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Institute of High Energy Physics
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Progress of HGCal module assembly @ IHEP

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On behalf of IHEP HGCal group

11/08/2020



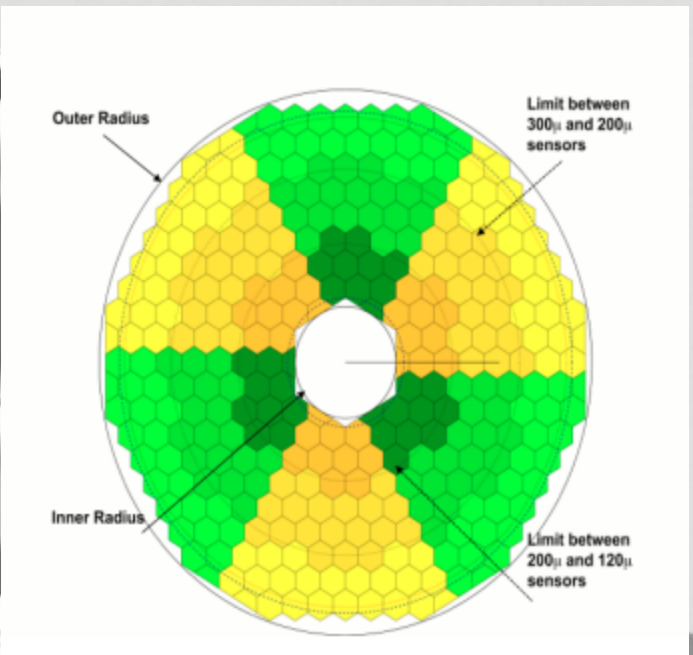
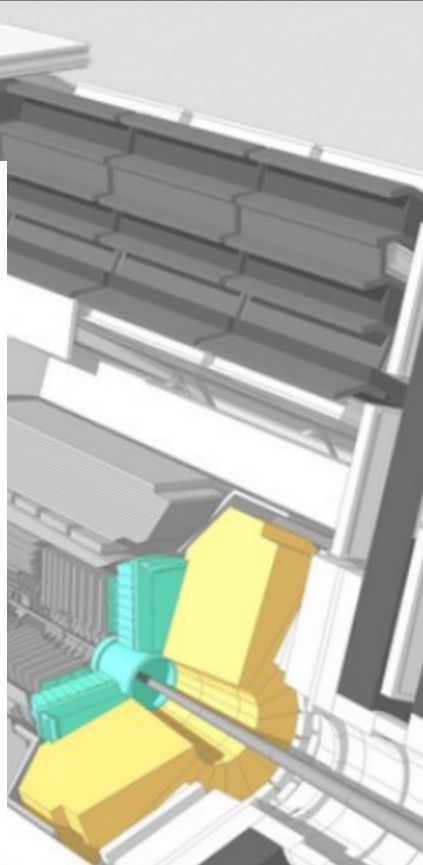
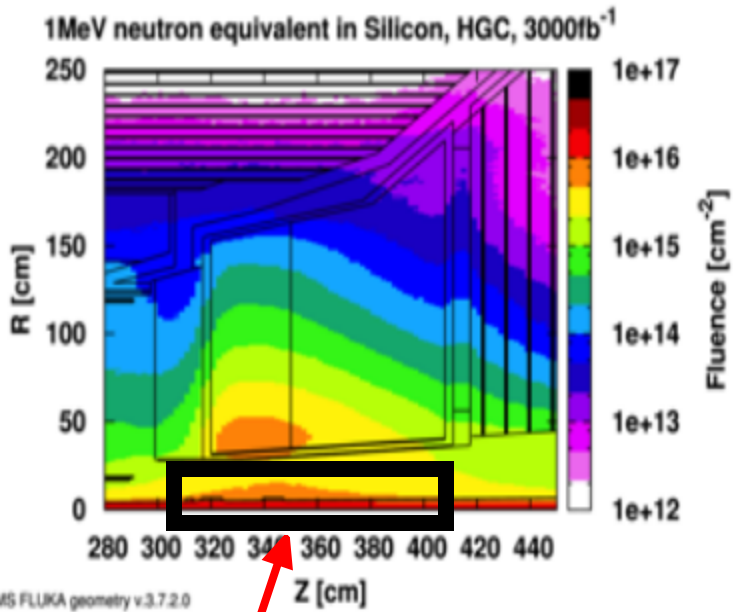
Outline



- **Introduce CMS HGCal**
 - **HGCal**
 - **Key equipment**
- **Status of HGCal module assembly**
 - **Module assembly workflows**
 - **Assembly tolerance**
 - **Status of module assembly at IHEP**
- **Summary and Plan**



CMS HGCal



Pre-shower+ECAL end-cap
 10^{16} 1 MeV neutron/cm²

CE-E 9th layer

Sensor thickness optimized vs radiation hardness

Whole calorimeter will be operated at -30°C



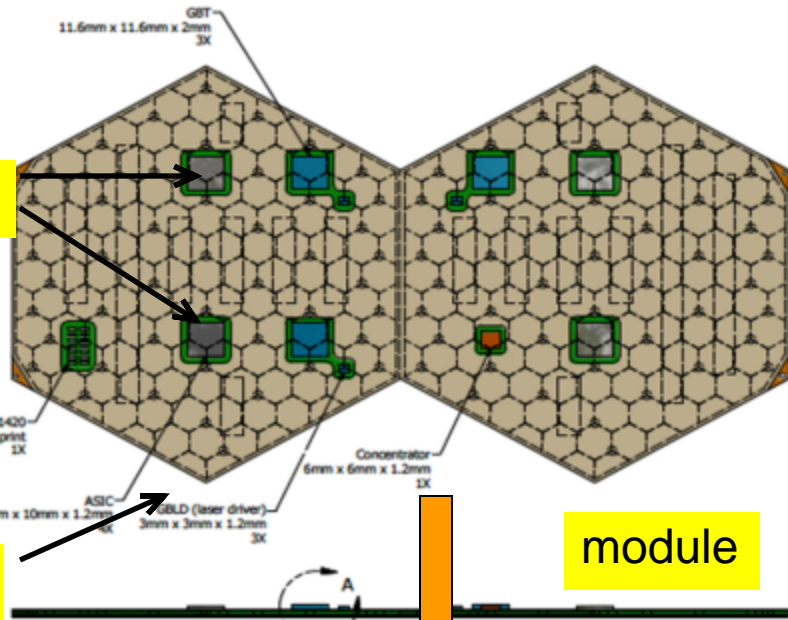
Contracture of CMS end-cap calorimeter



Construction:

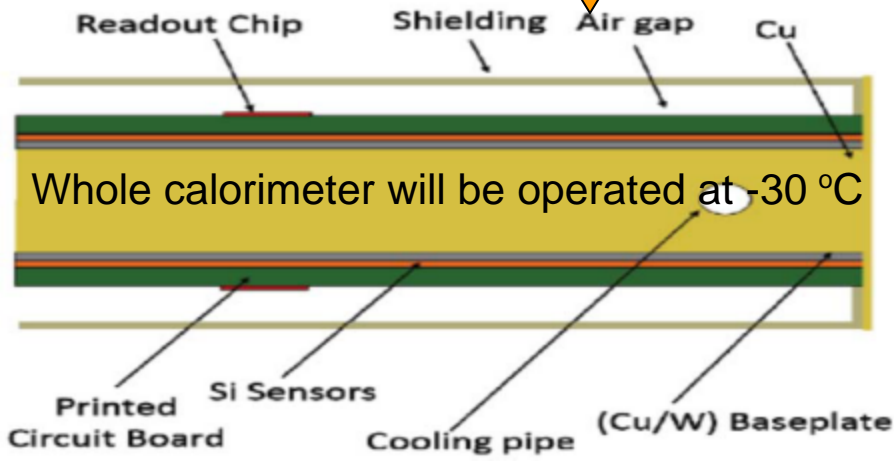
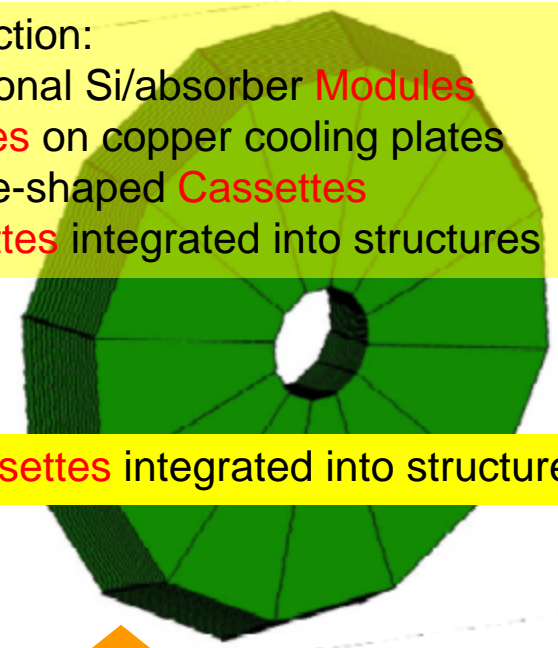
- Hexagonal Si/absorber **Modules**
- **Modules** on copper cooling plates wedge-shaped **Cassettes**
- **Cassettes** integrated into structures

FE-ASICs



Si sensor

Cassettes integrated into structures



Modules on Cu cooling plate

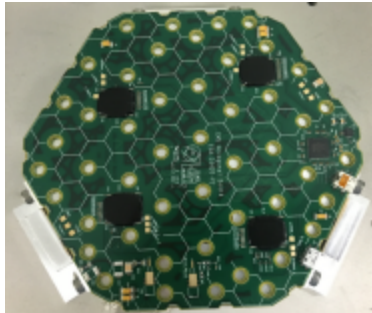
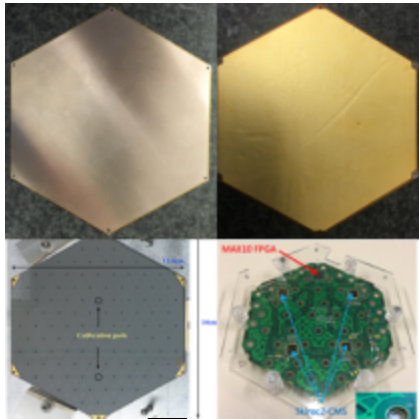
Wedge-shaped **Cassette**



