A Sticky Situation

Studies in Baseplate-Pixel Sensor Gluing of the Pixel Strip Modules for the CMS Phase II Upgrade

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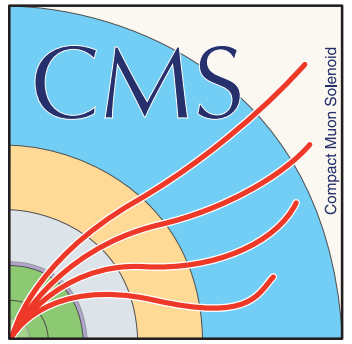
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES



Outline

01 HL – LHC and CMS Experiment

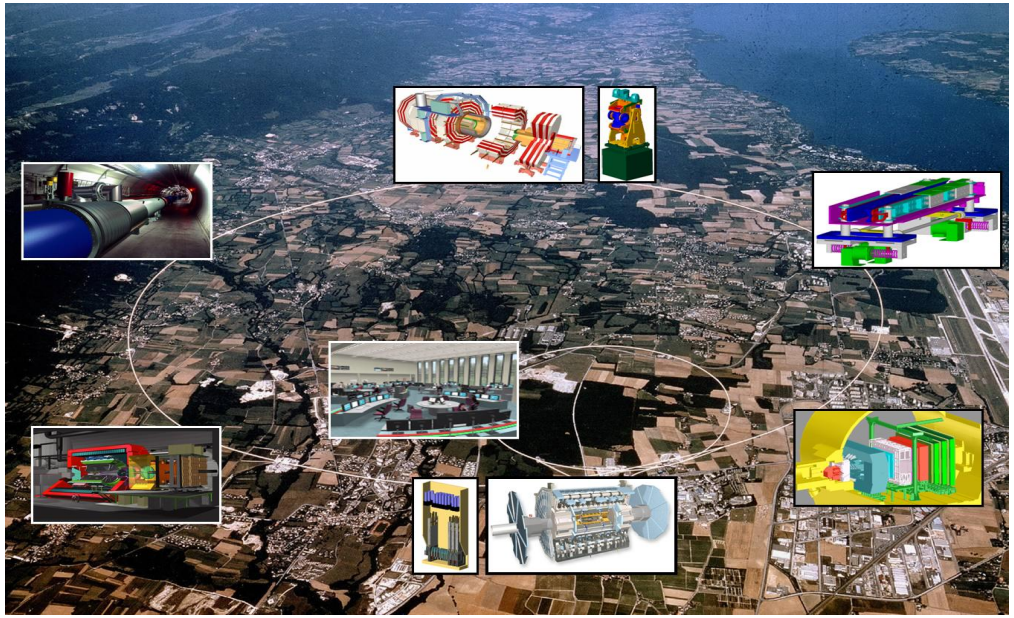


Figure 1: The Large Hadron Collider at CERN and its experiments

High –Luminosity Upgrade

$$\mathcal{L} = 10^{34} cm^{-2} s^{-1} \longrightarrow \mathcal{L} = 5 * 10^{34} cm^{-2} s^{-1}$$

