

Thermal Cycling Test for HGCaI Silicon Module

Speaker: Shiyang CHEN (THU)

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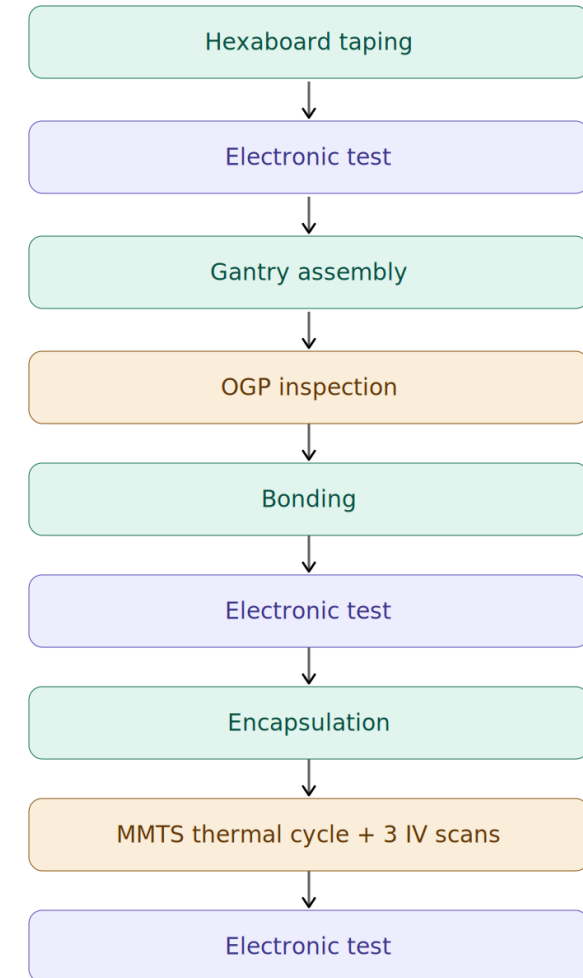
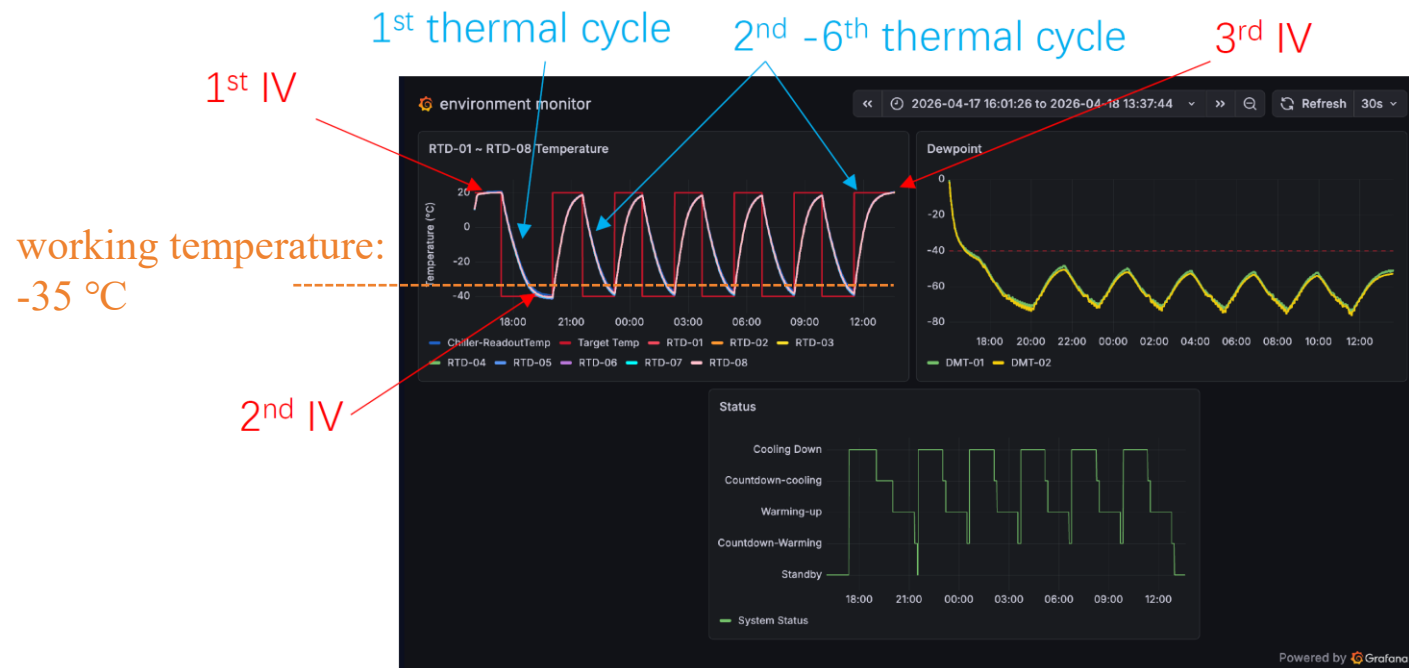


