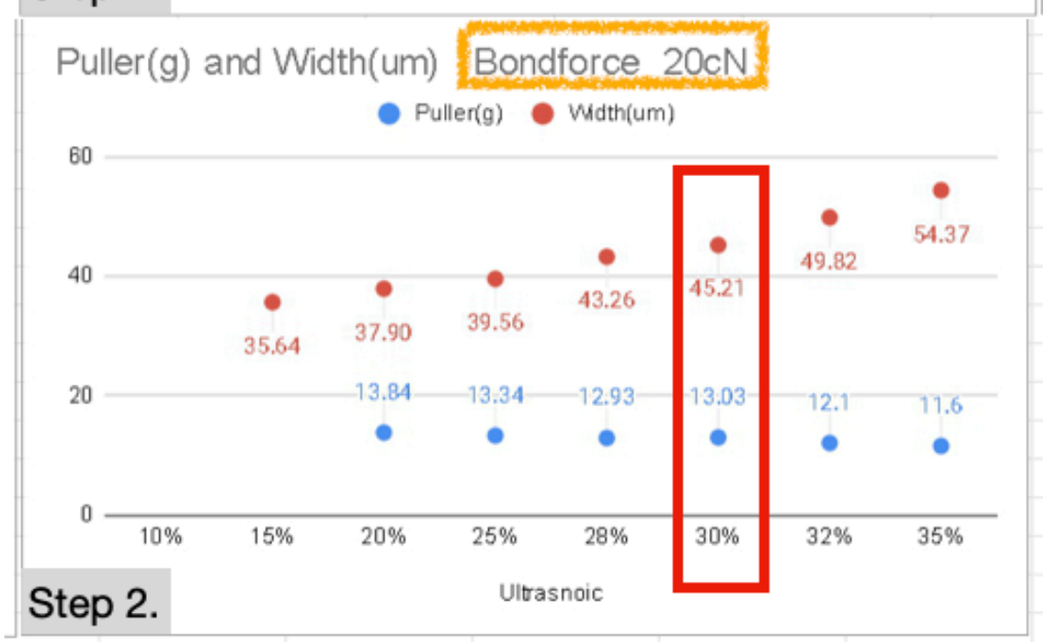
HDI handle is fixed in box by screws

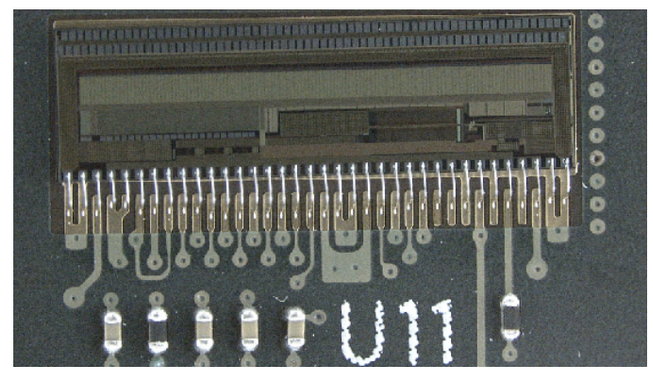
# Wire bond

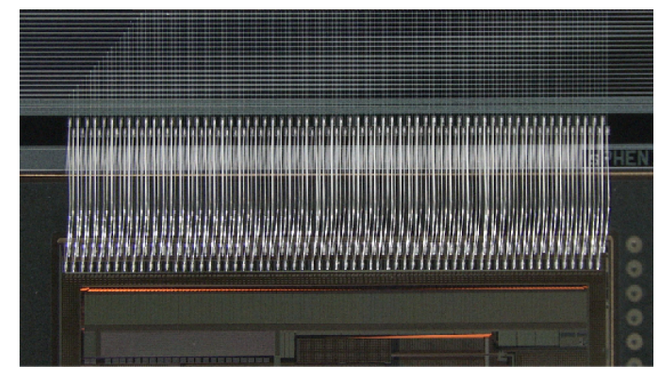
To find the best bond parameters