EXPLAND PHYSICS POTENTIAL OF LHC

Compact Muon Solenoid (CMS) Experiment

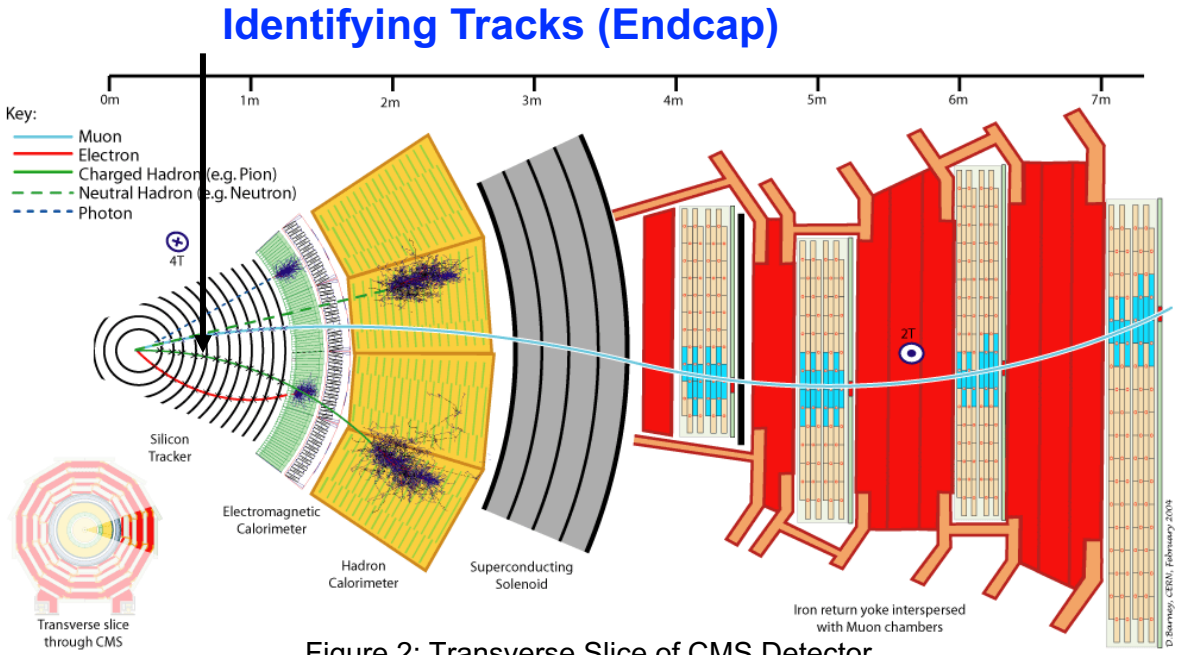


Figure 2: Transverse Slice of CMS Detector

- Cylindrical onion
- Determine the properties of particles in each collision

Bending Particles – identify charge and measure momentum

Identifying Tracks – determination of particle momentum

02 CMS Phase II Upgrade

Increase in Data Rates

Increase in Pile-Up

Radiation Damage

New Tracker that could do tracking at hardware level

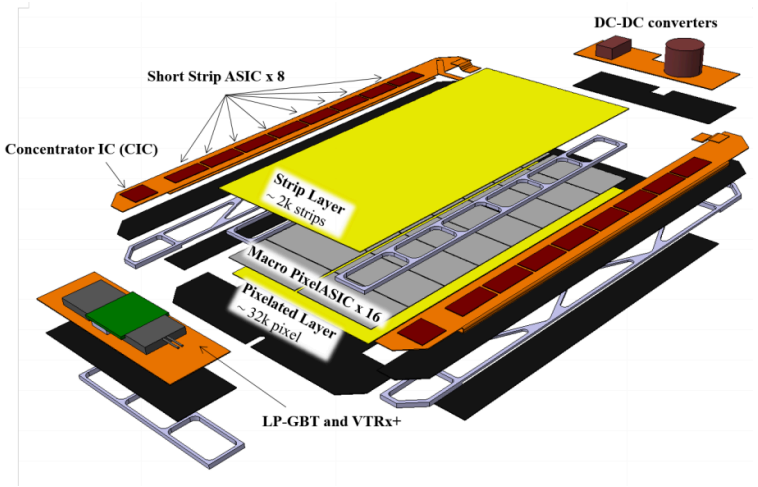


Figure 3: Pixel Strip (PS) Module in an exploded view

Phase II Upgrade: Pixel Strip (PS) Modules

DESY

1000 PS Modules

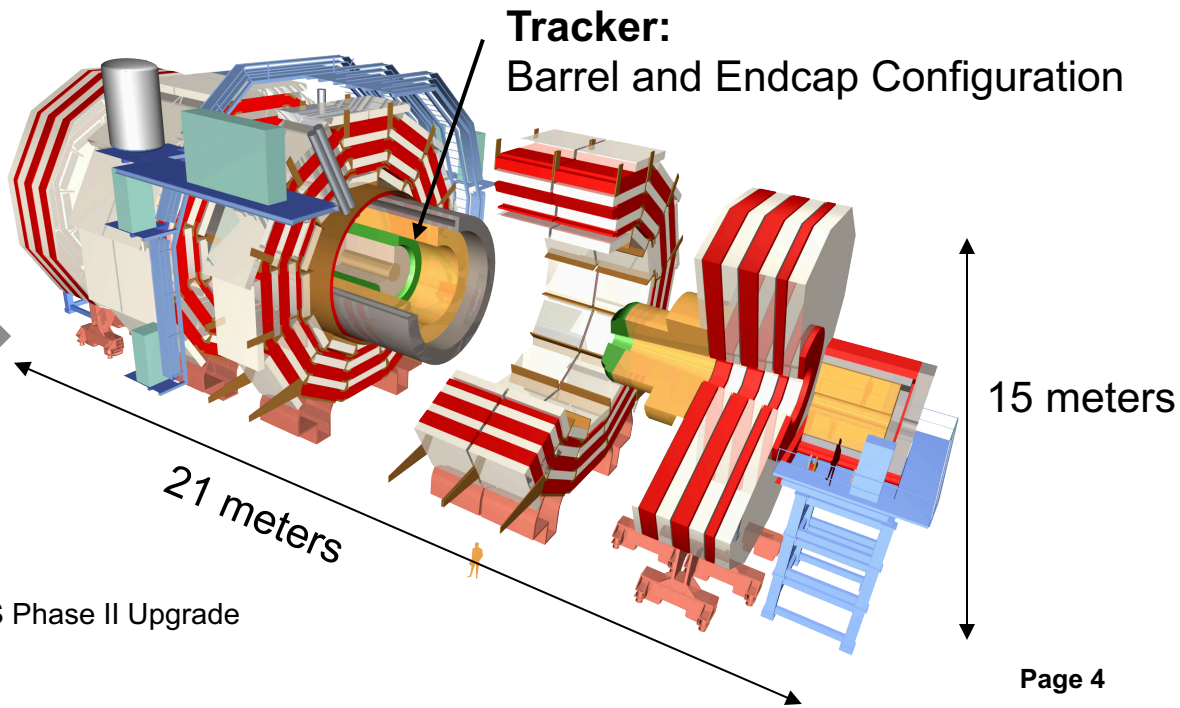


Figure 4: Role of DESY in the CMS Phase II Upgrade