Introduction

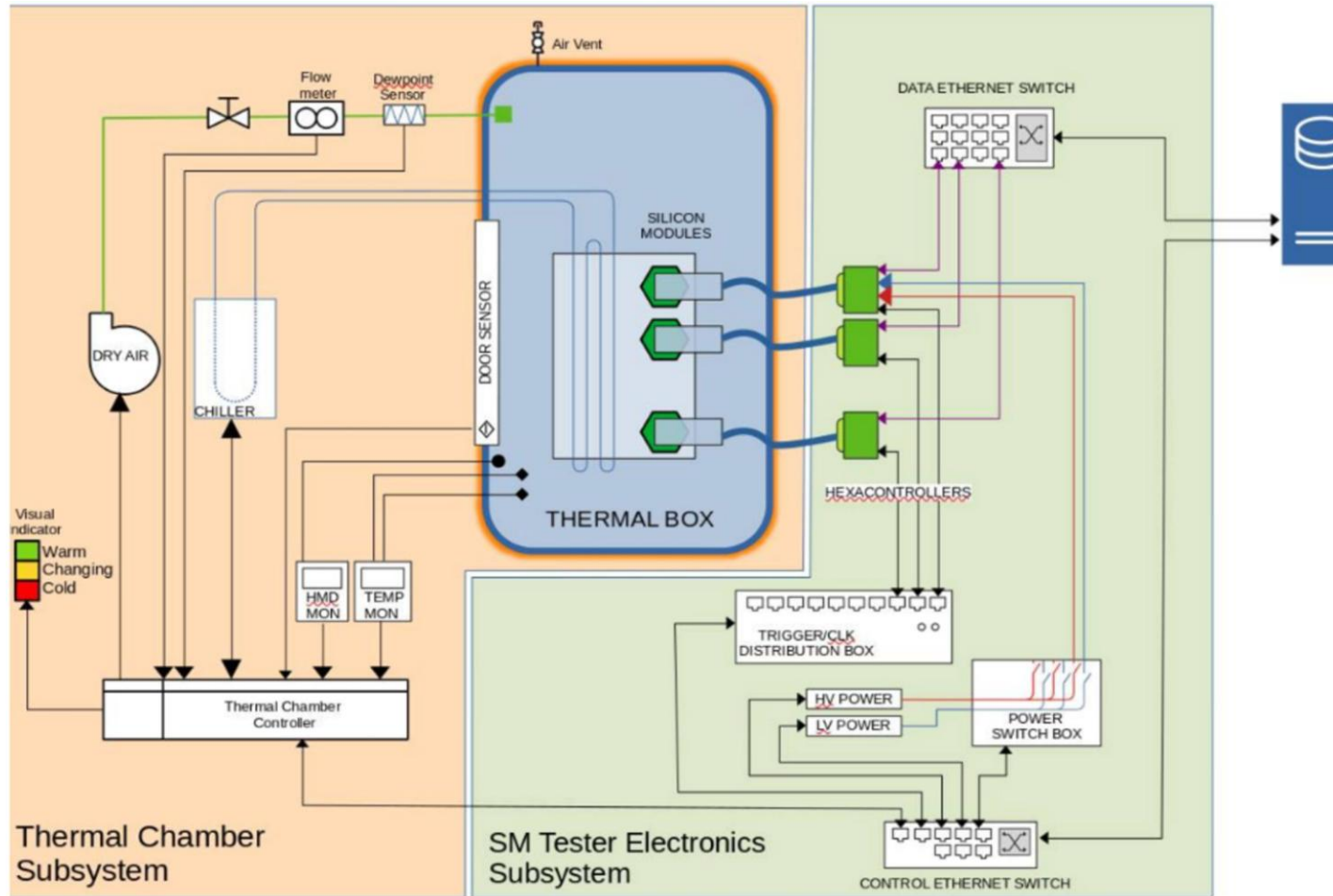
The thermal cycle & electronic test is performed with MMTS (Multi-Module Test System), 24 modules at a time;