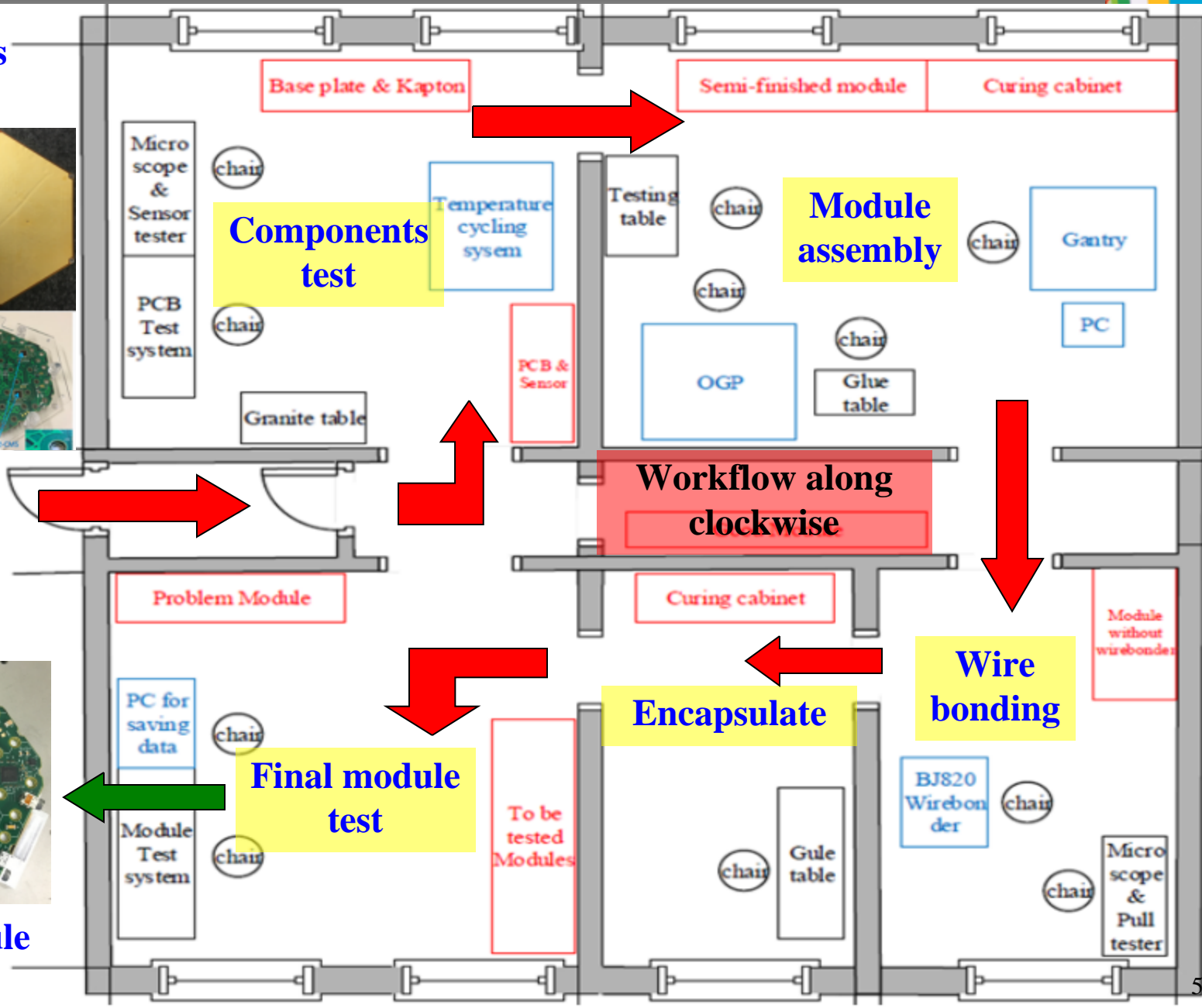


Module production workflows

Components of module



HGCal module

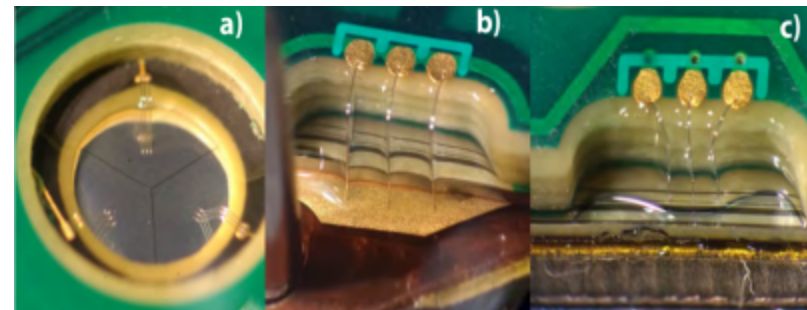
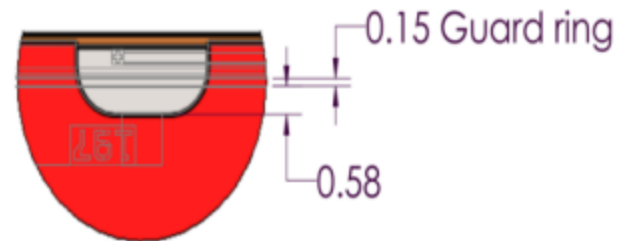
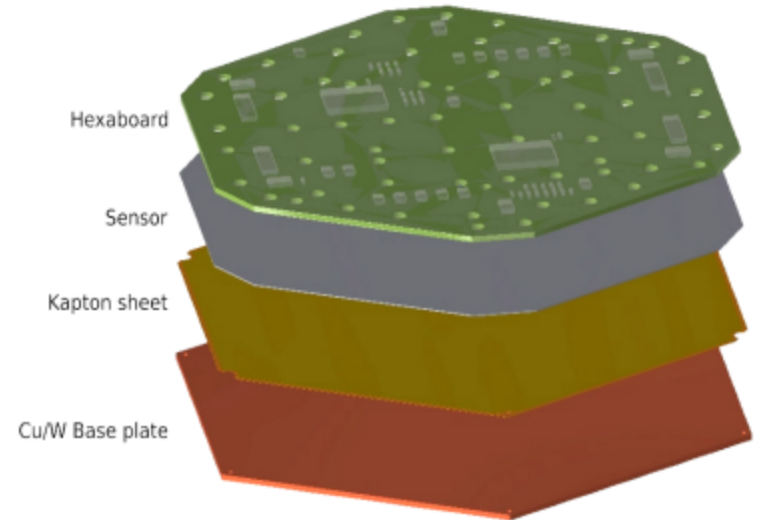




Module assembly requirements



- Dispense
 - Coverage area over 70%
 - The assembly procedure maintains an epoxy layer thickness of $75\mu\text{m}$
- Flatness & Alignment
 - Flatness of each layer should be more than $\pm 50\mu\text{m}$ for next glue dispense and wirebond
 - The each edge of the silicon is about $150\mu\text{m}$ away from the edge of the baseplate to protect silicon wafer
 - The tolerance for PCB placement in the horizontal and vertical directions is $\pm 75\mu\text{m}$.
- Wirebond
 - Three wire bonding per pixel pull strengths $\sim 0.1\text{N}$ (10g)
 - A nominal 128 channel module requires over 400 wirebond wires
 - Over 4000 wire need to be bond per day during mass production
- Encapsulation
 - All of the wirebonds are then encapsulated with Sylgard 186, a clear silicon elastomer with very high radiation tolerance





Tolerances



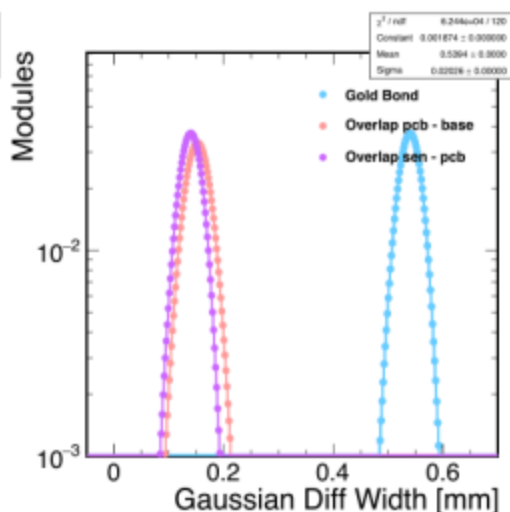
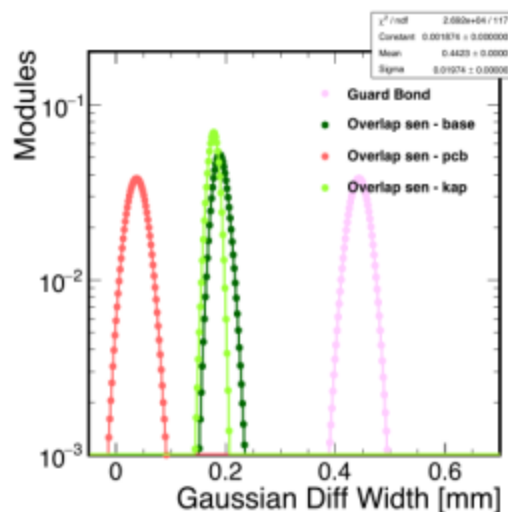
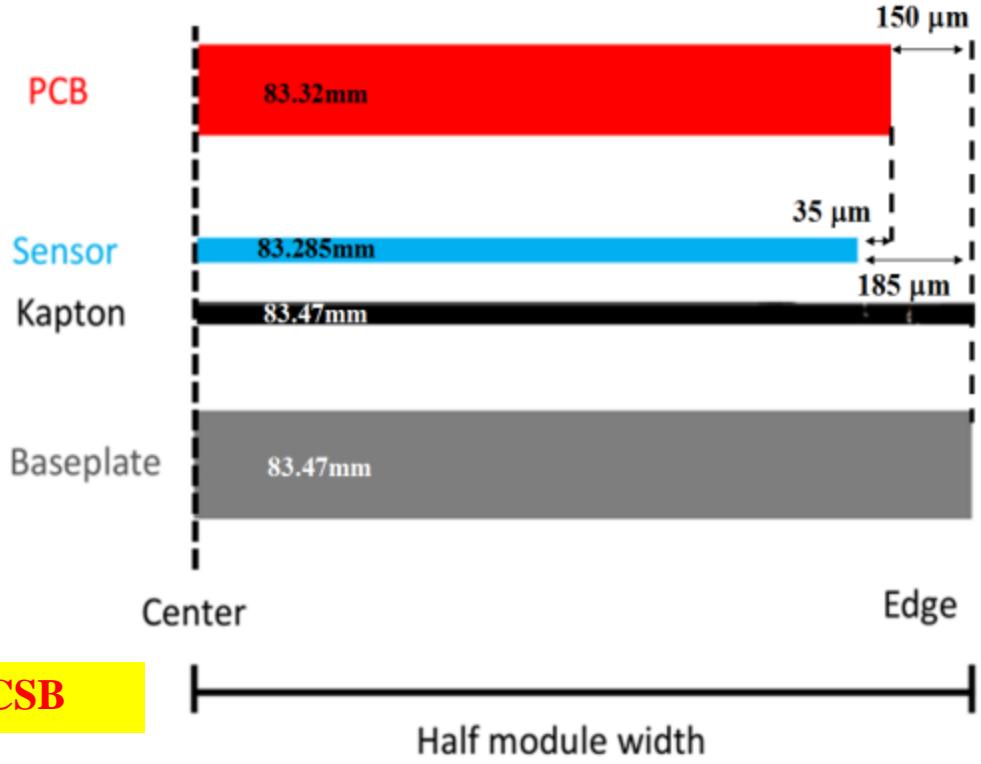
Inputs

- Baseplate=166.94±0.05mm
- Kapton=166.94±0.05mm
- Sensor=166.57±0.02mm
- Center=3.05±0.05mm
- PCB placement=±0.04mm
- sensor placement =166.94±0.05mm

Nominal values for alignment

- Guard Area: 695 m
- Gold Area: 800 m
- PCB-to-Baseplate: 150 m
- Sensor-to-Baseplate: 185 m
- Sensor-to-PCB: 35 m

UCSB



Tolerances simulated by Gaussian distribution

- Guard Area: 442.3±19.7 m
- Gold Area: 539.4±20.3 m
- PCB-to-Baseplate: 152.6±22.6 m
- Sensor-to-Baseplate: 190.2±14.5 m
- Sensor-to-PCB: 37.7 ±19.6 m



Tolerances



- Components

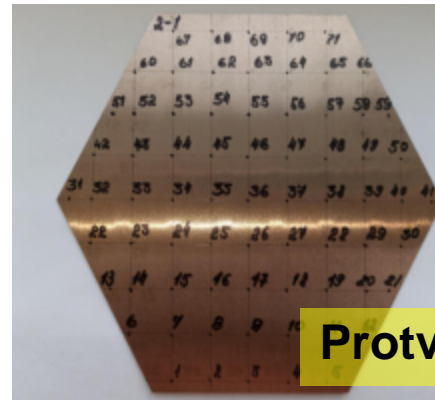
- The sensors and Au-Kapton sheets are manufactured very flat and uniform
- The baseplate is the main source of non-uniformities

- Gantry

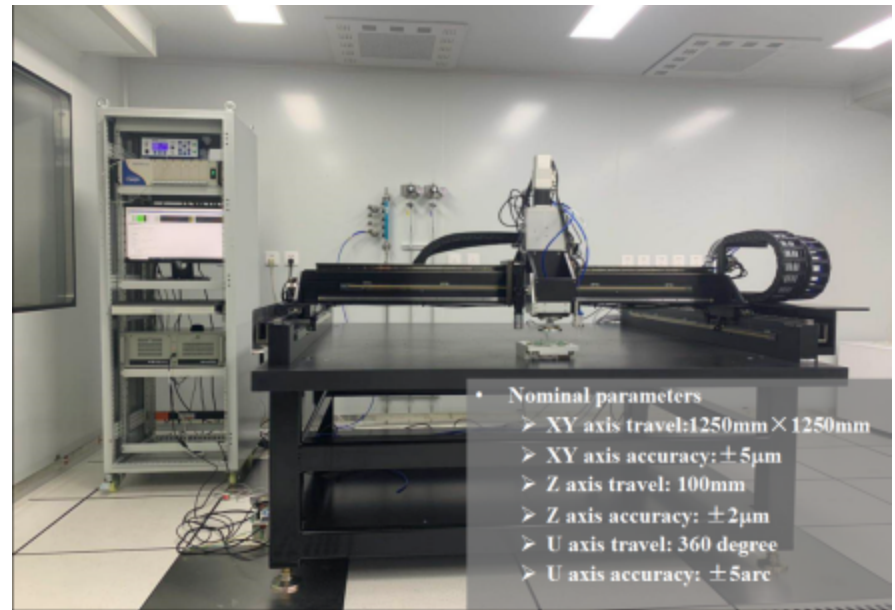
- XY axis accuracy: $\pm 5 \text{ m}$
- Z axis accuracy: $\pm 2 \text{ m}$
- U axis accuracy: $\pm 5 \text{ arc}$
- The optical system detects fiducial marks in the ranging from 50 to 150 μm with recognition precision better than 5 m .