03 Pixel Strip (PS) Module

Why is the Module designed this way?

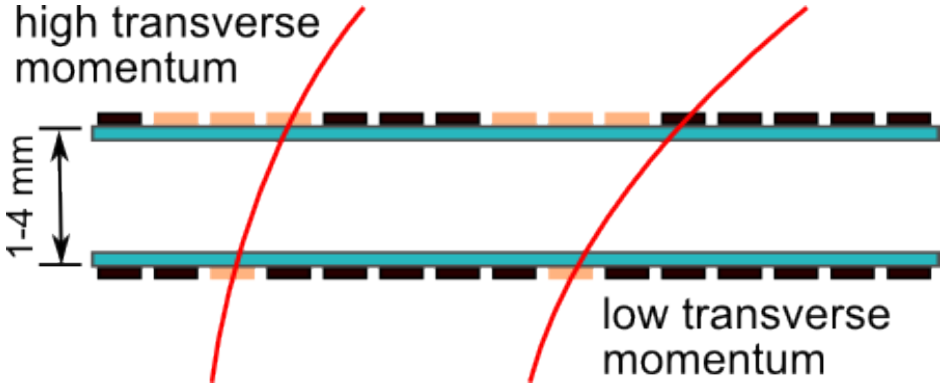


Figure 5: Red Lines (stubs) show how the module can discriminate between high and low transverse momentum

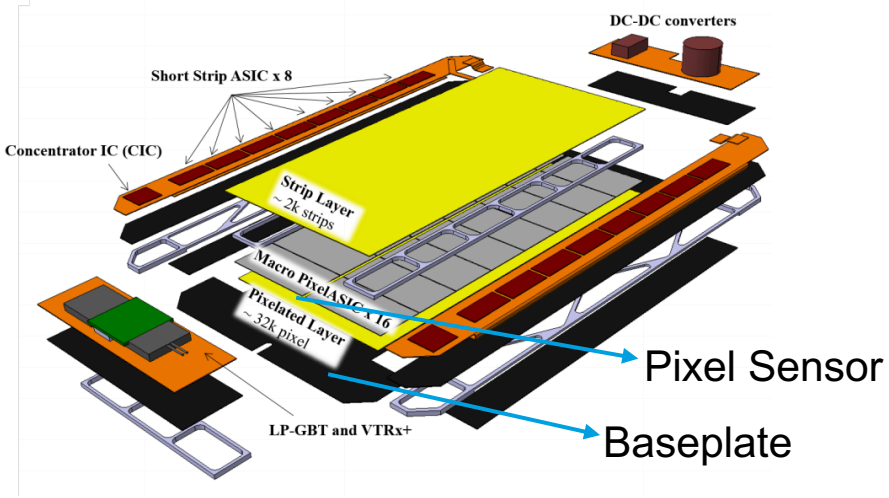


Figure 6: Focus on the Pixel Sensor and the Baseplate

Important points to consider:

- To meet demands of the high-luminosity upgrade, the PS Module must sustain a long lifetime
- Efficient cooling in the module is crucial for detector lifetime
- Contact between module and cooling is provided by a glue layer

RESEARCH FOCUS:

Develop a technique of glue application between the baseplate and pixel sensor to achieve a good thermal contact by having a **thin layer of glue** with **minimal air bubbles**