"Chip to HDI" bonding parameter scan



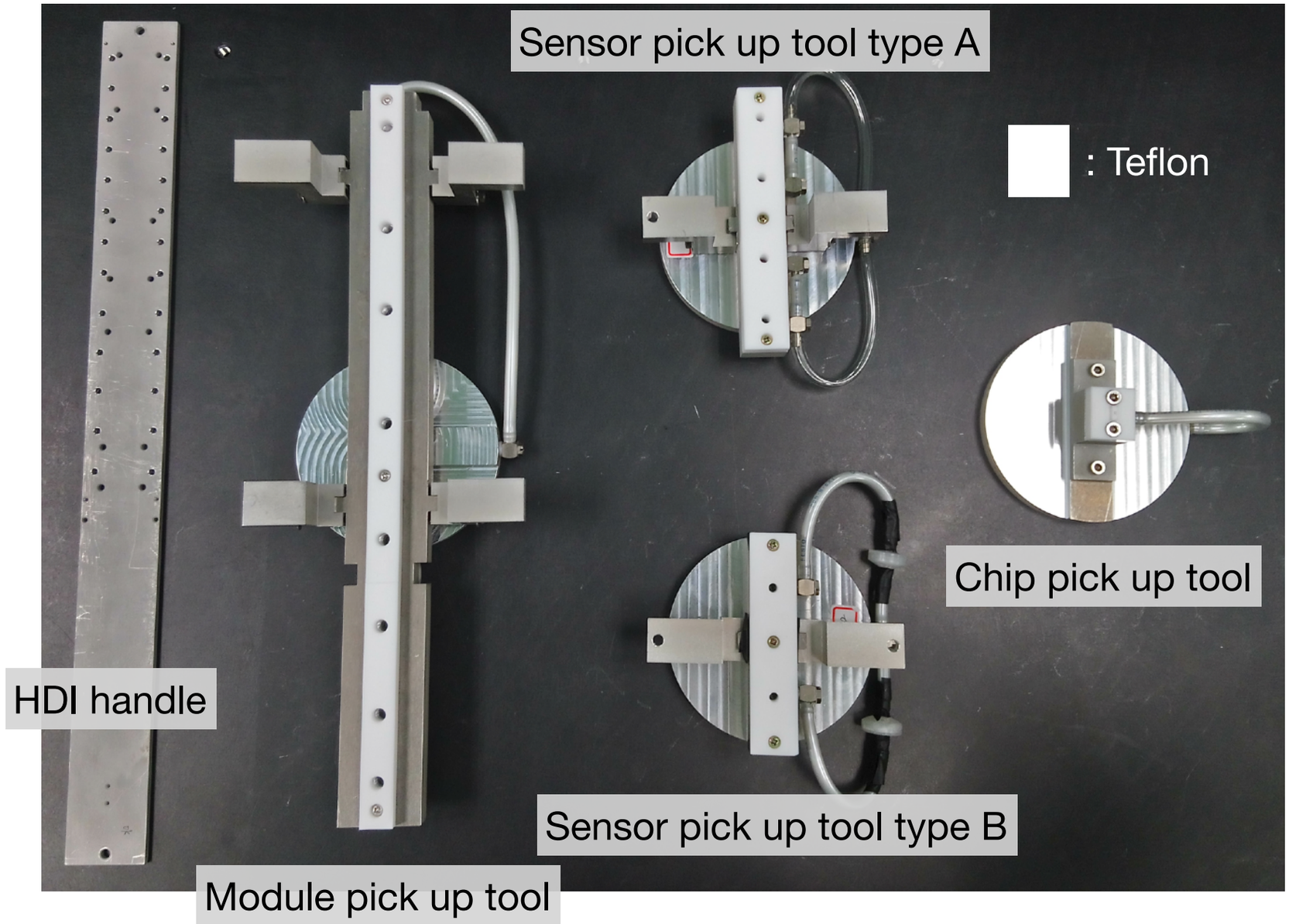
- Chip to sensor, un-bonded result
  - < 6 channels : 10 modules
  - 33 channels : 1 modules