- Tools

- Flatness of assembly tool could be manufactured about $\pm 20 \text{ m}$



Measured plate deviation from the plane (non-flatness) for prefabricated baseplates ranged from 0.000 to 0.212 m.



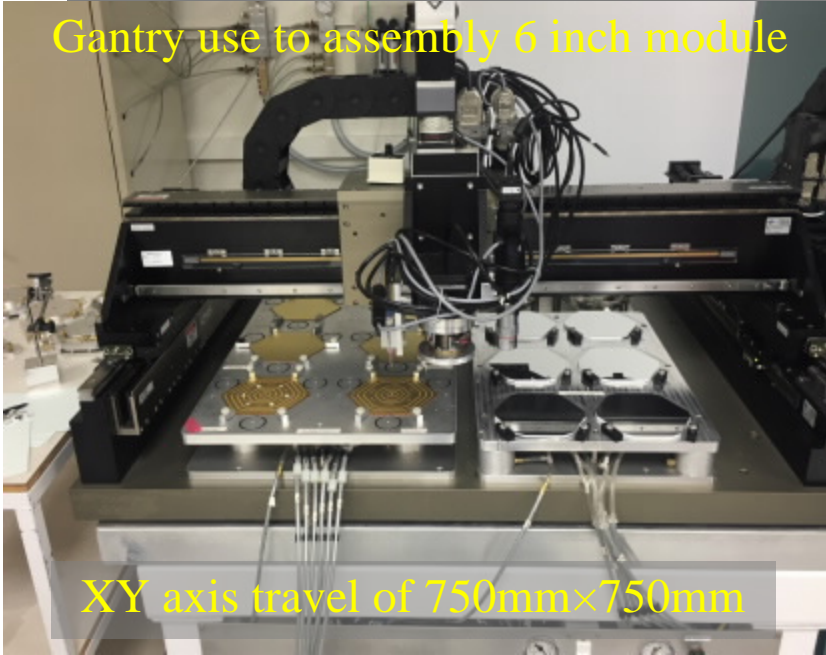
- Nominal parameters
 - XY axis travel: 1250mm × 1250mm
 - XY axis accuracy: $\pm 5 \mu\text{m}$
 - Z axis travel: 100mm
 - Z axis accuracy: $\pm 2 \mu\text{m}$
 - U axis travel: 360 degree
 - U axis accuracy: $\pm 5 \text{ arc}$



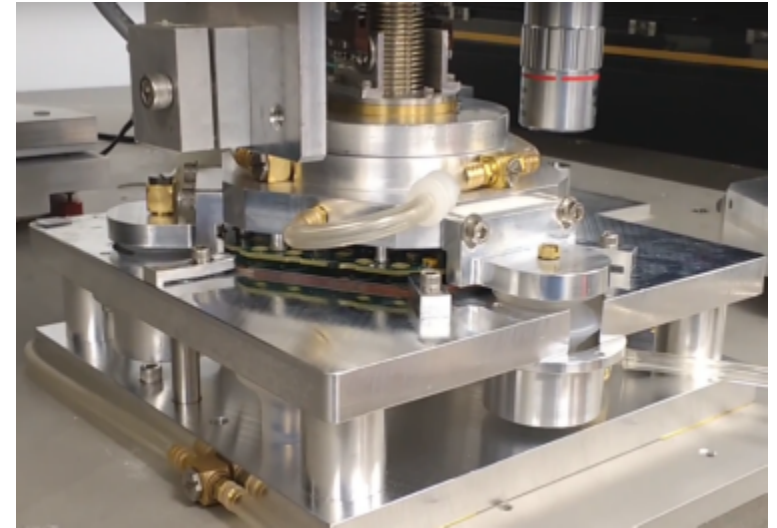
Module assembly @UCSB



Gantry use to assembly 6 inch module

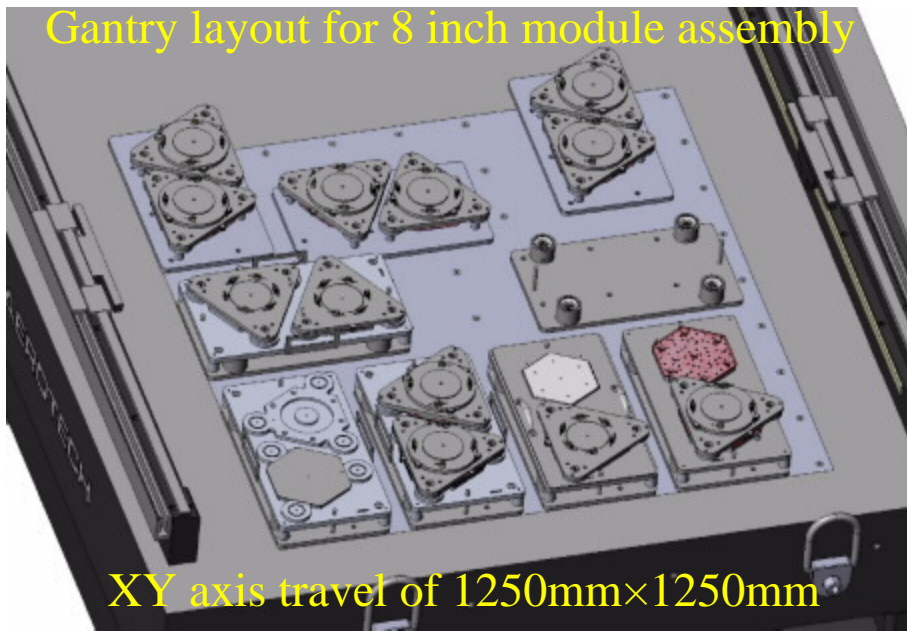


XY axis travel of 750mm×750mm



- **A robotic pick-and-place gantry is used to assembly HGCal module**
 - Optical system detects fiducial marks
 - Vacuum system pick-and-place component
 - Glue dispenser used for epoxy dispensing
 - Glue dispensing for six module with 6 inch per one run
 - New gantry with XY axis travel of 1250mm×1250mm will arrival at UCSB for 8 inch module assembly

Gantry layout for 8 inch module assembly



XY axis travel of 1250mm×1250mm



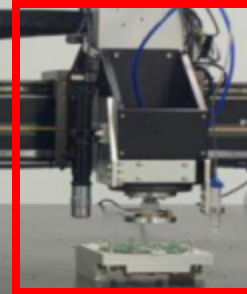
Gantry @ IHEP



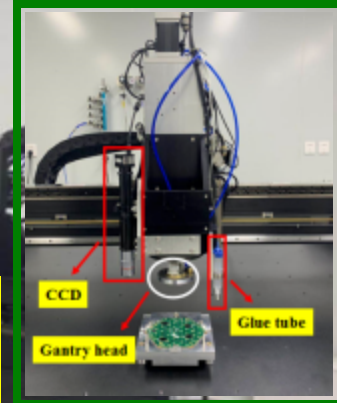
High precision dispenser



High pressure & vacuum system



Vision system

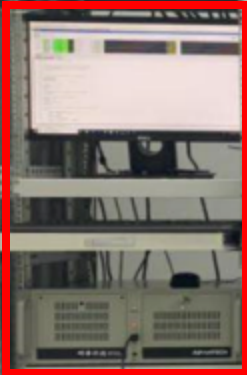


CCD

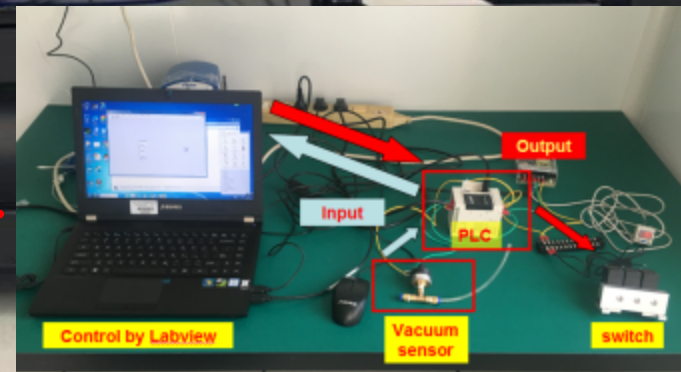
Gantry head

Glue tube

Gantry control



Vacuum control



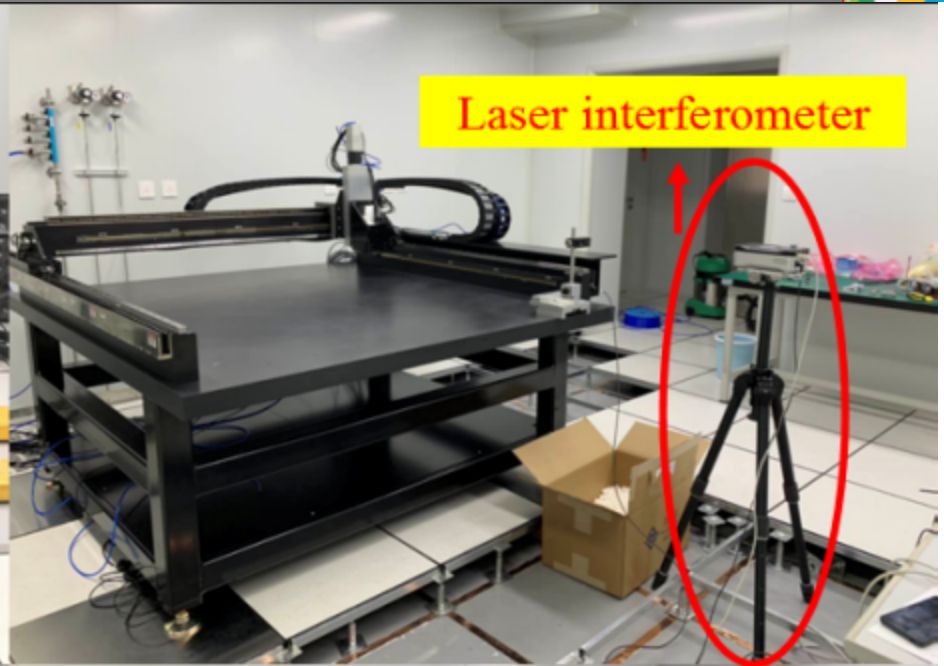
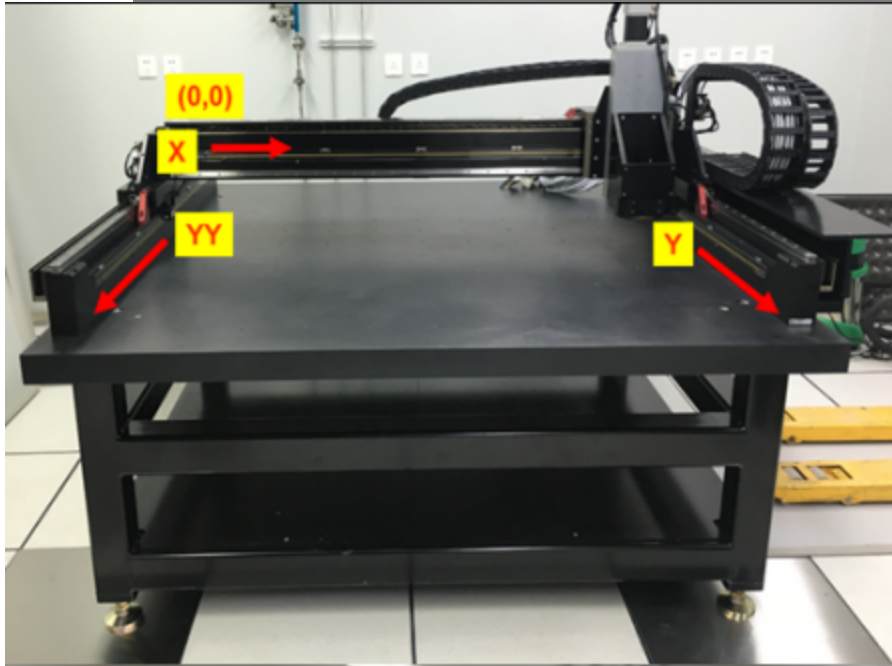
Control by Labview

