Module Prototyping for the CEPC/AGORA Inner Tracker

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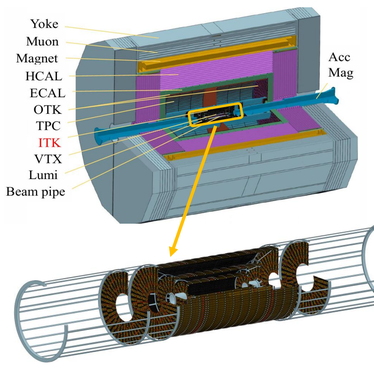
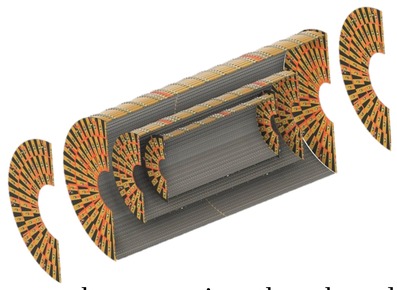
Abstract

Utilizing advanced 55 nm HVCMOS technology, the Inner Tracker (ITK) is a key component of the AGORA detector tracking system, originally proposed for the CEPC. The ITK features a highly modular design, with each basic module integrating up to 14 sensor chips. Pending the availability of full-size chips, prototyping efforts have commenced with dummy sensors that replicate the geometric dimensions and material composition of the final chips. Concurrently, a suite of customized assembly tools has been designed, and the assembly workflow is being established. This poster will present the latest progress in module prototyping.

1. Introduction

The HV-CMOS Inner Tracker (ITK) is a key subsystem of the tracking system. It employs monolithic HV-CMOS pixel sensors fabricated using 55 nm CMOS technology to achieve high spatial resolution, a low material budget, and excellent mechanical stability.

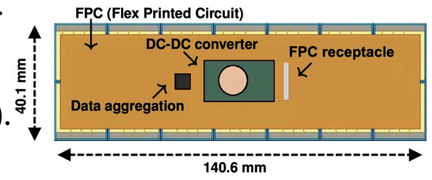




The inner tracker comprises three barrel layers and four endcap layers, with a total active area of 20 m² and 47,024 sensors in total.

➢ITK Module design from CEPC TDR

- Sensor layout: 14 sensors (2 rows × 7 columns).
- Module size: 140.6 × 40.1 mm².
- Electrical connections: Wire bonds to the Flexible Printed Circuit (FPC).
- FPC functions: Power, data, clock, and command signal routing.
- Integrated electronics: DC–DC converter and data aggregation chip.



➢R&D Plan for ITK Module Prototyping

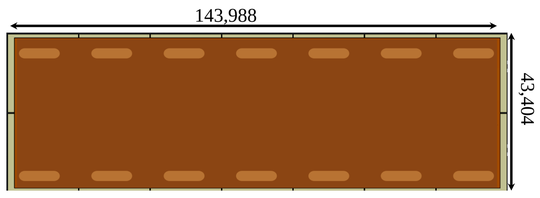
- Mechanical Prototyping: Develop and validate the assembly process.
- Thermal-Mechanical Prototyping: Assess thermal-mechanical stability.
- Functional Prototyping: Validate functionality and readout performance.
- Module Qualification: Evaluate overall performance and reliability.

This poster focuses on the first step of the R&D program: **Mechanical Prototyping,** which includes:

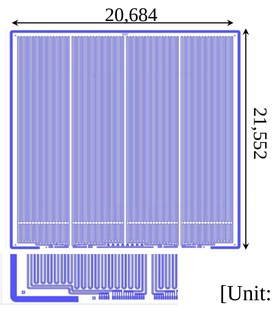
- Development of customized assembly tools.
- Establishment of the module assembly process.
- Fabrication of dummy modules using dummy sensors.

2. Dummy module design

Dummy module is designed to replicate the geometry and mechanical structure of the final ITK module, enabling the development and validation of assembly procedures before functional sensors become available.



[Unit: μm]



[Unit: μm]

➢Dummy sensor: Dummy COFFEE v2

- Same size as the final chip
- With metal traces for thermal study
- With real pads and pattern to facilitate assembly

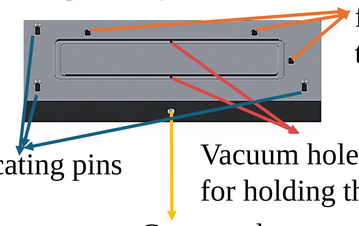
➢Dummy hybrid: Designed based on the dummy sensor size.