Chip to HDI parameter

Old -> BF : 28cN, UI 28%

New -> BF : 20cN, UI 30%

# Assembly tools



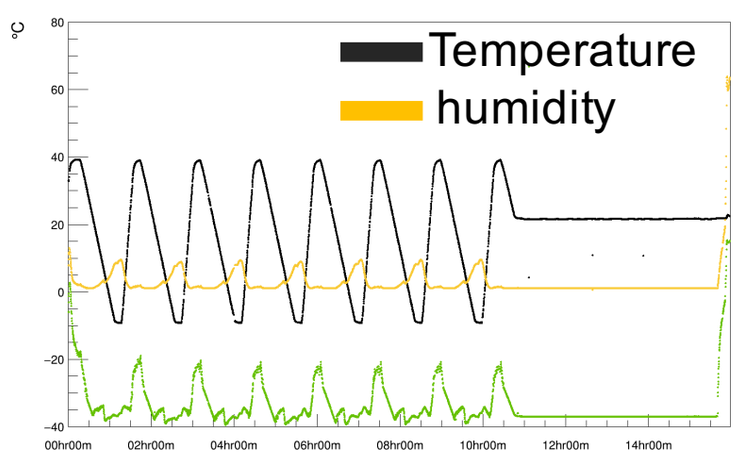
# Thermal cycle

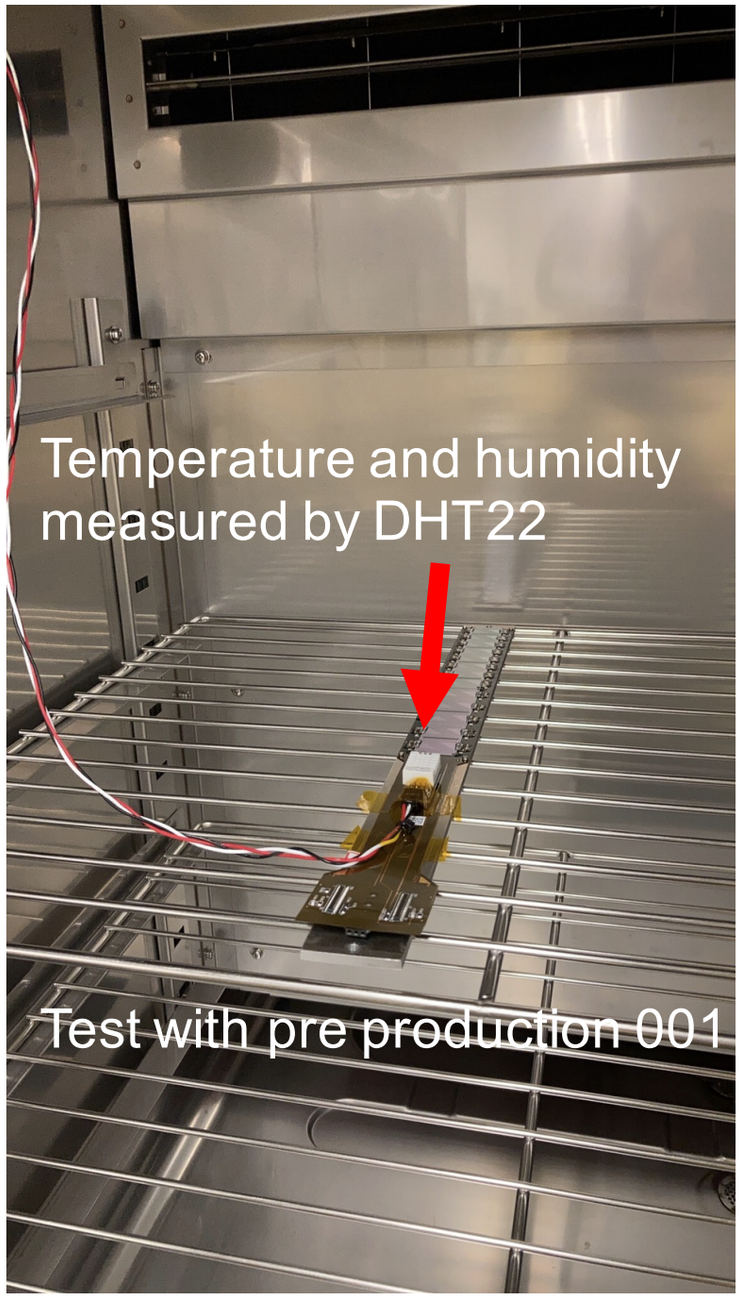
$$\text{AccelerationFactor} = \left(\frac{\Delta T_{test}}{\Delta T_{use}}\right)^{m}, \quad m = 3$$