Currently, MMTS is able to execute thermal cycle and IV scan, the pedestal run still needs development;

The quality control (QC) chain is complete with MMTS and after MMTS electronic test.



Framework



The thermal cycling and testing system incorporates two sub-systems: thermal chamber and silicon module tester; Two separate control systems are created for these sub-systems: MMTS GUI and PLC controller & PC;

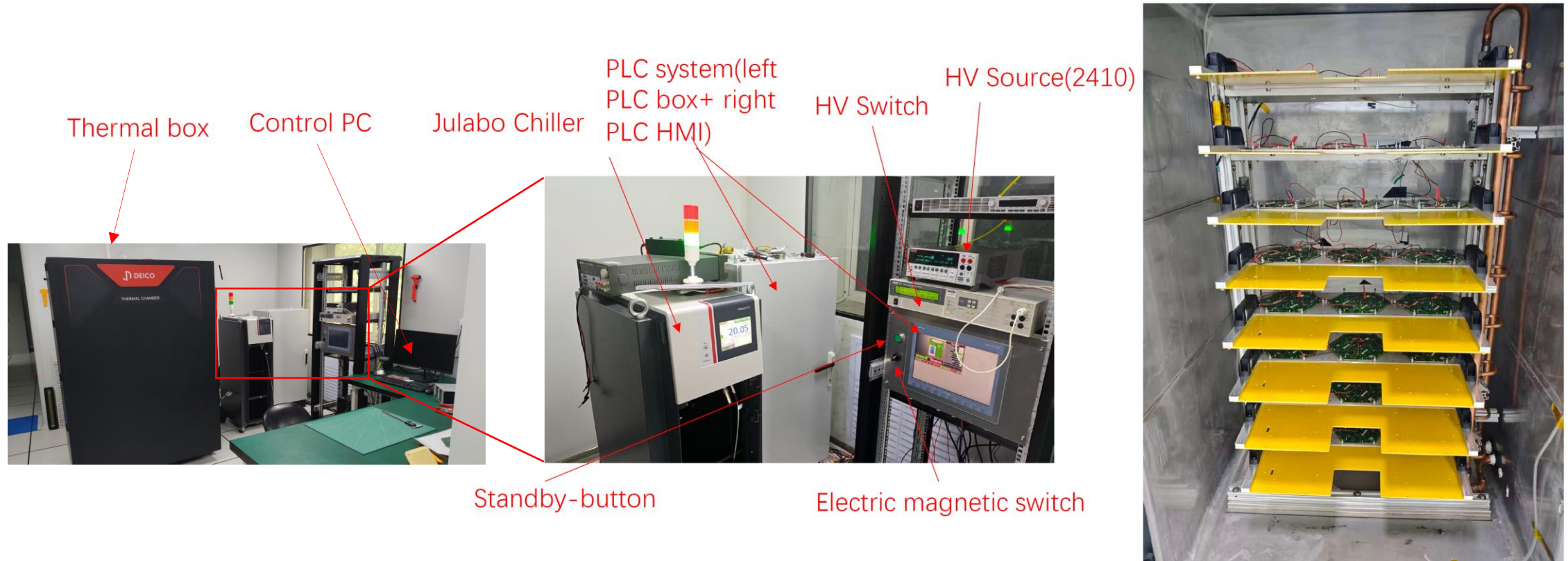
The temperature and humidity monitor prevents condensation;

The testing results are stored in local database and uploaded to central database.