04 Automated Assembly

The Hardware

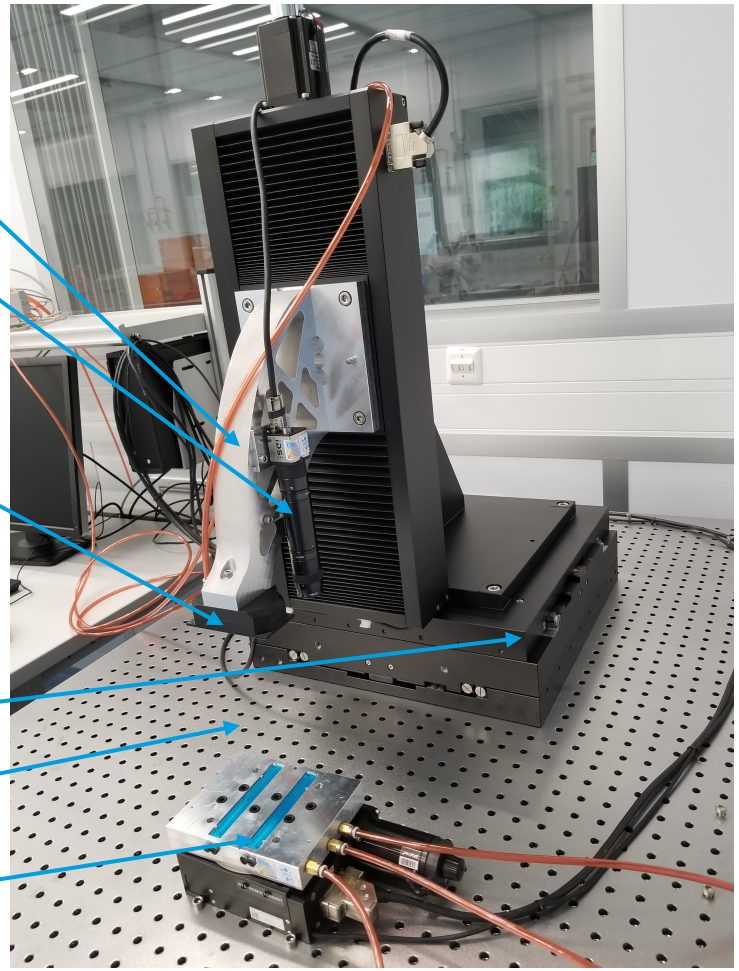
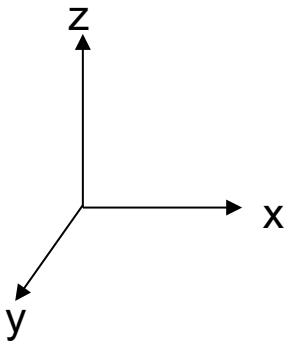


Figure 7: Hardware Parts



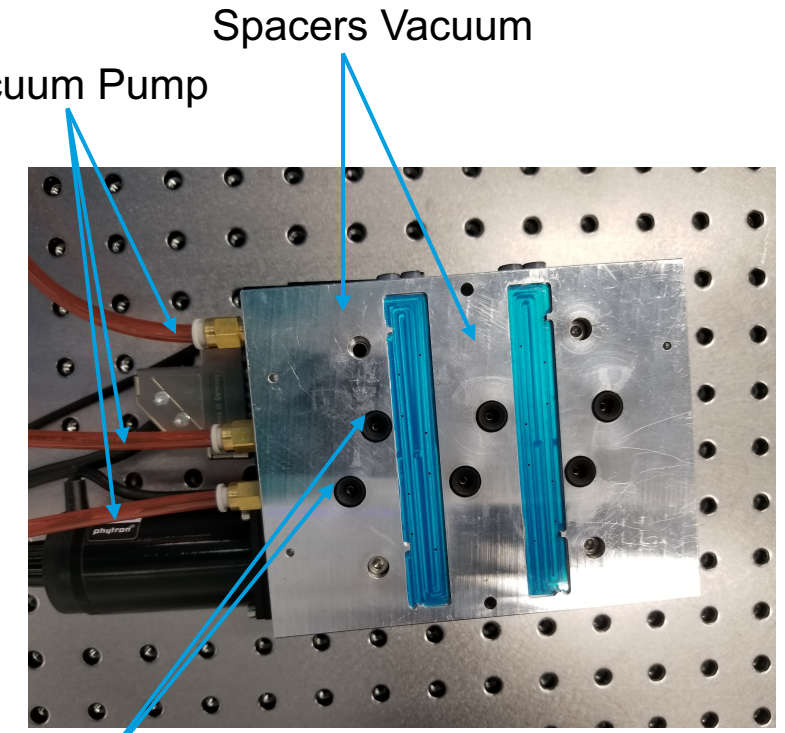


Figure 8: Rotation Stage Parts

- Integration of Gluing Method to the automated assembly
- Affects the choice on the types of glues that we can use

04 Automated Assembly

Working with specifications and constraints of assembly

To utilize the capabilities of the **Automated Assembly**:

- Two Types of Glues
  - Fast Curing (10 mins) – related to increase efficiency
  - Slow Curing (24 hrs.) – help achieve thin layers

Achieving specifications using Automated Assembly:

1. Exploit the precision of the motion stage to achieve a thin glue layer with excellent coverage

2. Positioning of two types of glues

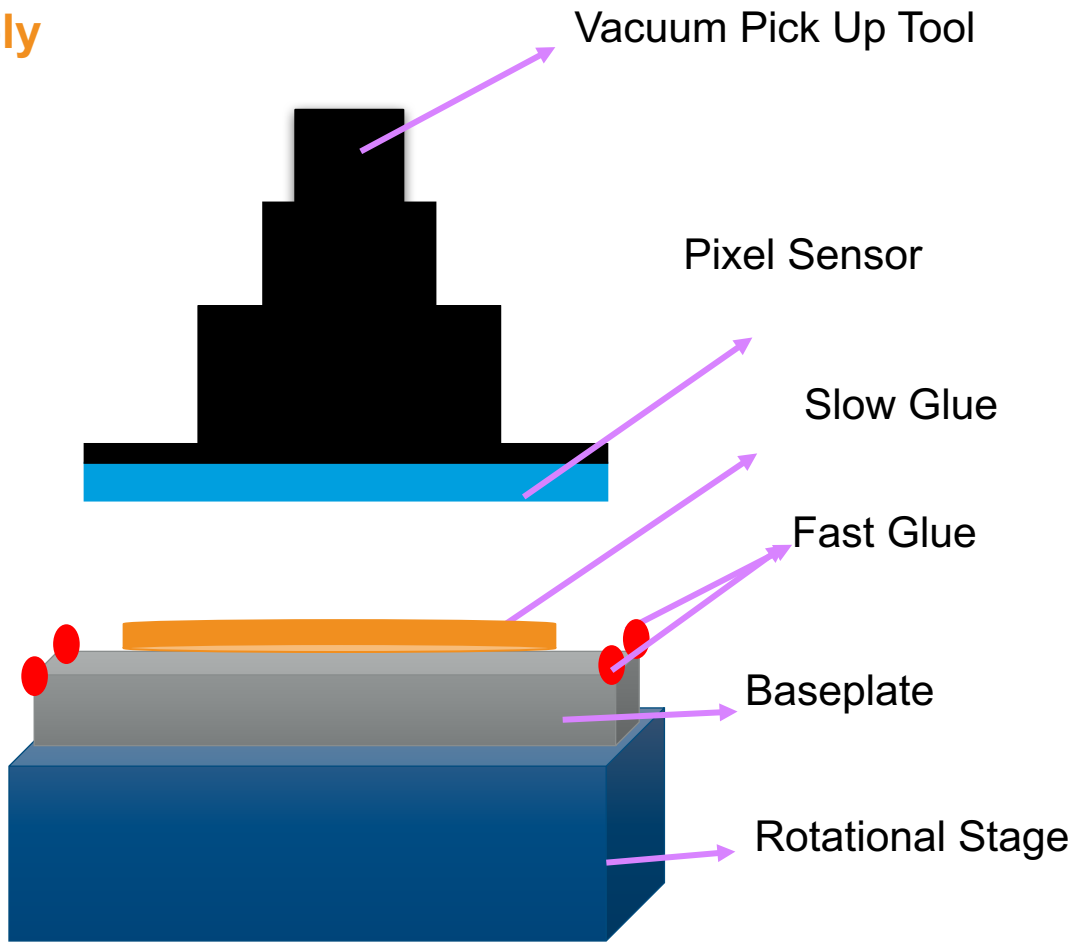


Figure 9: Schematic of Baseplate – Pixel Sensor Gluing

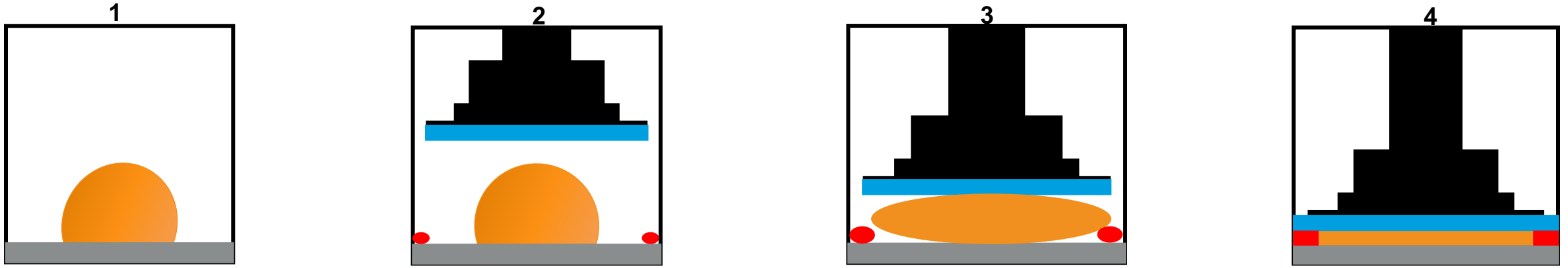
05 Baseplate-Pixel Sensor Gluing

Gluing Approach

Goals for the gluing method

1. Minimal Air Bubbles – presence of air bubbles inhibits cooling
2. Thin Layer of Glue – allow more heat to pass through and make its way to the cooling pipe
3. Integration of fast and slow glue – want fast glue to penetrate the baseplate layer and not react with slow glue

New Proposed Method



(1): Facing forward, the glue is applied vertically along the base plate.