Vacuum sensor

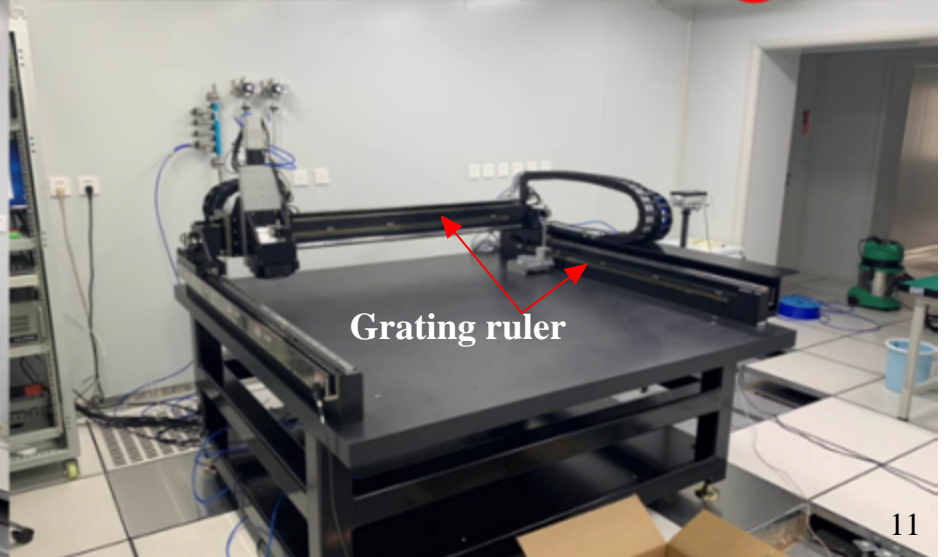
switch



Calibration



YY Axis calibration

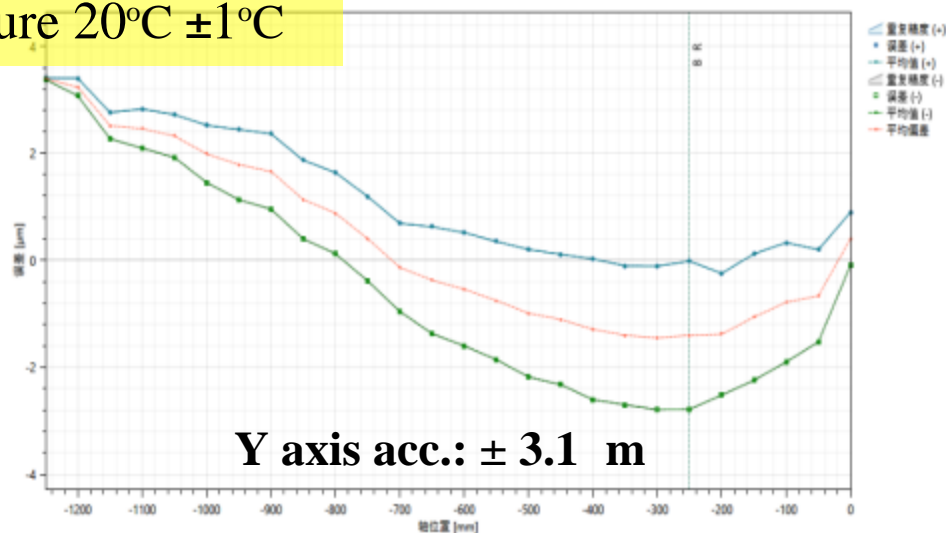
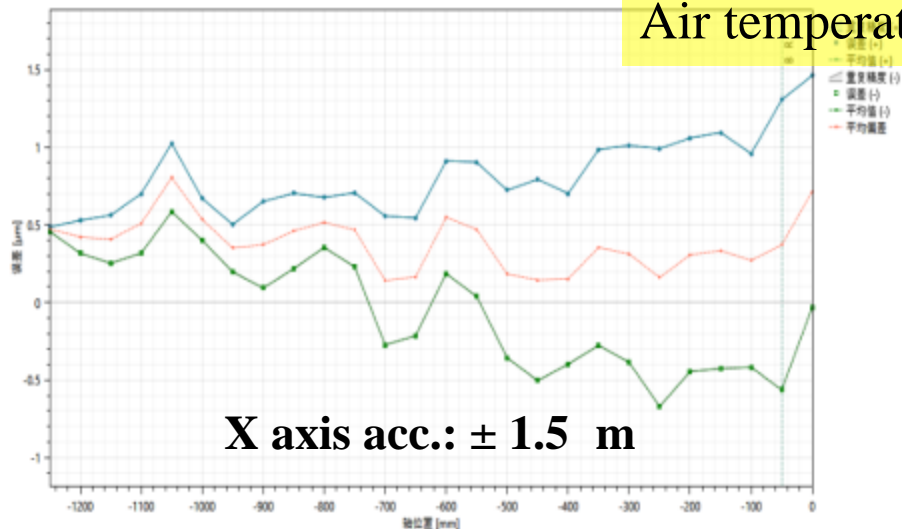


X Axis calibration



Position accuracy of XYZ axis (1D)

Air temperature 20°C ±1°C



轴位和垂直轴位不确定度条件: 1.测试法

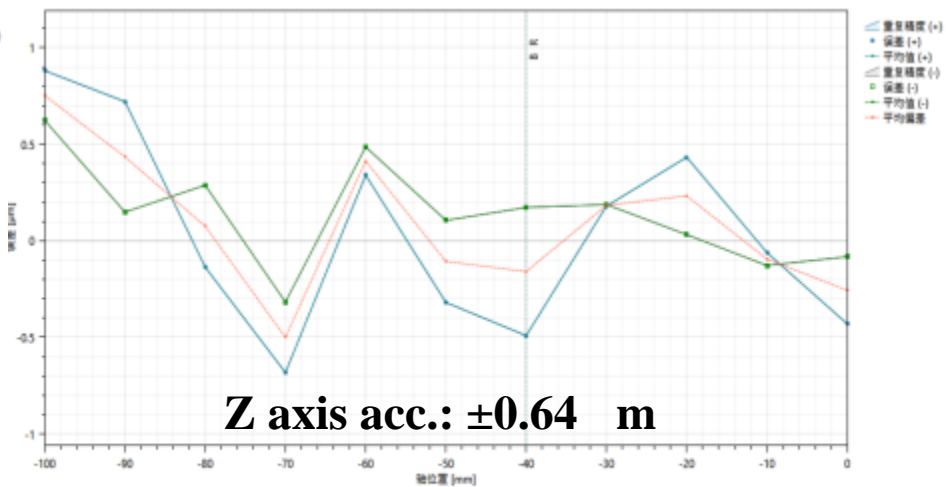
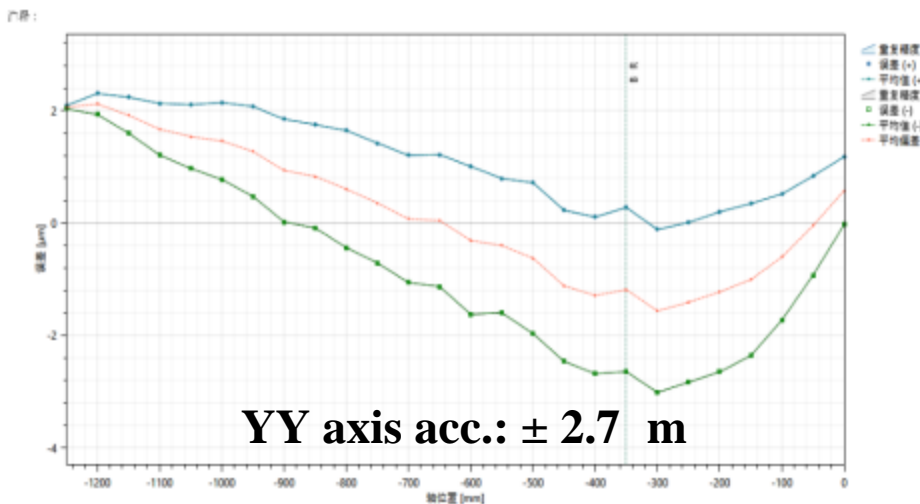
名称	(+) μm	(-) μm	(Bidir) μm
精度 (A)			
偏差精度 (R)	0.98	1.26	2.13
系统偏差 (E)			

名称	位 (μm)
误差 (B)	1.87
平均误差	0.87
平均偏差 (M)	0.66

轴位和垂直轴位不确定度条件: 1.测试法

名称	(+) μm	(-) μm	(Bidir) μm
精度 (A)			
偏差精度 (R)	3.65	6.17	6.20
系统偏差 (E)			

名称	位 (μm)
误差 (B)	2.77
平均误差	1.68
平均偏差 (M)	4.84



轴位和垂直轴位不确定度条件: 1.测试法

名称	(+) μm	(-) μm	(Bidir) μm
精度 (A)			
偏差精度 (R)	2.42	5.05	5.32
系统偏差 (E)			