Facilities

Main devices: Thermal box, Julabo Chiller, PLC system, HV source (Keithley 2410), Switch (Virtek 964i), Control PC;

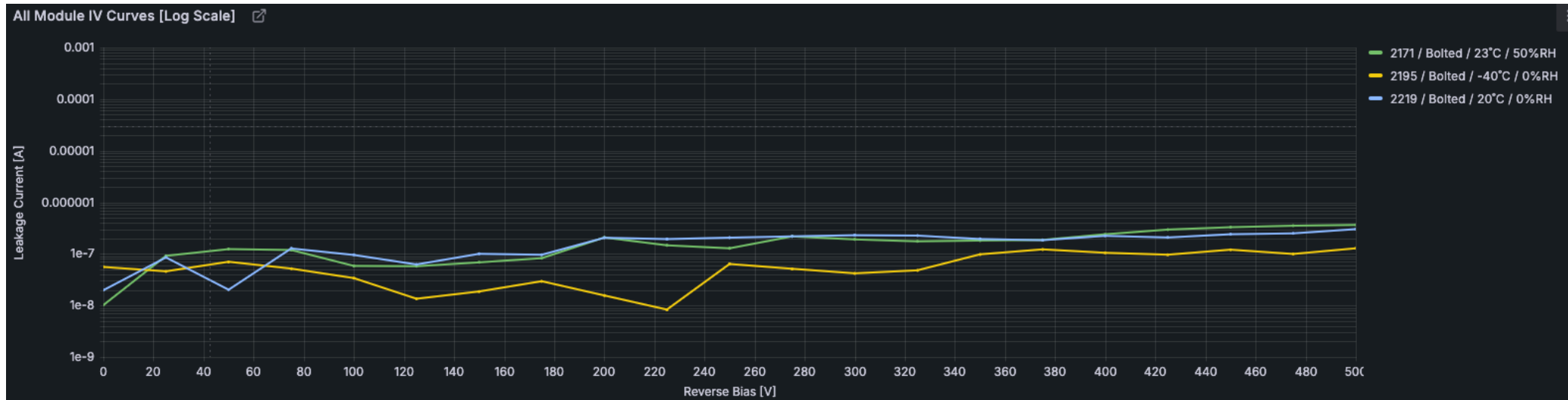
Software control consists of 2 parts: PLC_toolkits (to control PLC&chiller, upload data into DB), MMTSGUI (Control IV scan, display env monitor& IV curve plot).



Capacity

MMTS includes 6 thermal cycles (cooling down to -40°C and warming back to $\sim 20^{\circ}\text{C}$) and 3 IV scans ($\sim 20^{\circ}\text{C} + \sim 50\% \text{RH}$, $\sim -40^{\circ}\text{C} + 0\% \text{RH}$, $\sim 20^{\circ}\text{C} + 0\% \text{RH}$);

MMTS can test 24 modules in one batch within about 18 hours.