- Flexible, heat-resistant, electrically insulating polyimide (PI) substrate for FPC.
- With metal traces to allow wire bonding

3. Assembly tools

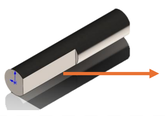
Customized assembly tools were designed for manual prototype assembly.

■Jig for hybrid



■pins

To position the hybrid/sensor.



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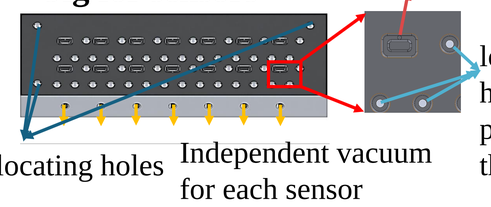
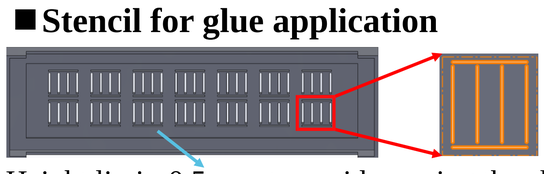
■Jig for sensors



■Stencil for glue application

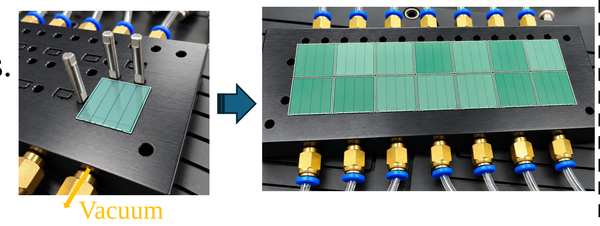


Height limit: 0.5mm, to avoid pressing the chip.