名称	位 (μm)
误差 (B)	2.92
平均误差	1.97
平均偏差 (M)	3.68

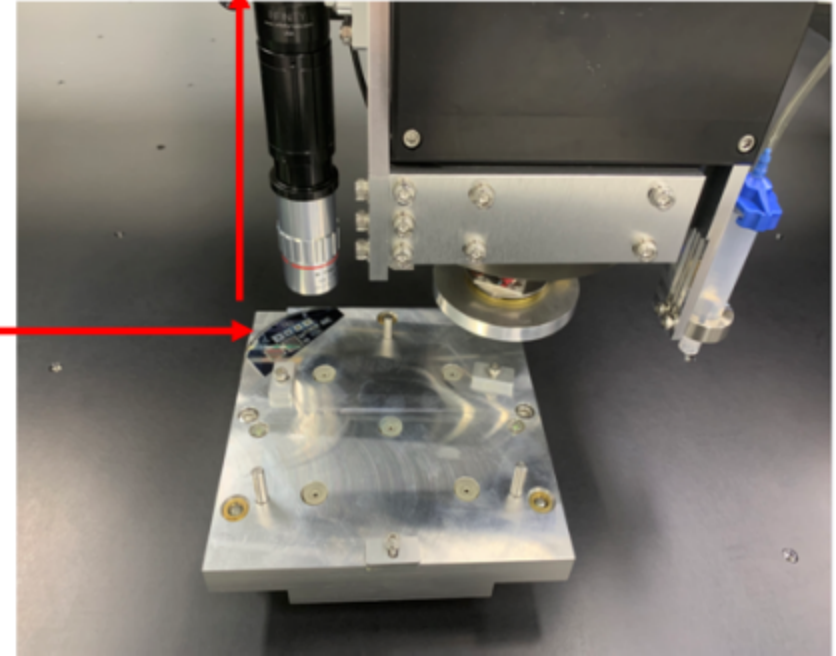
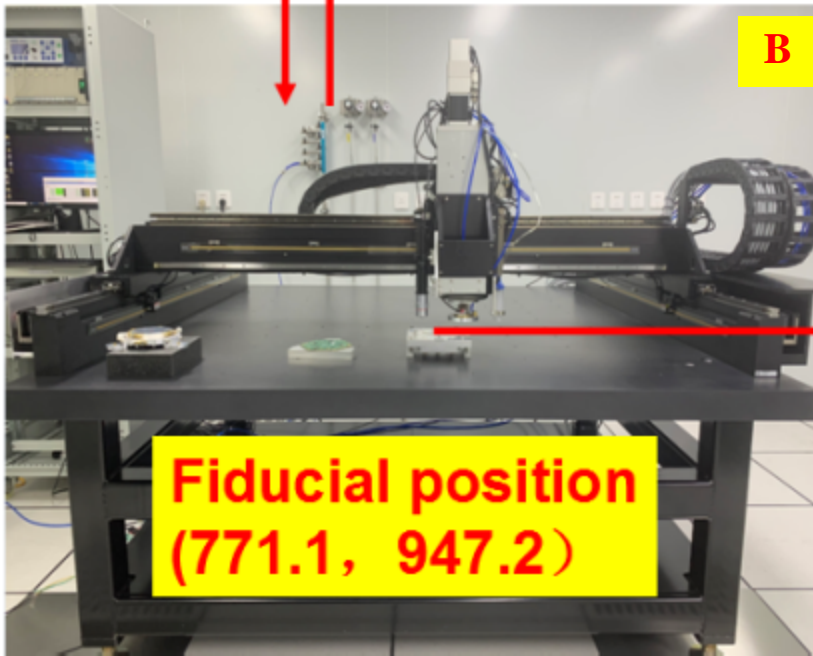
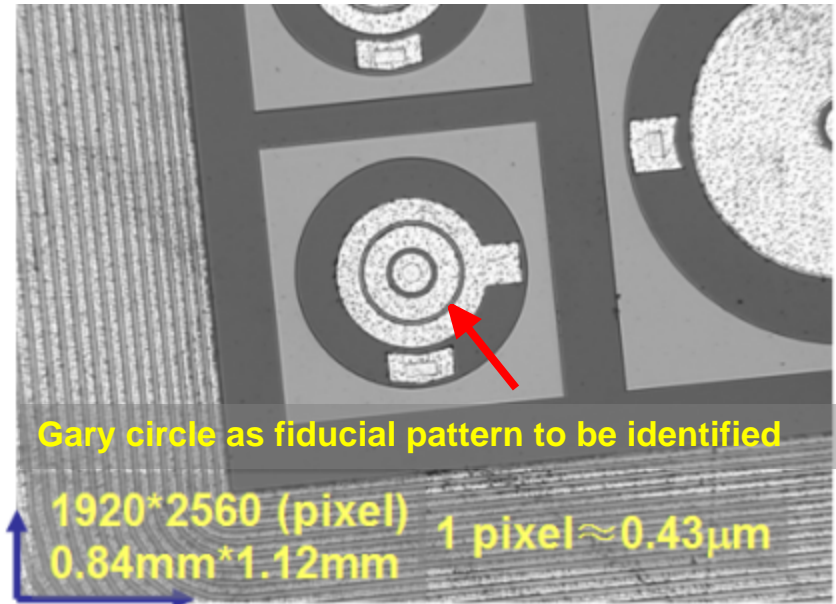
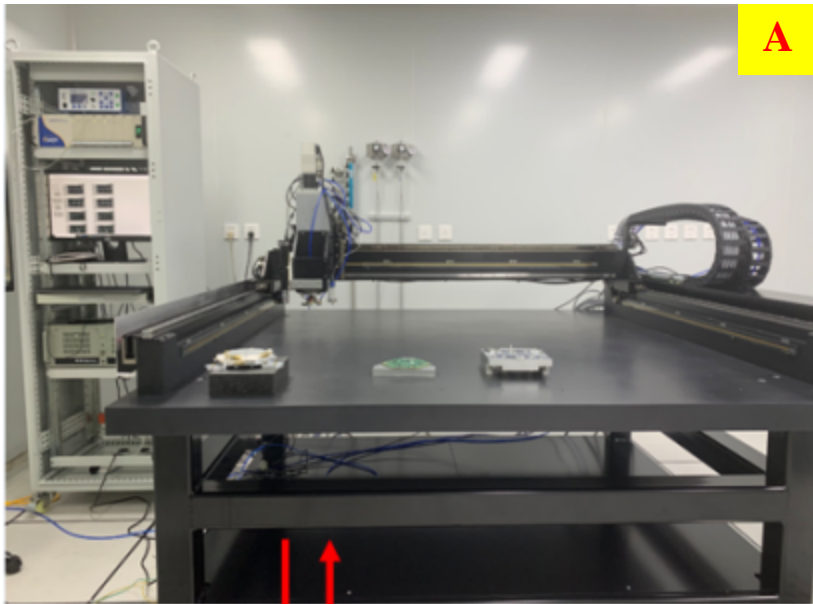
轴位和垂直轴位

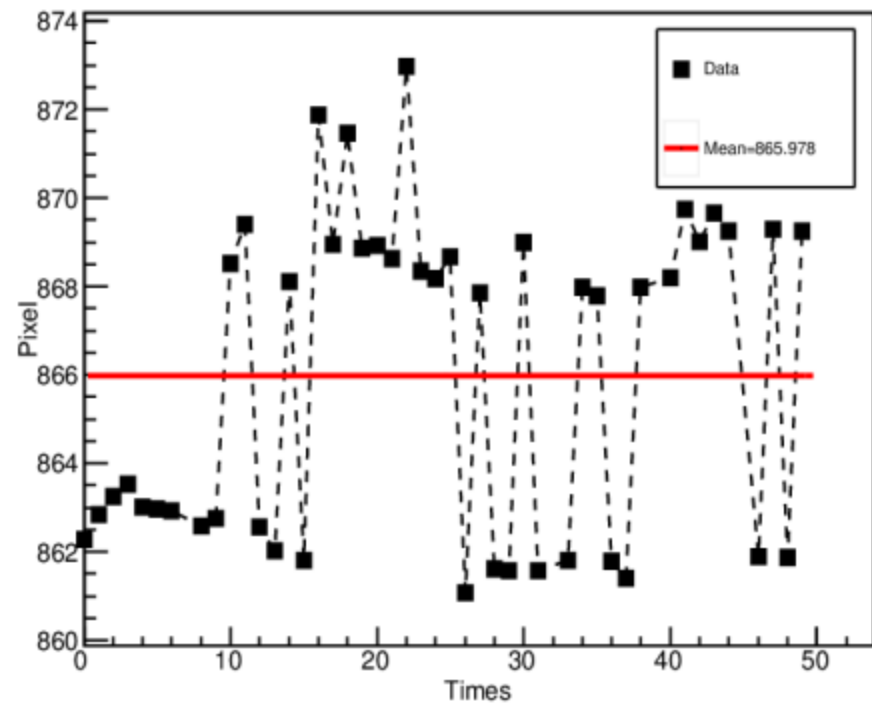
	(+) μm	(-) μm	(Bidir) μm
(A)			
精度 (R)			
偏差 (E)	1.56	0.94	1.56

名称	位 (μm)
误差 (B)	0.68
平均误差	-0.10
平均偏差 (M)	1.25

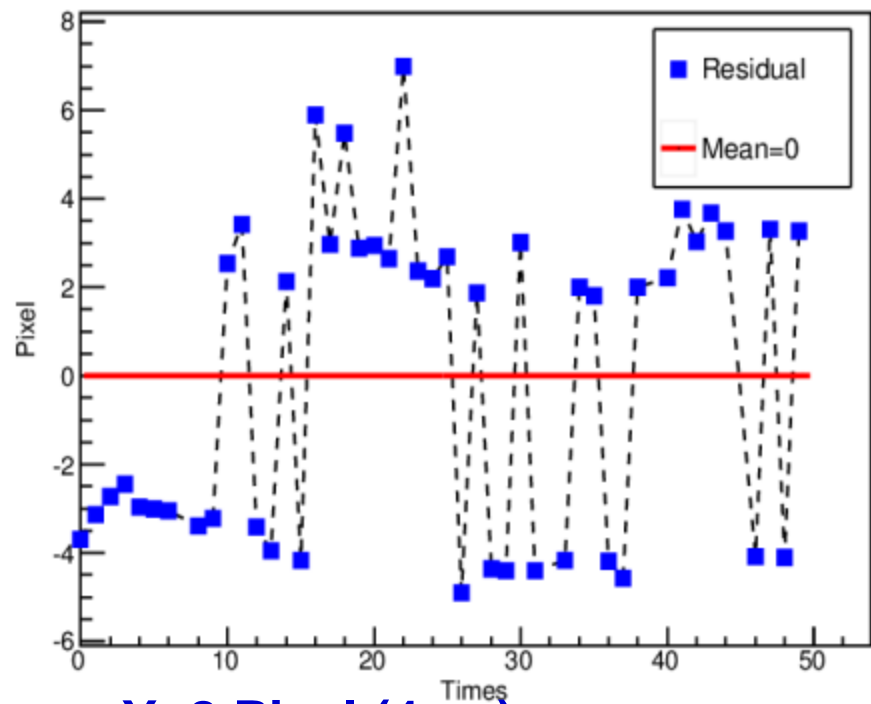


Pattern recognition precision

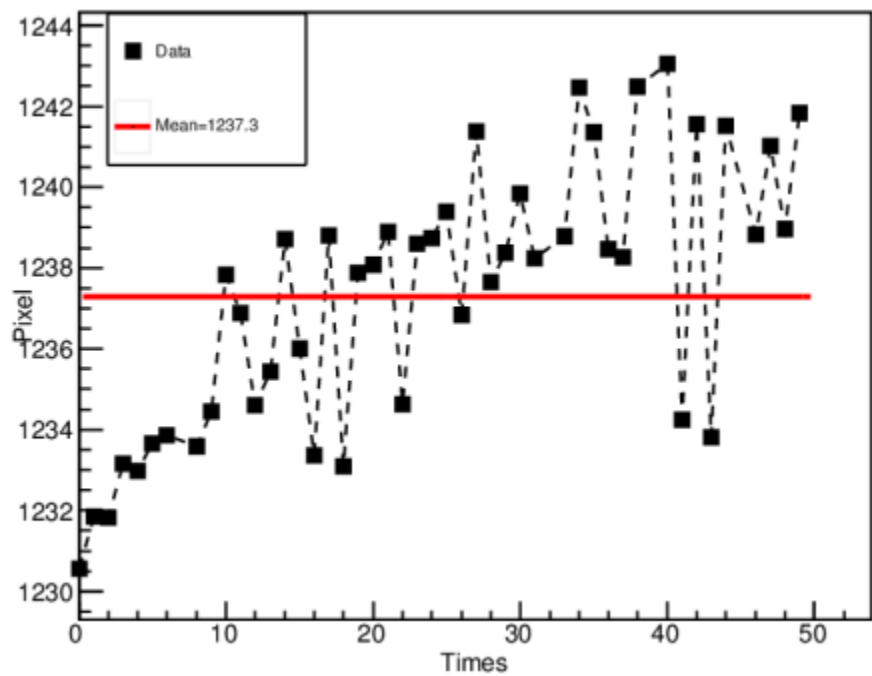




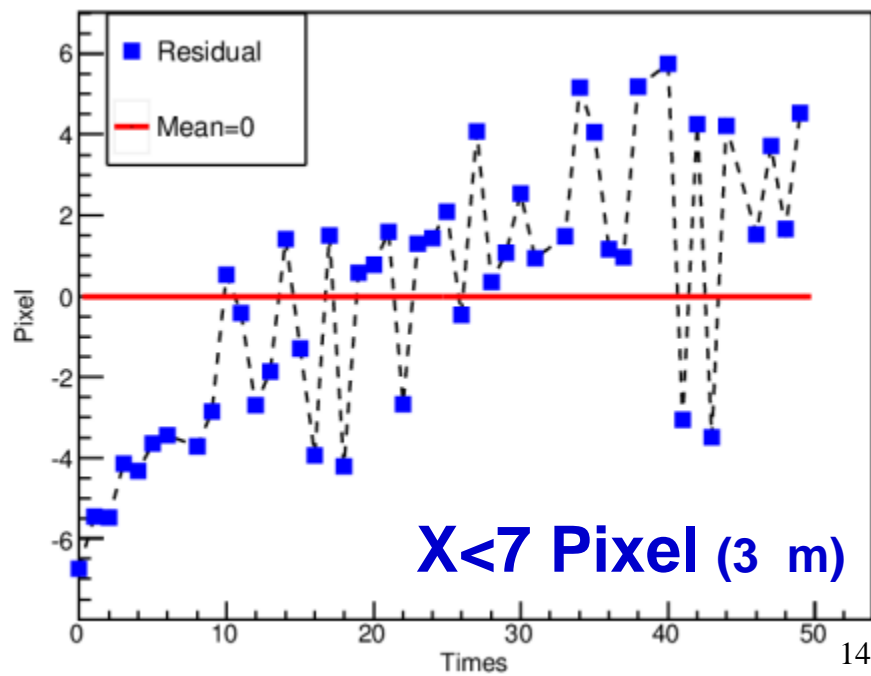
Y



Y < 8 Pixel (4 m)