(2): The motion stage with the sensor is attached to the vacuum pick up tool and the fast glue is applied into the corners of the sensor marking

(3): At a slow rate, the sensor is brought down so that the glue will slowly move outward.

(4): Once the sensor has completely attached with the baseplate we get an even layer of glue

Figure 10: Potential method for the baseplate and pixel sensor gluing

05 Baseplate-Pixel Sensor Gluing

TRIAL 1

- The amount of slow curing glue dispensed was calculated.

Potential slow curing glue Layer thickness (CMS Specifications):

- 25 μm, 50 μm, and 75 μm

Specific Gravity of Glue Mixture: $1.15 g/cm^3$

$$V_1 = (49)(98.5)(0.025) = 120.66\, mm^3 \sim \ 0.139g$$

$$\boldsymbol{V_2 = (49)(98.5)(0.050) = 241.33\, mm^3 \sim 0.278g}$$

$$V_3 = (49)(98.5)(0.075) = 361.99\, mm^3 \sim 0.416\text{g}$$

Mass of glue was derived from the volume and specific gravity

- After outlining the markers on the baseplate, it was transferred to the weighing scale to measure the amount of slow curing glue

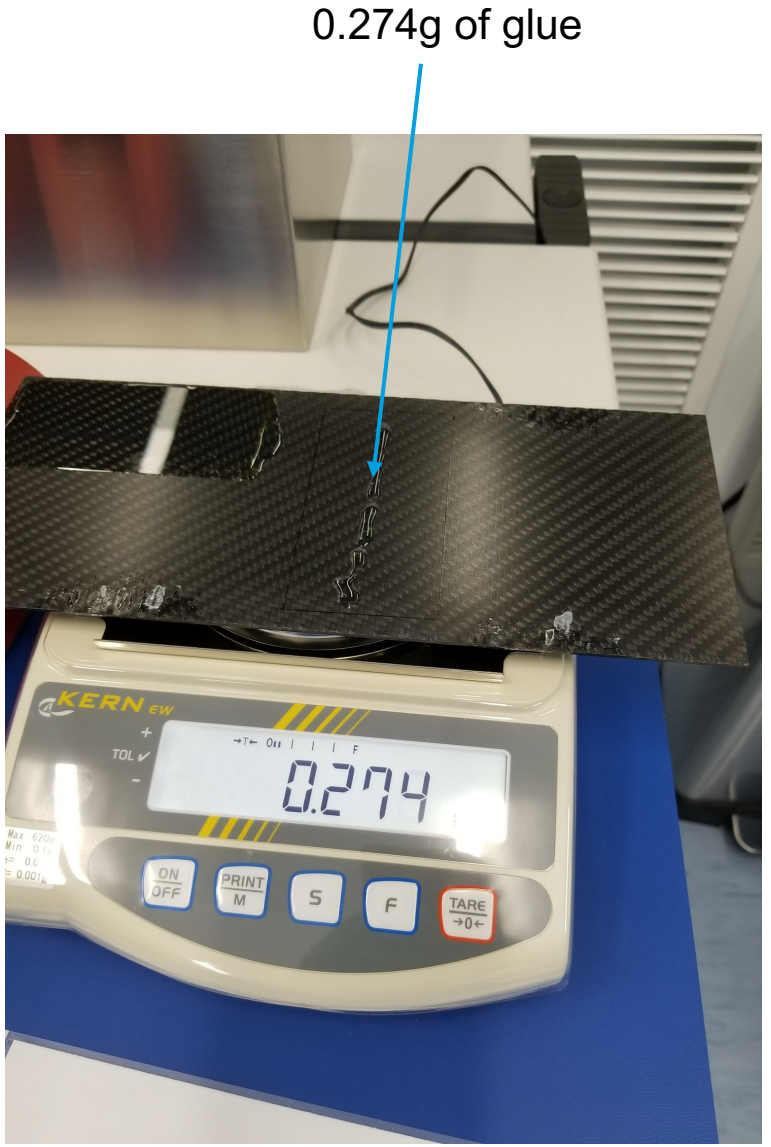


Figure 11: The baseplate is on top of the weighing scale to measure the amount of glue dispensed

05 Baseplate-Pixel Sensor Gluing

TRIAL 1: Results and Observations

- Used option 2, which is 0.278g of slow curing glue
- There was an excess of slow curing glue on one side of the sensor, we suspected the sensor and the baseplate were not parallel after weighing glue X
- Minimal air bubbles were formed ✓
- **Learning:**
  - Fix re-alignment of baseplate and sensor after applying glue
  - Add more markers to the baseplate to improve positioning of the glue