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

- $\Delta T_{use}$ = 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

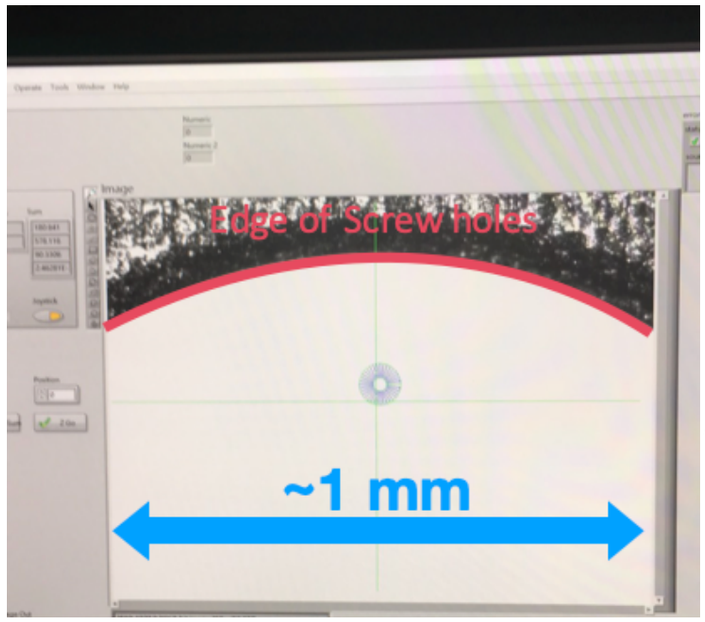
Temperature : -10 $^0C$ ~ 40 $^0C$
Heating time : 17 mins
Cooling time : 50 mins
Repeat : 7 times



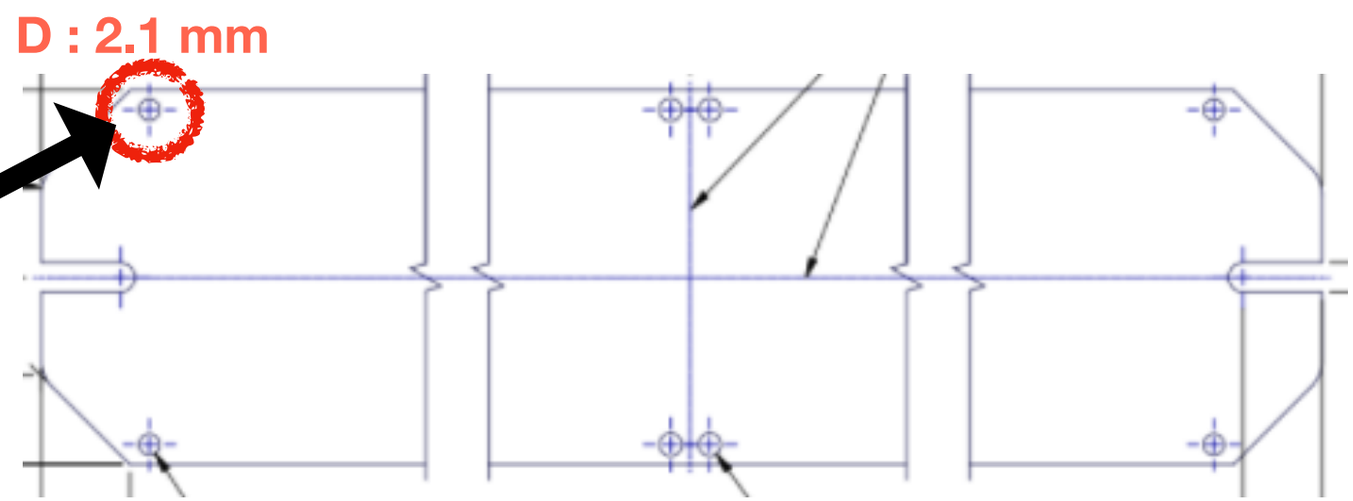



# Photo of assembled modules

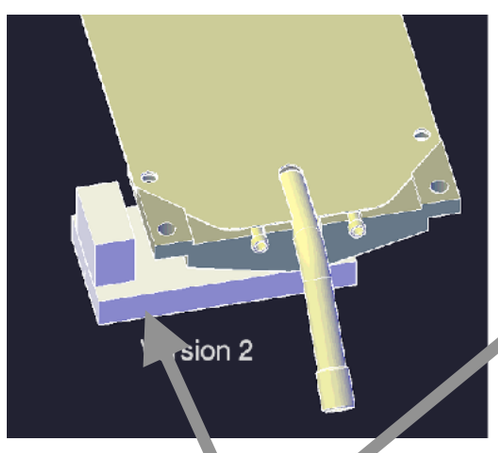
# Ladder assembly : method to measure stave