4. Assembly procedure

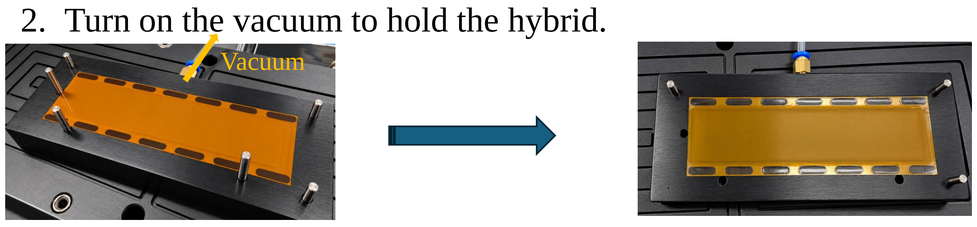
➢Step 1. Sensor Positioning

1. Position the sensor using locating pins.
2. Turn on the vacuum to hold the chip.
3. Repeat steps for all 14 sensors.



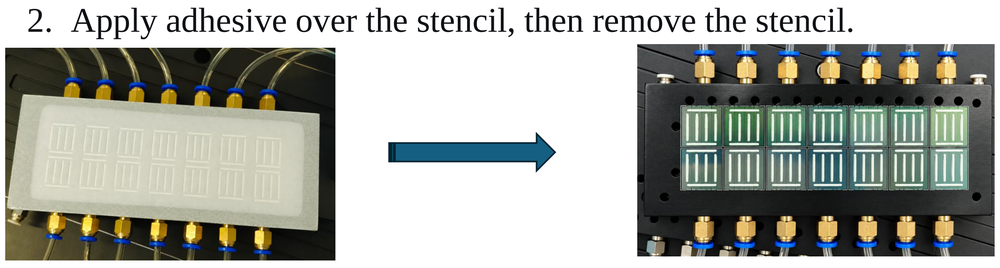
➢Step 2. Hybrid positioning

1. Position the hybrid using three locating pins.
2. Turn on the vacuum to hold the hybrid.



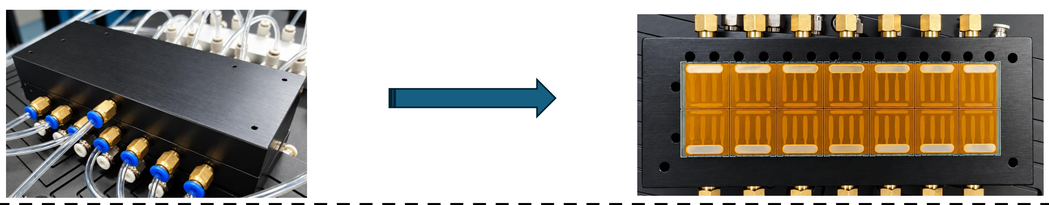
➢Step 3. Adhesive application

1. Place the stencil over the sensors.
2. Apply adhesive over the stencil, then remove the stencil.



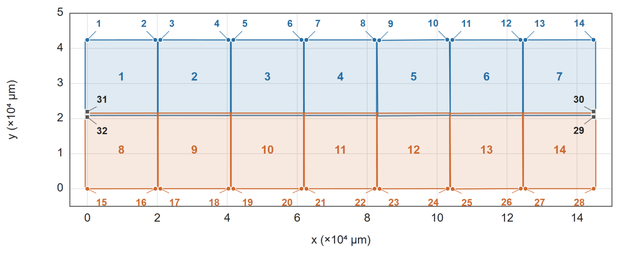
➢Step 4. Module Assembly

1. Align and mate the adhesive-applied sensors and hybrid.
2. Turn off the vacuum on the hybrid jig and remove it after adhesive curing.



5. Prototype validation

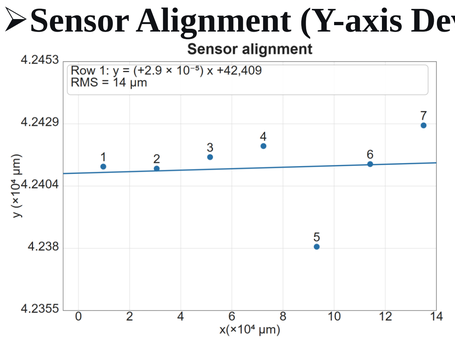
For the assembled module, the positions of 32 exposed fiducial targets on the sensor surfaces are measured to evaluate sensor alignment, gaps between adjacent sensors, and in-plane sensor rotation.

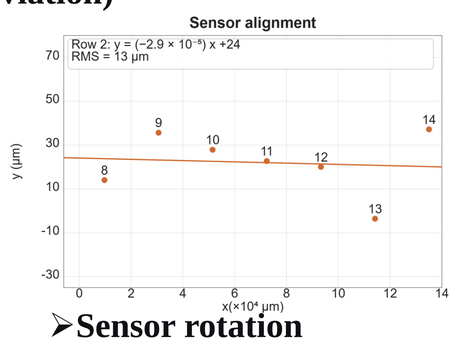




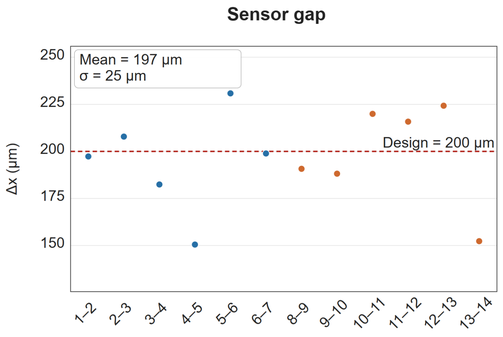
The Quick Vision Apex enables high-precision, non-contact optical measurement for accurate dimensional inspection.

➢Sensor Alignment (Y-axis Deviation)

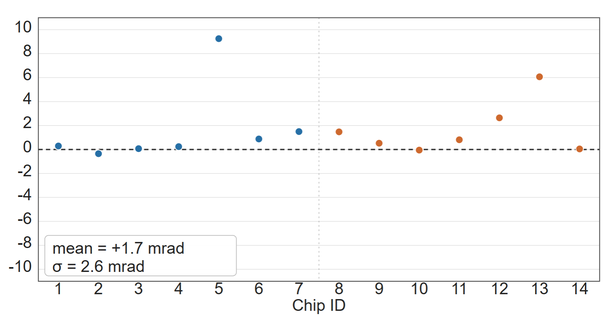




➢Sensor gap along X-axis



➢Sensor rotation



6. Current status & Outlook

➢Current Status

- ✓ Customized tools for manual assembly have been designed.
- ✓ The assembly workflow has been initially established.
- ✓ Dummy sensors have been produced for module prototyping.
- ✓ The first dummy module has been assembled using dummy sensors.

➢Outlook

- ☐Automatic assembly using gantry system to be investigated for mass production.
- ☐Assess bonding integrity and mechanical stability.
- ☐Integrate dummy electronics and thermal loads.
- ☐Evaluate thermal performance, deformation, and cooling efficiency.

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