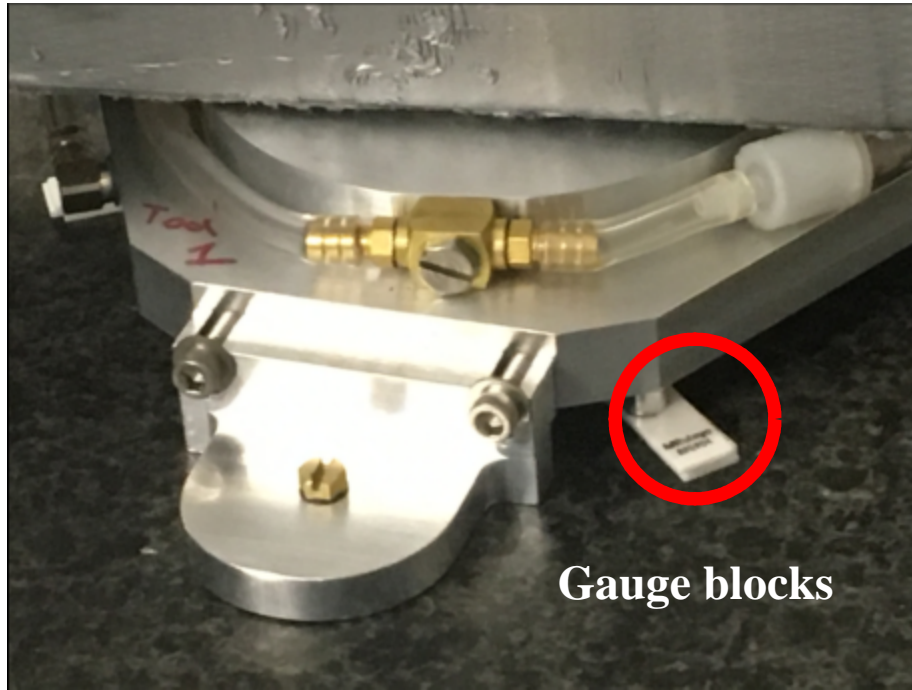
X



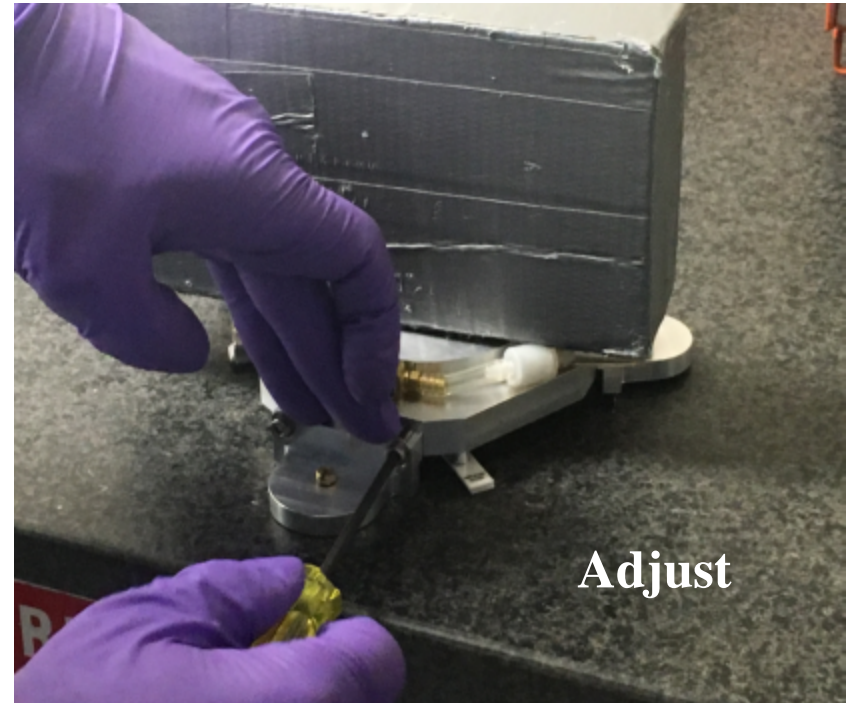
X < 7 Pixel (3 m)



Thickness control



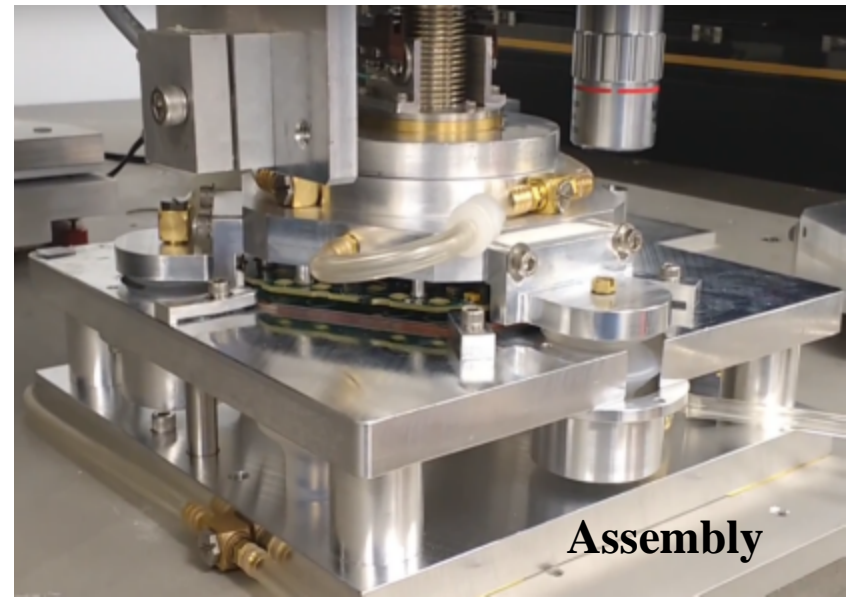
Gauge blocks



Adjust

- **Steps**

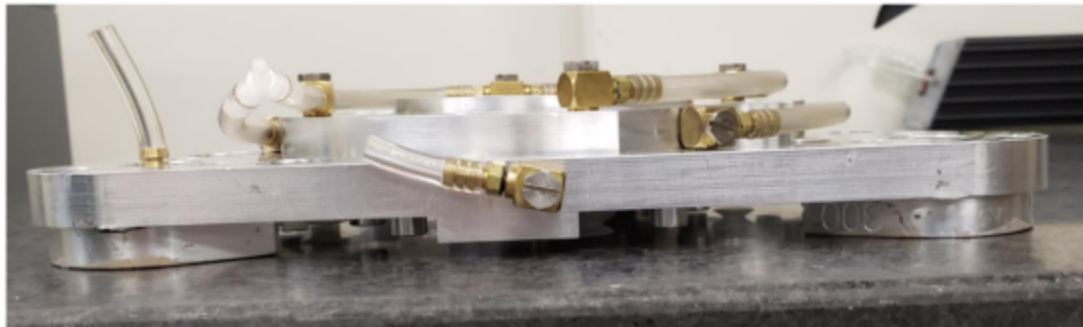
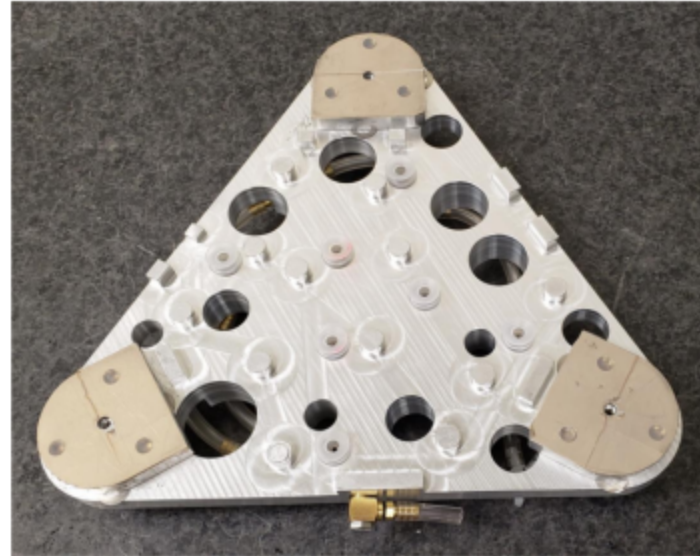
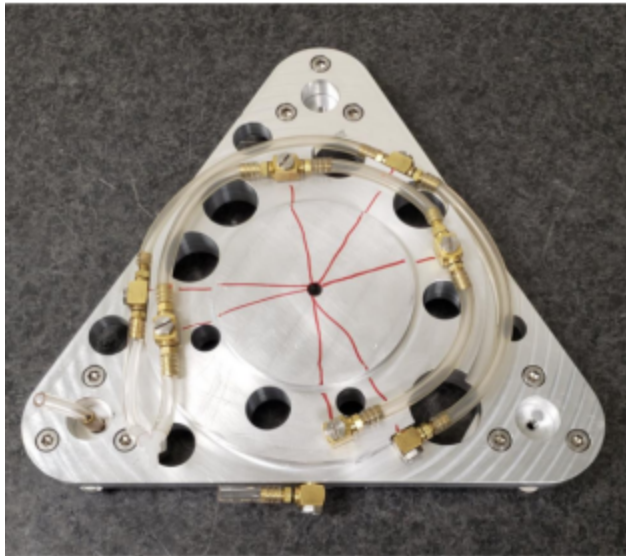
- Choose nominal gauge blocks to simulate the total thickness of module
- Place gauge blocks between marble table and pick-up tool
- Adjust the screw so that the tool touch to the gauge block tightly
- Adjusted tool is used for module assembly