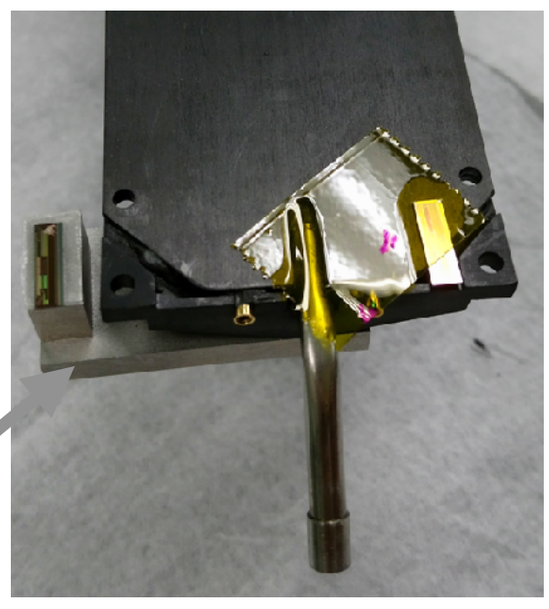



Holes on stave are too big for camera




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**

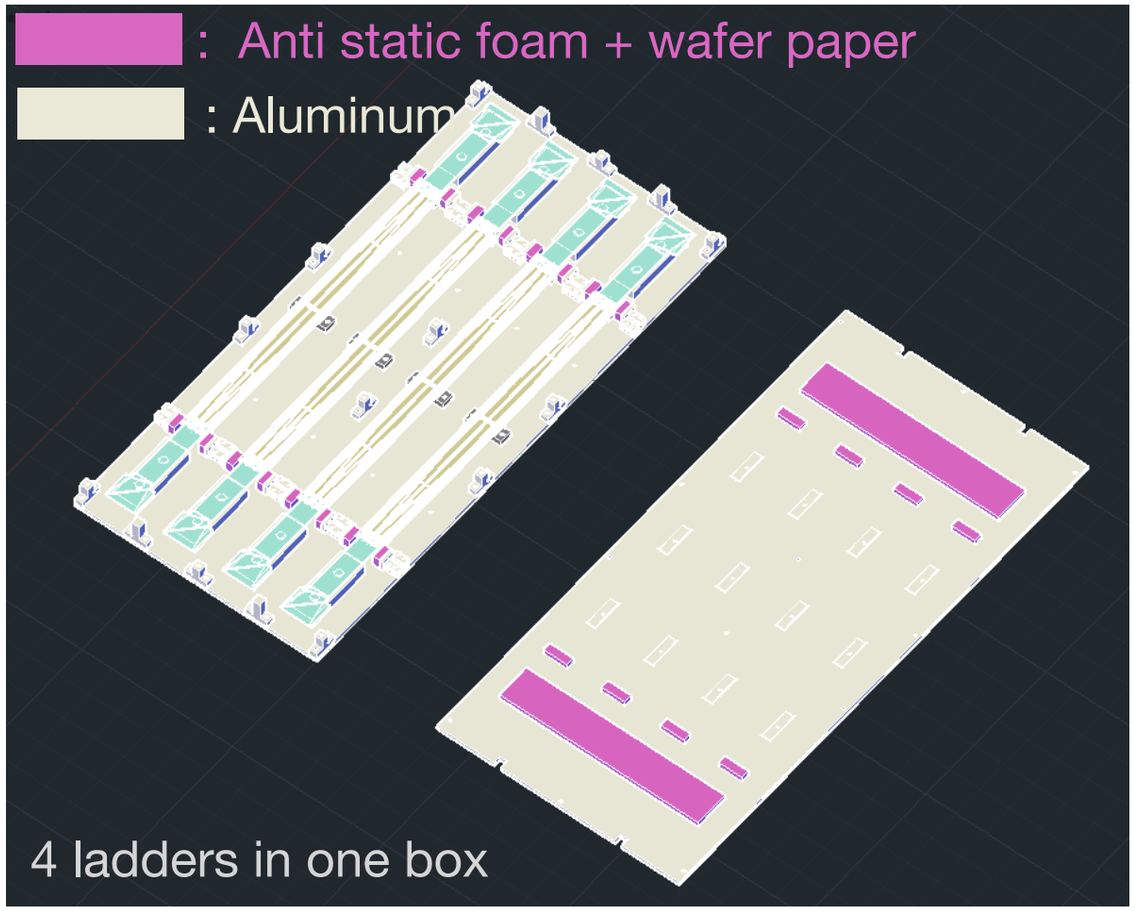
# Production tracking

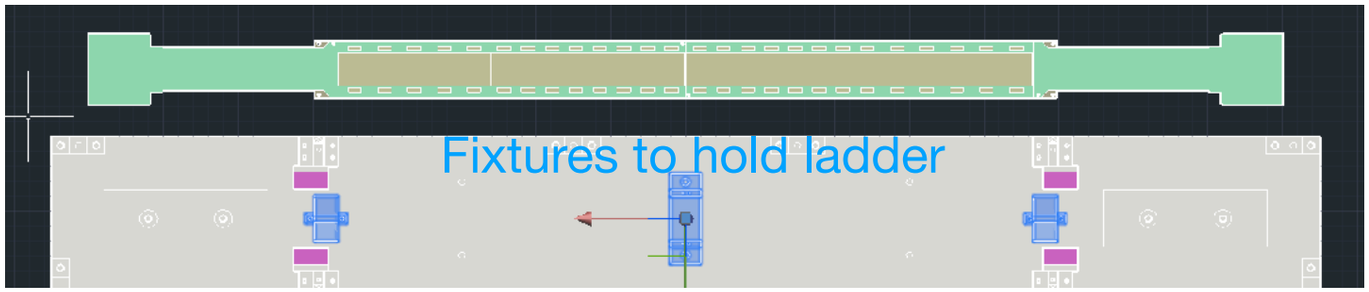
| Module ID | status | sensor ID | calibration test | HDI pads test (8 pads) | X error um (A/B) | Y error um (A/B) | rotate error rad (A/B) | bonding |
|---|---|---|---|---|---|---|---|---|
| | 0 : pad measurement<br>1 : chip to HDI<br>2 : sesnor to HDI<br>3 : post-encapsulation<br>4 : post - thermal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