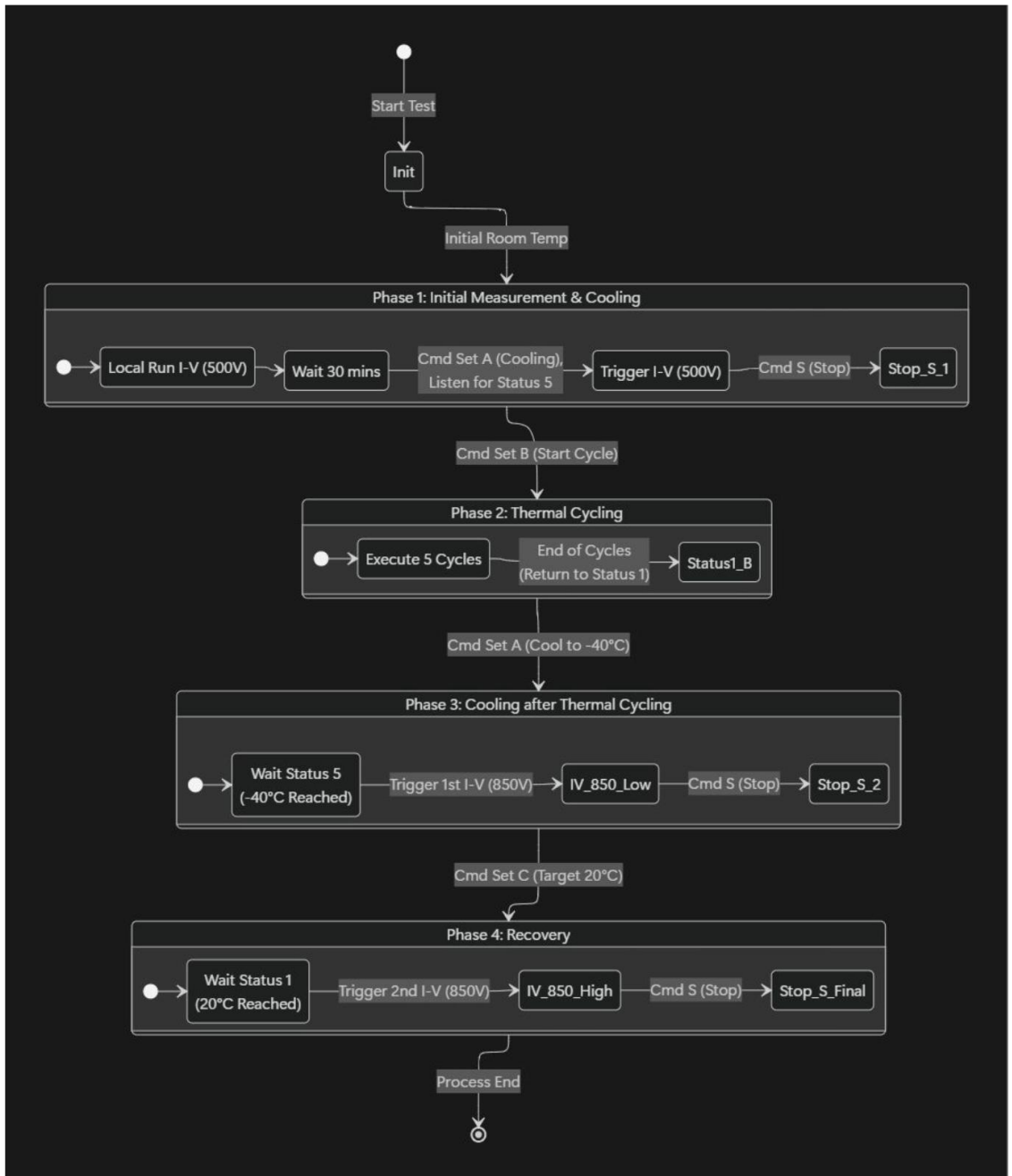


Upgrade: Auto-test

Github repo here: <https://github.com/dilvv/mmts>;
Based on Lian-Shen Tsai's [MultiModuleTeststandUI](#)
and Xing-Fu Su's [PLC_toolkits_mqtt_NTU](#). Need to
set up both 2 project first; (Need to set upstream to
those 2 repos)

Details in [README.md](#);
Combined both PLC_toolkits & MMTSUI, can do
thermal cycle and IV scan automatically;
One-button test, input all modules series number, click
“AutoTest”/”Thermal Cycle” is all you need;

Tested > 200 modules since June, works fine. Also
doing 100 cycles test now(do IV2 low-temp test each
10 cycles). Stop button tested, fixed some bugs.