Assembly



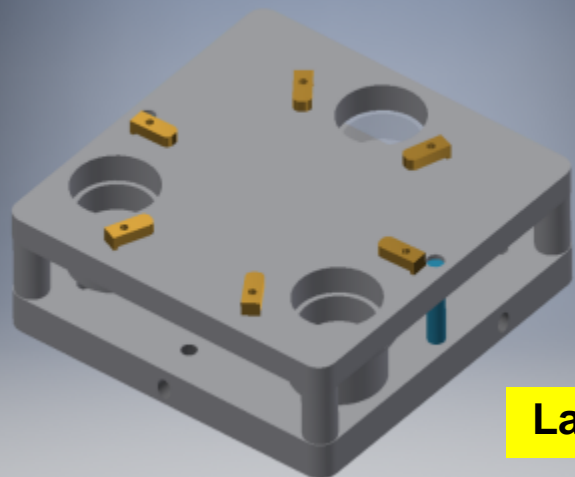
Pickup tooling improvements



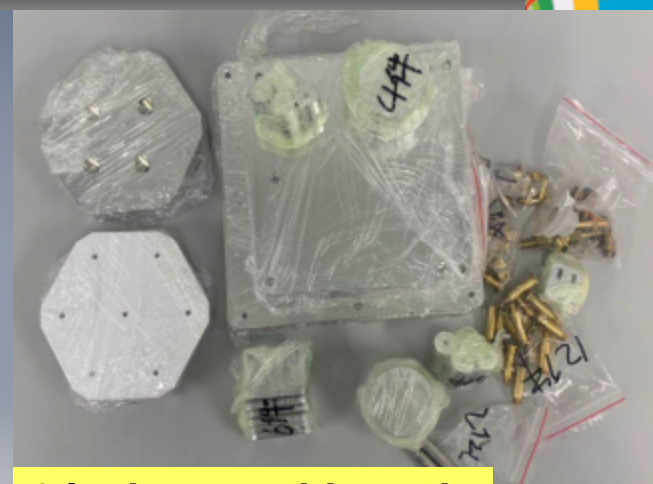
- **Assembly tooling for 8 inch module**
 - Feet maintain constant height
 - No shimming saves time
 - Separate feet for different sensor and baseplate thicknesses
 - Relief holes for lightening tool



Assembly tooling @ IHEP



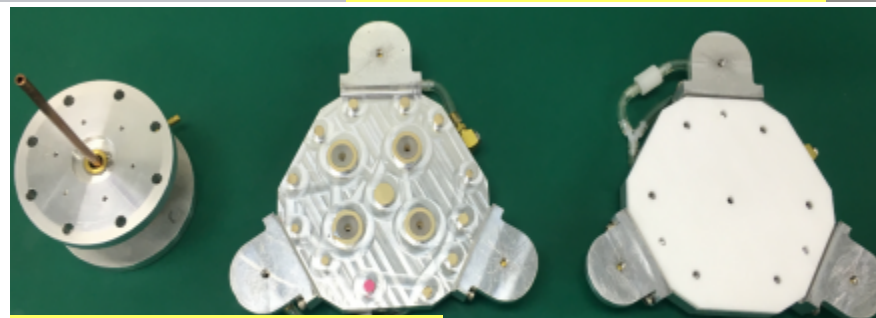
Layout



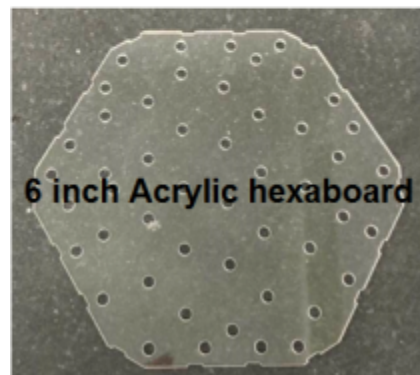
6 inch assembly tool

- **Assembly tooling and dummy components**

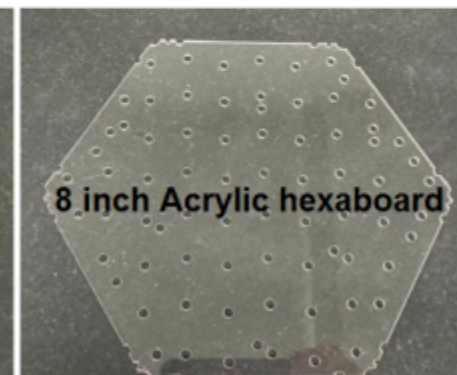
- 6 inch pickup tool for sensor and PCB are ready at IHEP
- Dummy acrylic PCB use to glue dispenses test
- Assembly tray and pedestal for 6 inch module arrived to IHEP this week



6 inch pickup tool



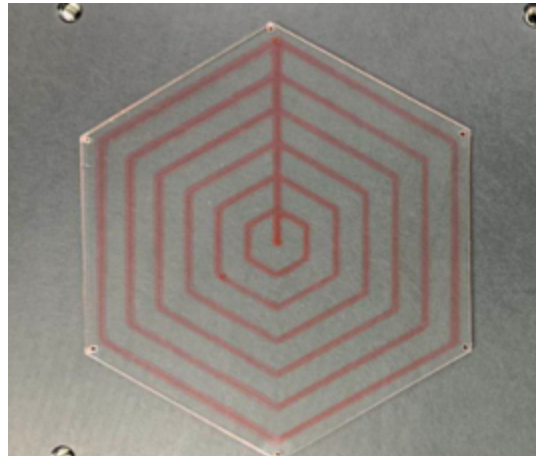
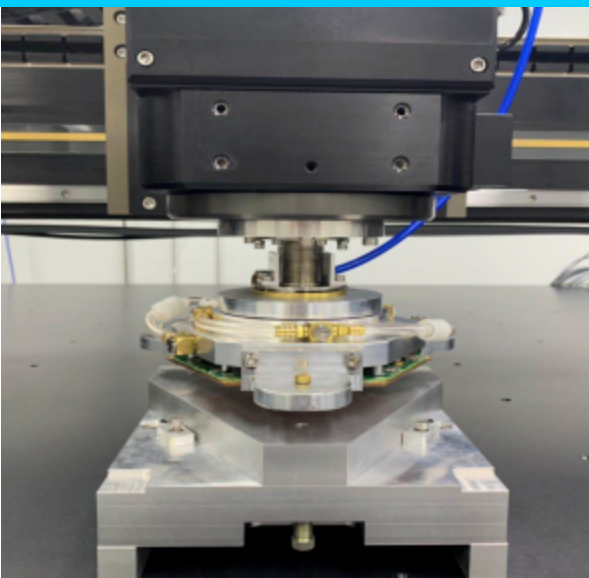
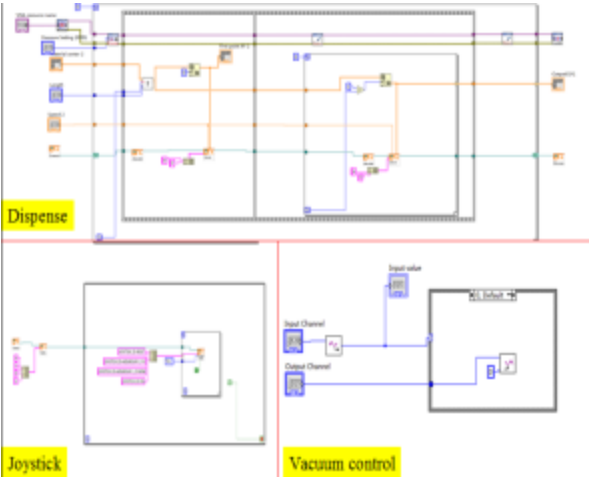
6 inch Acrylic hexaboard



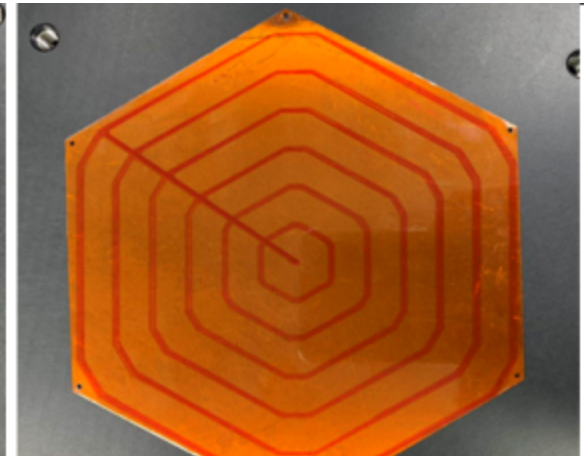
8 inch Acrylic hexaboard



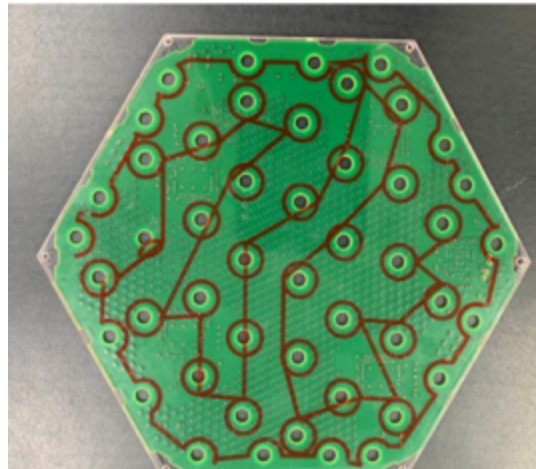
Assembly test @ IHEP



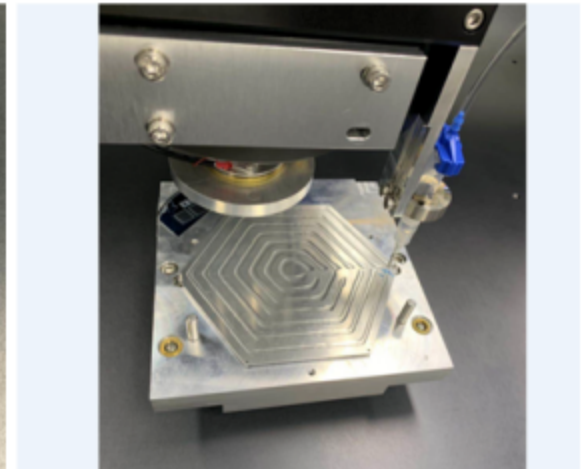
Glue pattern for baseplate



Glue pattern for kapton



Glue pattern for sensor



Glue dispense training



Gantry qualification steps based on what was done for the CMS tracker

By UCSB

These exercises will be done by all MACs to obtain a record of the performance of the individual machines. We might want to repeat some or all of them regularly during production.

1. Position precision

- Tests the precision of manual measurements with the gantry system

2. Pattern recognition precision

- Tests the precision of the pattern recognition system



Finished

3. Alignment precision

Absence of dummy PCB and sensor with fiducial

- Certifies the accuracy of picking and placing components

4. Assembly procedure precision

Tools are being fabricated

- Certifies the accuracy of assembling an actual module

5. Gantry calibration versus CMM

Calibration by laser interferometer

- Compare gantry measurement of a glass calibration plate with measuring the same plate on a CMM

UCSB will work out procedures for all these qualification steps and perform them on our gantry. We will create a Twiki page for all MACs to report their results.