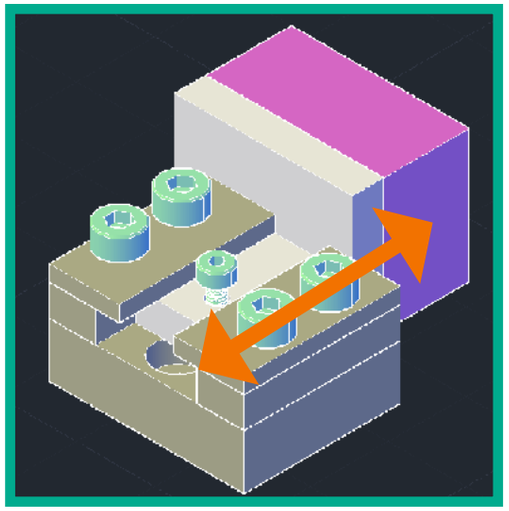
# Modules storage in Taiwan

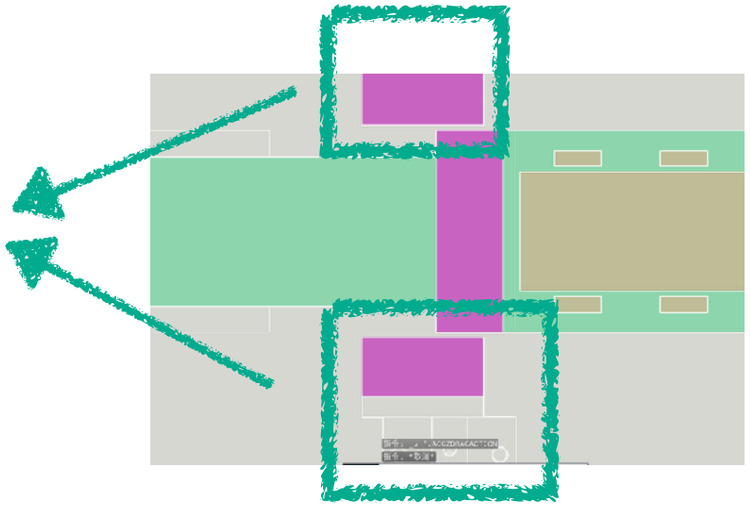
Modules are stored in clean room

# Ladder transportation & storage

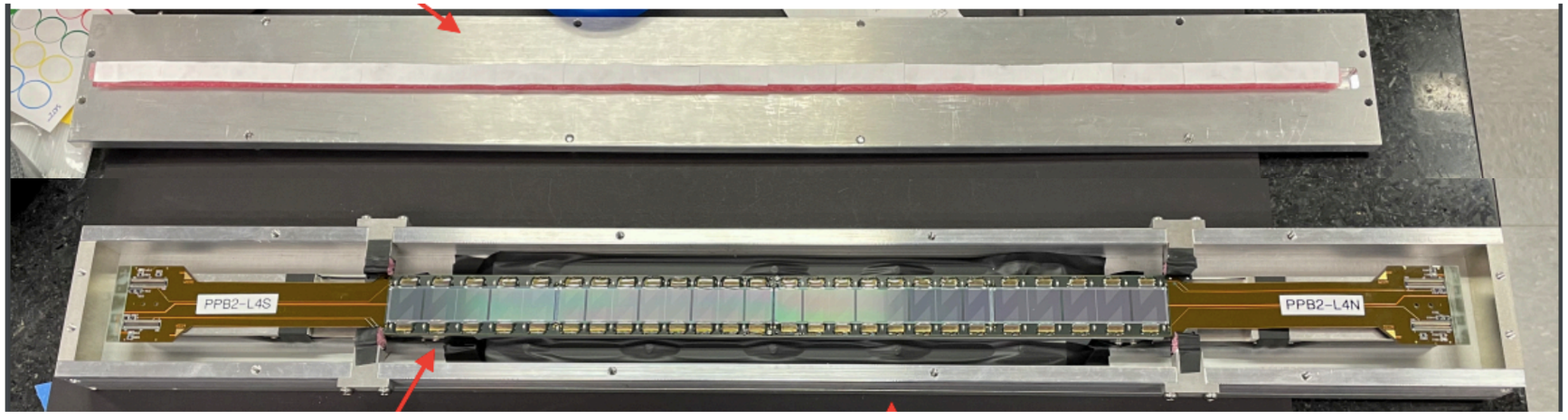