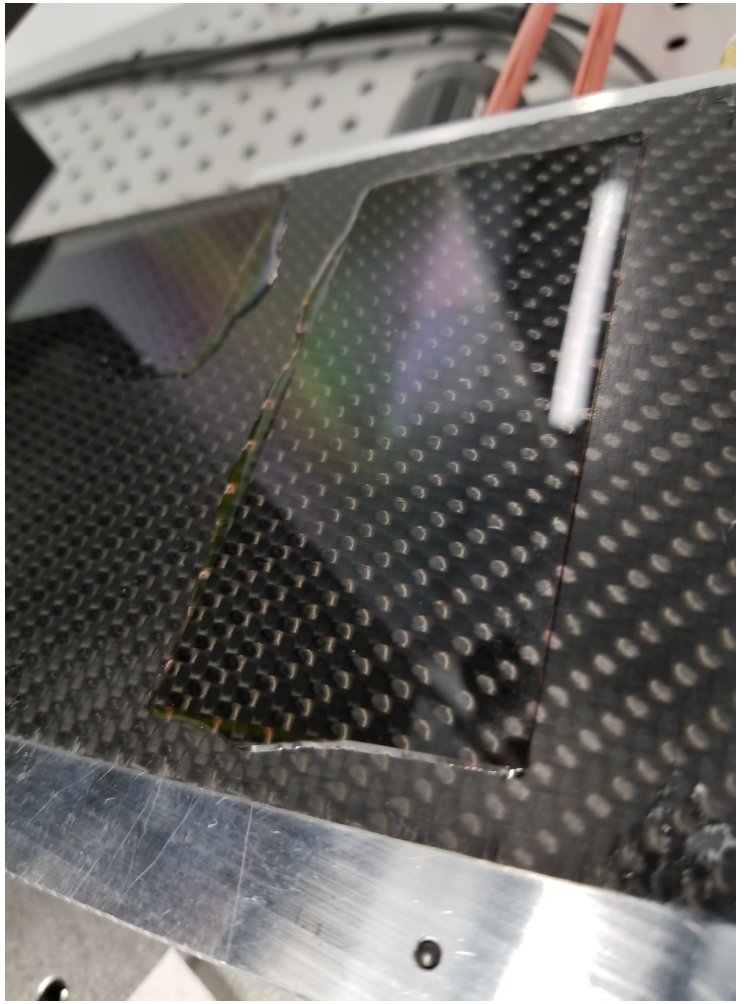


Figure 12: Baseplate and sensor after 24 hour curing time

05 Baseplate-Pixel Sensor Gluing

TRIAL 2

- Two improvements:
  1. Ball joint: improves the parallelness between the base plate and sensor
  2. Additional markers on the baseplate: makes the slow glue equidistant from the center and have a symmetric glue layer

- Used option 1 for the thickness

$$V_1 = (49)(98.5)(0.025) = 120.66\,mm^3 \sim \ 0.139g$$

- Measured the thickness before and after
- Thickness of baseplate and pixel sensor: ~ 0.84 mm

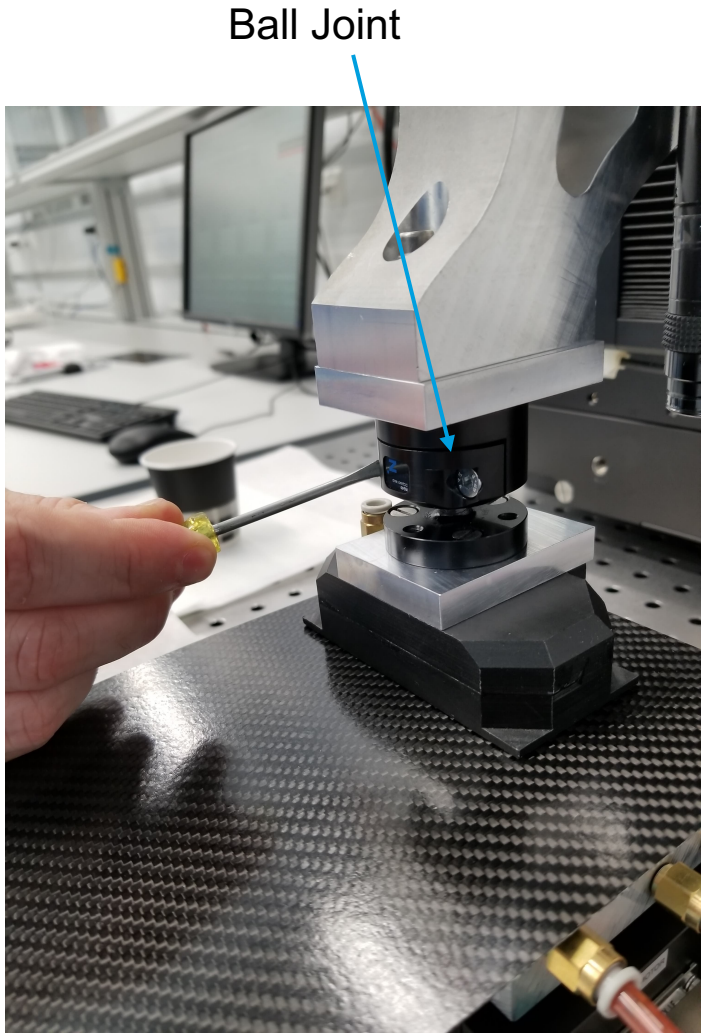


Figure 13: New experimental setup for the method including the ball joint on the motion stage. Calibrating the ball joint to be parallel to the baseplate