Exercises for learning to use the gantry system

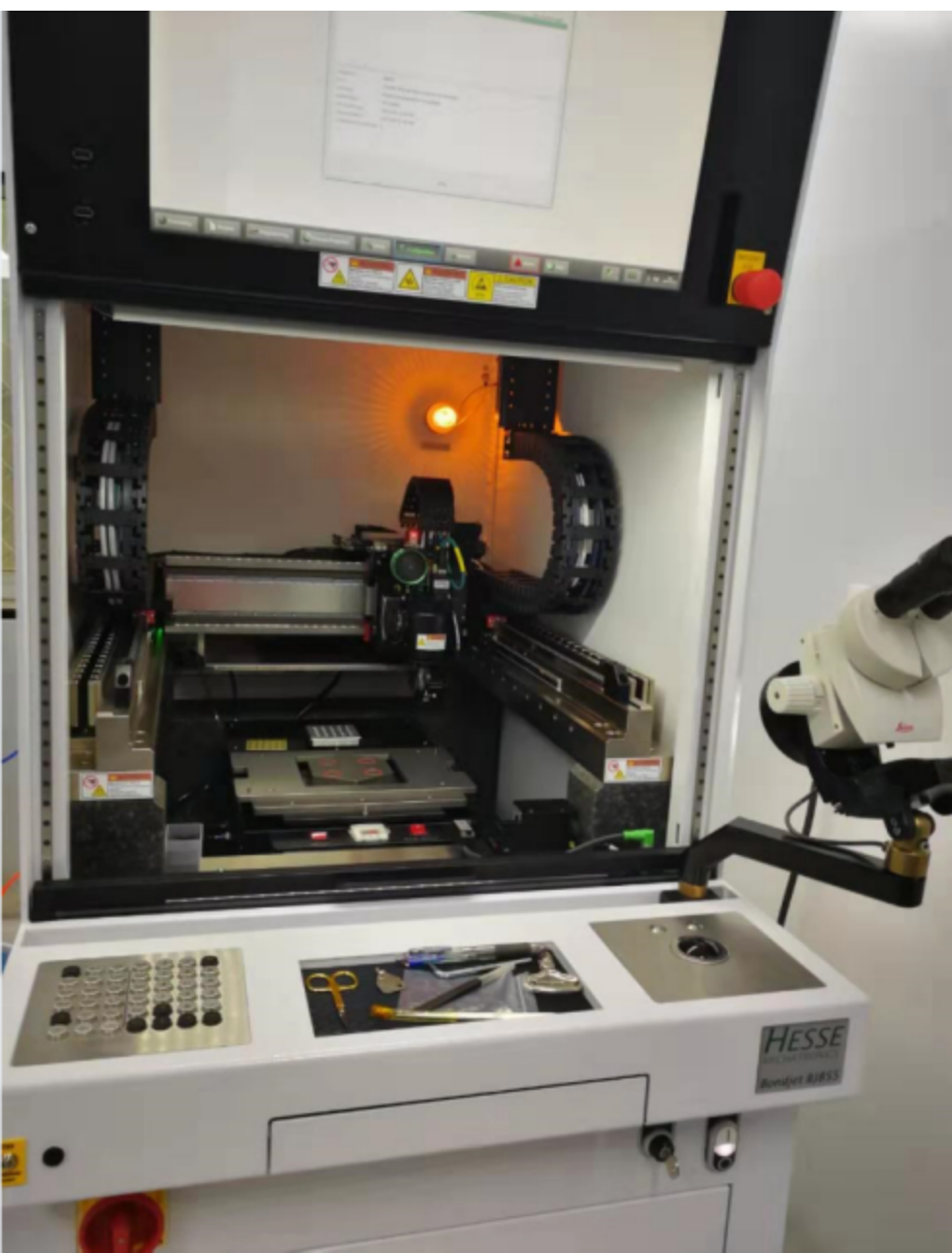
By UCSB

1. Measure how parallel gantry head is to gantry table and fixtures.
2. Exercise movement X,Y, Z, Theta(Linear movement, Circles etc.)
3. Practice controlling dispenser(Controlling pressure, moving speed, different patterns)
4. Practice controlling vacuum(Turn on/off vacuum programatically, read out sensors etc.)
5. Practice Gluing on acrylic sheets(Glue gap consistency and spread)
6. Practice picking and placing pick up tool(without any components)
7. Practice picking and placing pick up tool and dummy acrylic components
8. Practice gluing on acrylic dummy pieces
9. Practice gluing and picking and placing on dummy components(non-acrylic)

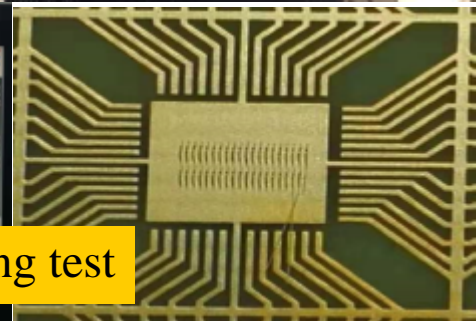
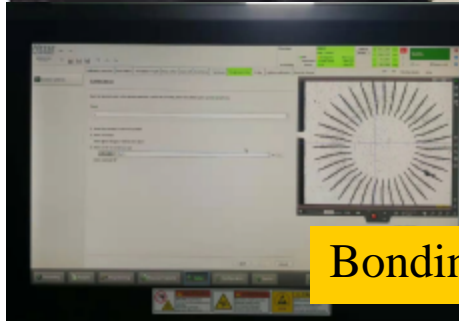
On going



Wirebond training @ IHEP



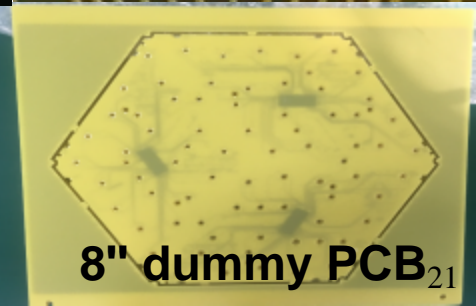
Training



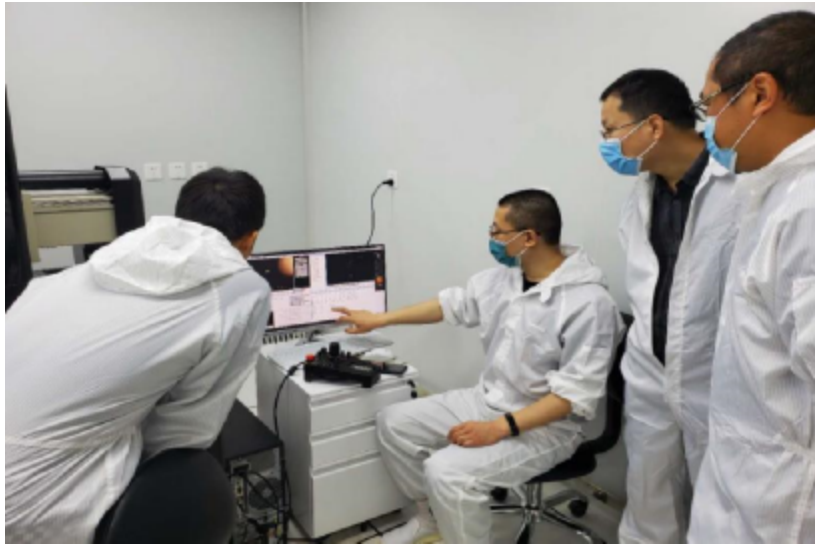
Bonding test



8" dummy sensor



8" dummy PCB₂₁

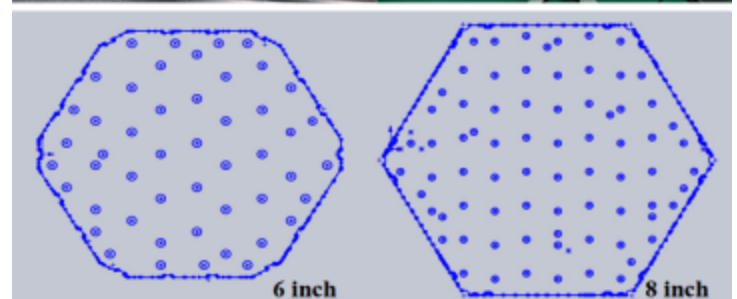
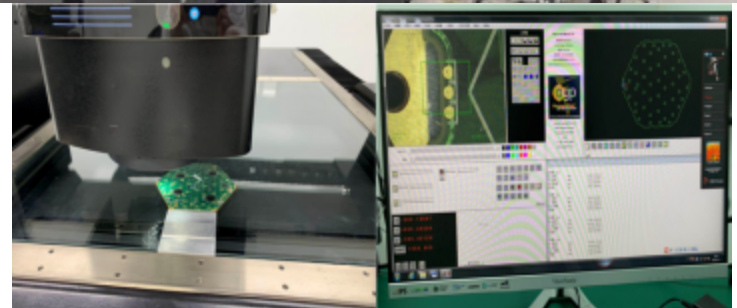


- **On site training**

- Basic operation.
- Pattern recognition: line, circle and arc
- 3D Measure

- **Exercise**

- Draw 6&8inch PCB pattern





Summary



Equipments	Tooling	Material	QC
Gantry arrival	6 inch pickup tool, assembly tray and pedestal	6 & 8 inch dummy acrylic PCB 6 & 8 inch dummy sensor	On going and finish part of QC task
Bonder arrival	6 inch vacuum pedestal	8 inch dummy PCB 8 inch real PCB	On going
OGP arrival	-----	-----	-----
Mini Gantry arrival	-----	-----	-----
Pull tester not yet	-----	-----	-----

All tooling and material should be switched to 8 inch module assembly in final QC task

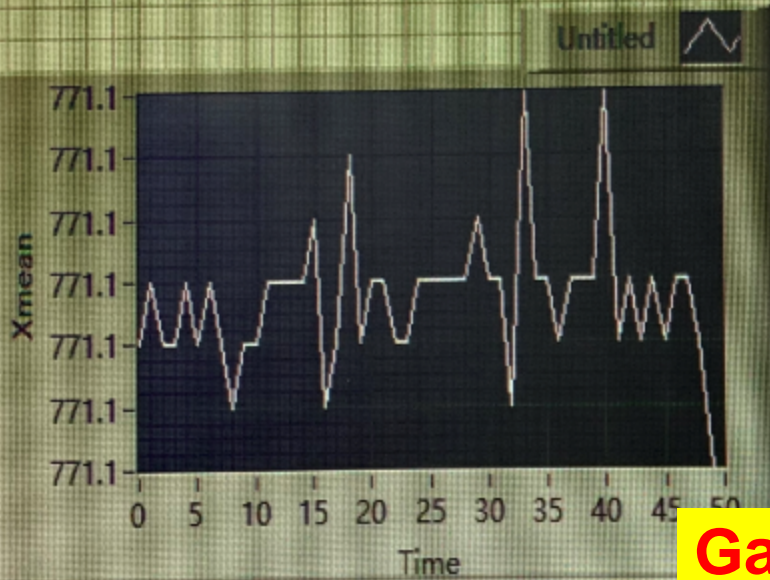


Plan



	Milestone Description	Duration	Finish by
1	Cleanroom lab space set up		
2	Have all equipment installed		Sep 11 th 2020
3	Train operators on all equipment		Sep 11 th 2020
4	Acquire all the necessary tooling		Oct 23 rd 2020
5	Acquire all dummy components and supplies		Oct 23 rd 2020
6	Qualify the gantry and wirebonder		Nov 6 th 2020
7	Develop glue patterns using acrylic dummies	2 weeks	Nov 20 th 2020
8	Build 10-15 dummies with blank silicon	4-6 weeks at one glue step per day	Jan 8 th 2021
9	Acquire all real components		Jan 15 th 2021
10	Build 4 dummies with HPK dummy sensors	2 weeks	Jan 22 nd 2021
11	Build 2 real modules!	1 week	Feb 1 st 2021

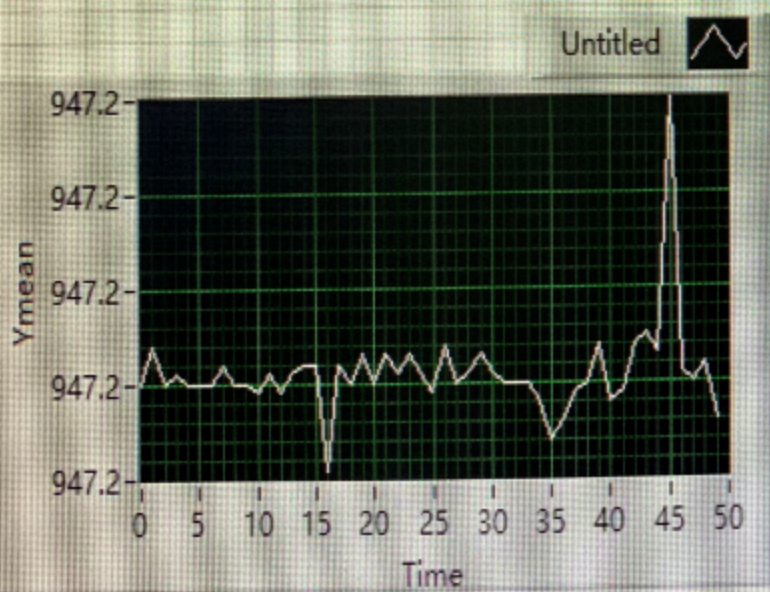
Back up



X



Gantry position



Y