The box is capable for ladder transportation and storage

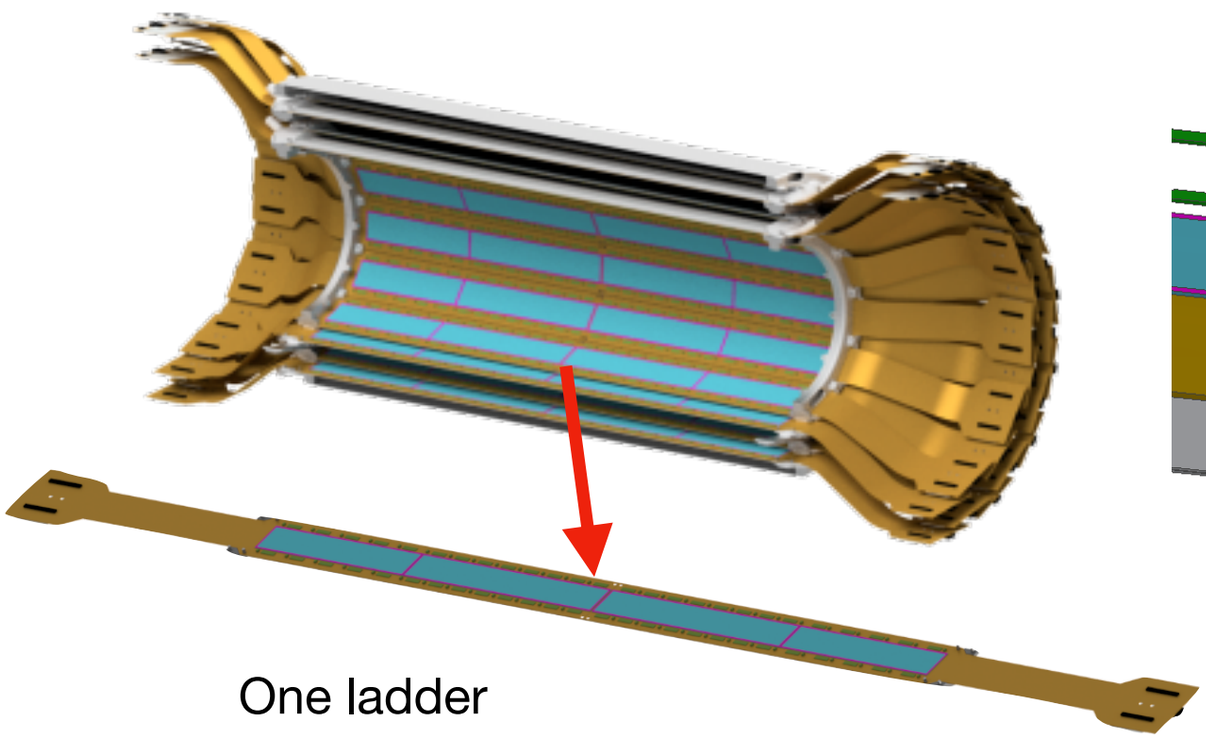


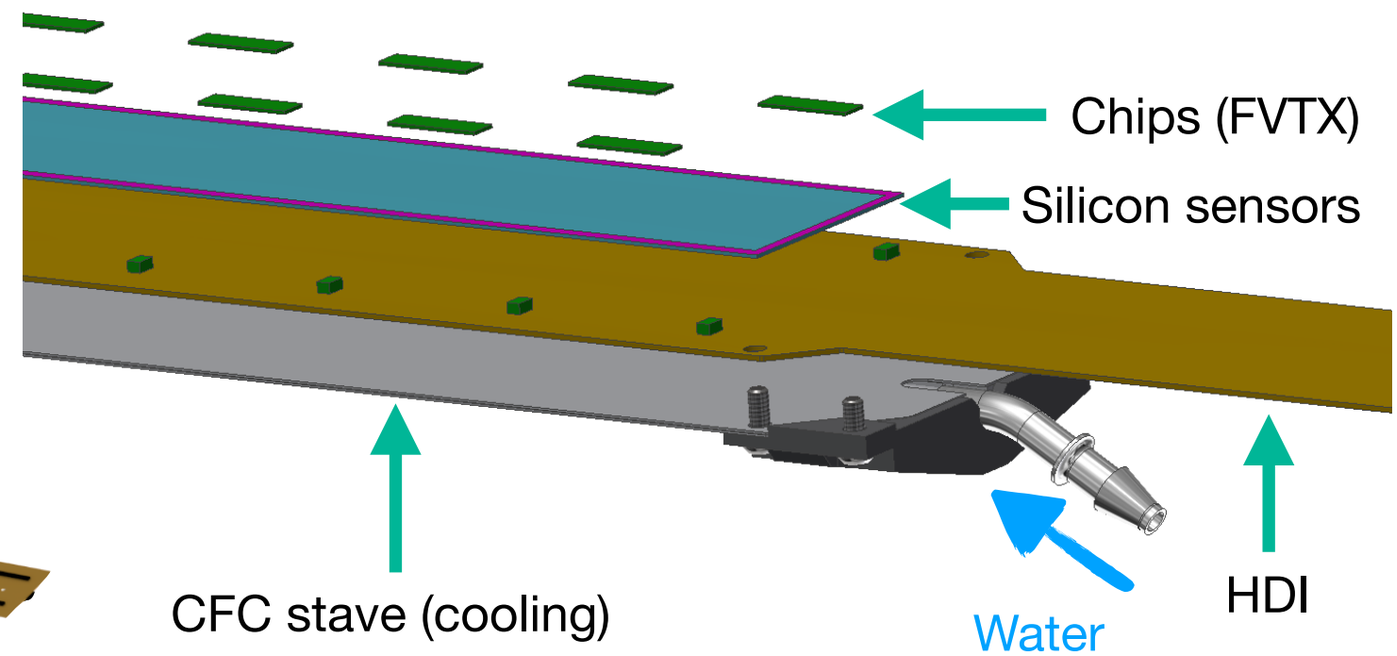

Prototype box is produced, shipping 1 ladder from BNL to NWU