05 Baseplate-Pixel Sensor Gluing

TRIAL 2: Results and Observations

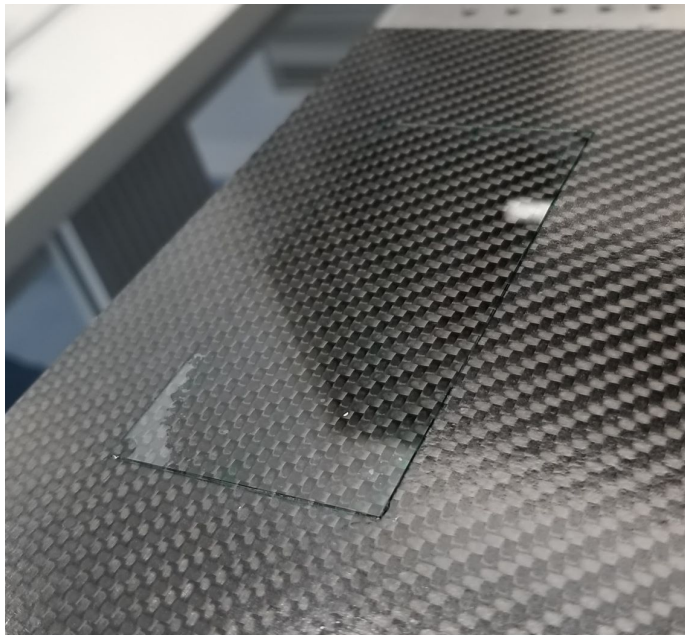


Figure 14: Baseplate and sensor after
5 minute fast glue curing time

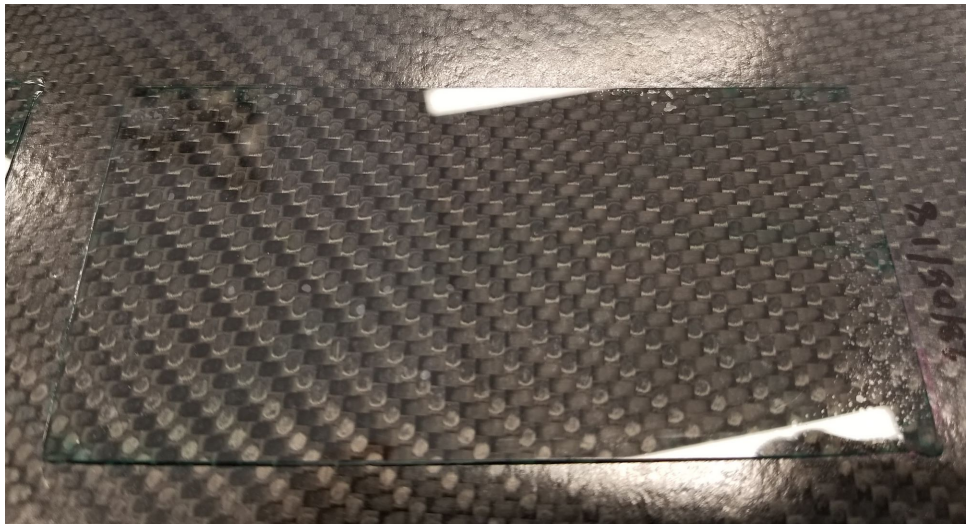


Figure 15: Baseplate and sensor after
24-hour slow glue curing time

- After 5 minute curing time, there was the intentional gap between the fast and slow glue
- After 24 hour curing time, through capillary action we achieved full coverage with minimal air bubbles formed.
- Thickness of baseplate and pixel sensor with glue layer: ~ 0.84 – 0.85 mm

06 CONCLUSION

Thin glue layer was achieved using the motion stage system

- Measured a thin layer of glue in the order of 10 µm, which is better than specifications

Minimal air bubbles were formed through the good positioning of fast and slow curing glues

- Good positioning improved because of the outlined markers on the baseplate

Good integration of fast and slow curing glues is observed

- No reaction between fast and slow curing glues
- Observed the intentional gap between fast and slow curing glue after contact
- Optimum slow curing glue amount: 0.138 – 0.15 g

06 FUTURE WORK

NEXT STEPS

- Fine tuning of amount of slow curing glue
- Commissioning of Glue Machine to automate the dispense of slow curing glue

ACKNOWLEDGEMENTS

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CMS GROUP

BACKUP