Upgrade: Auto-test

- **AutoTest:** standard test procedure, 6 thermal cycles in total, 1 pre-thermal IV test(IV1 test), then IV test @1st thermal cycle's low-temp (PLC status: Countdown-cooling) (IV2 test), then do last dry room temp IV test when all thermal cycles done (IV3 test).
- **Thermal Cycle:** input total cycles you want, then set which cycles you want to do IV2 test (low-temp IV).
- **IV1 Test:** do pre-thermal test independently (room temp, 50% humi).
- **IV3 Test:** do post-thermal test independently (room temp, 0% humi).
- **Stop Thermal/AutoTest:** stop both PLC & IV test. (stop PLC by control_HMI.py --stop).

AutoTest	Cycles 5	IV2 cycles e.g. 2,4	Thermal Cycle
Stop Thermal/AutoTest	IV1 Test		
IV3 Test	Clear Modules		

Total thermal cycles
Current segment
(IV2 cycles and normal
cycles need different configs,
so different segment)

Status running

Auto Batch Status
batch: 20260815-141212
status: running
phase:
thermal_segment_17_complete
phase state: waiting
thermal cycles: 92
segment: 17/20 (cycles 73-81)
completed logical cycles: 72/92
current segment elapsed: 18h 9m 12s
last complete segment: 4h 11m 34s
average segment time: 15h 17m 26s
IV2 cycles: 2, 12, 22, 32, 42, 52, 62, 72, 82, 92
next IV2: cycle 82
Waiting for 3 consecutive PLC status samples with code 1.
PLC: Cooling down
dewpoint 1: -76.45 C
dewpoint 2: -76.53 C
updated: 2026-08-26T13:13:00+08:00

Upgrade: Auto-test

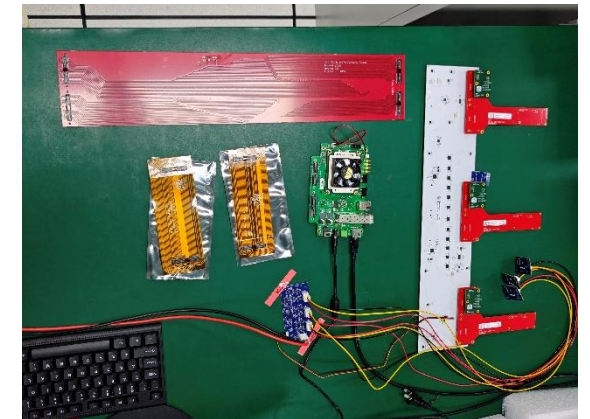
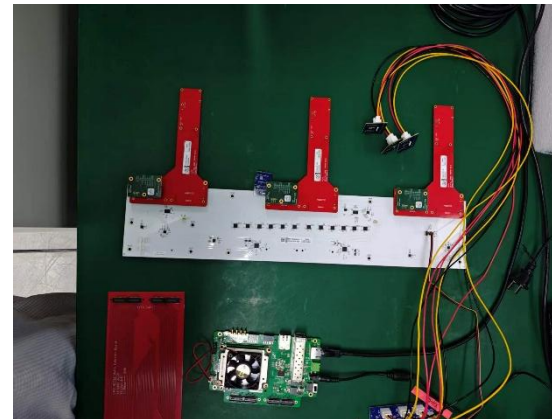
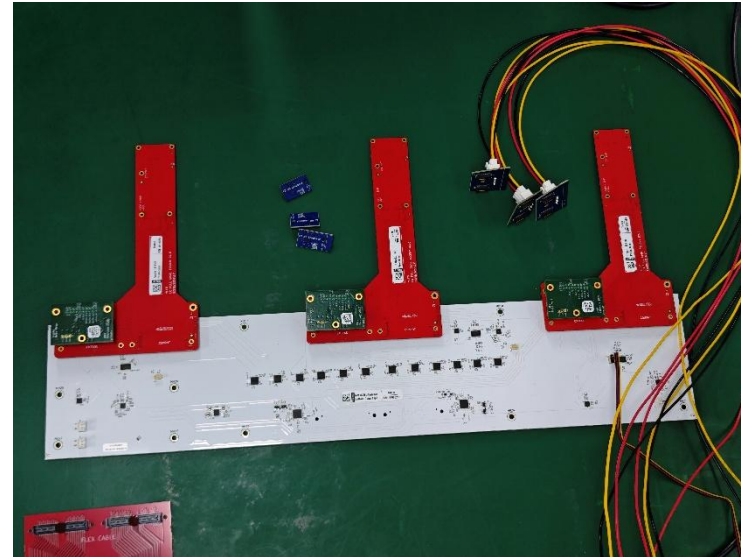
Operation Logic:

- Scan the module serial numbers into the UI using a barcode scanner, then select “AutoTest” or “Thermal Cycle”;
 - **AutoTest**: fixed to 6 thermal cycles, with IV2 performed during the first cycle;
 - **Thermal Cycle**: allows users to configure both the total number of cycles and which cycle(s) include IV2;
 - *Both modes automatically perform IV1 (pre-thermal) before cycling and IV3 (post-thermal) after the final cycle;*
1. After IV1, the system monitors the PLC and starts thermal cycling once both DMT dew points are below -30°C . At the IHEP MAC, the IV1 and cooling time are normally sufficient for the dew point to reach this safe threshold;
 2. When the PLC reaches “Countdown Cooling”, IV2 (low-temperature) is performed. Cycles containing IV2 use a dedicated PLC configuration with `idle_cold_min` = 59 min, while normal cycles use 10 min;
 3. The PLC status is continuously monitored throughout cycling. After the final cycle reaches “Standby”, IV3 is automatically started;

Upgrade: Auto-test



Thermal cycling test with MMTS system



Test integration of electronic test with MMTS

Upgrade: Mass Production

The goal for 16 Modules/Day has been achieved successfully;

Feasibility of 24 Modules/Day production is under discussion;

Working process: Gantry → OGP → Bonding → Encapsulation → Electrical Test / Thermal Cycling

Preliminary Considerations:

- **Gantry and wire bonding** may require **extended working hours or shift operation** with the current setup;
- **OGP and electronic testing** could become important throughput constraints when scaling toward 24 modules/day; **(MUX system's set up can be very helpful for electronic testing workflow)**
- Further optimization, particularly the **MMTS-based electrical testing workflow**, may help increase the overall throughput. **Thermal cycling is expected to support the target throughput;**

Preliminary estimate: reaching 24 modules/day may require additional manpower, extended/shift operation, and further workflow optimization.

Test Results

- 78 V3C modules were tested with MMTS: all perform well;
- 394 V3D modules were tested using MMTS: 23 modules are downgraded to C after thermal cycle (broken), 6 modules turn to B after thermal cycle, 2 modules are found ESD damaged after thermal cycle;

Module status	Grade A	Grade B	IV grade C/F module	ESD module	Downgrade from A-B	Sum
V3C, Before thermal cycle	78	-	-	-	-	78
V3C, After thermal cycle	78	-	0	-	0	78
V3D, Before thermal cycle	387	2	4	1	-	394
V3D, After thermal cycle	356	2+6	4+23	1+2	6	394

Installable (V3C + V3D, grade A+B)

passed MMTS test: ~ 93.6%

V3C passed MMTS (grade A+B): 100%

V3D passed MMTS (grade A+B): ~92.38%

Summary

MMTS system is utilized in thermal cycling and IV curve measuring for HGCal silicon modules;
Each module goes through thermal cycles between room temperature and -40 °C;
The IV performance is tested before, during and after thermal cycling;
Pedestal run is under development at the moment;

An automated thermal cycling test script is implemented based on previous software;
The whole system operates well in the past few months;
A capacity of up to 24 modules per day is expected;

Thank you!

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