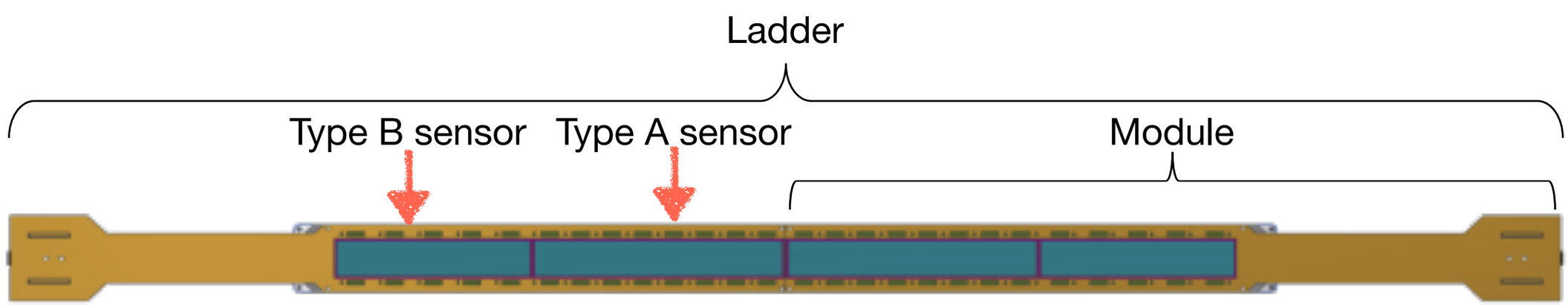
# INTermediate Tracker (INTT)

2 layers of silicon strip detector

Module = 1 HDI + 26 chips + 2 silicon sensors
Ladder = 2 modules + 1 CFC stave




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