



AOMSUC-15 2025 FYSUC

THE 15TH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE (AOMSUC-15)
2025 FENGYUN SATELLITE USER CONFERENCE (2025 FYSUC)

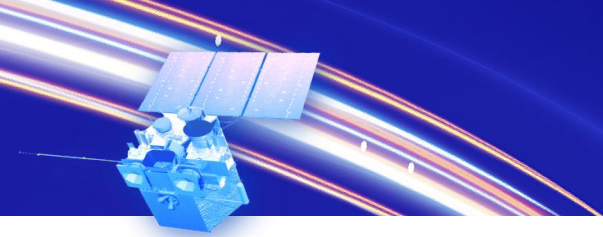
Research progress on space infrared radiation reference SI-traceable subsystem

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➤ Outline

- **Research Background**
- **Research Objectives**
- **Technical Approach**
- **Test Results**
- **Conclusion**

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* Inter-Comparison of Suomi NPP CrIS with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements, 2014.
 * Importance of error sources in climate data on different analysis scales. C. J. Merchant, 2014

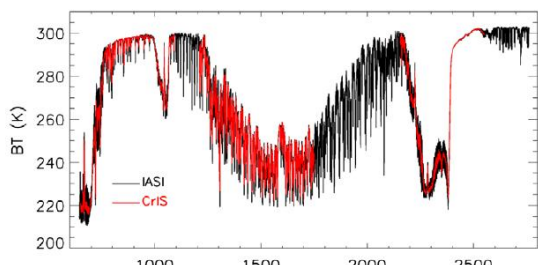
Development of science and technology

Key Points

Remote sensing data from different sources have calibration differences

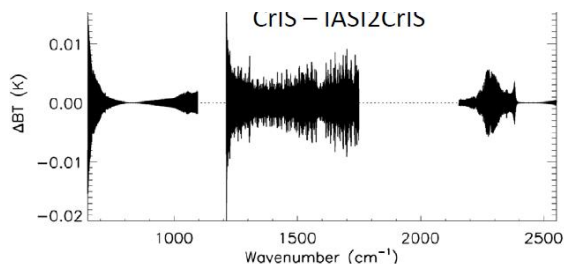
Needs

High-precision quantification & SI-traceability

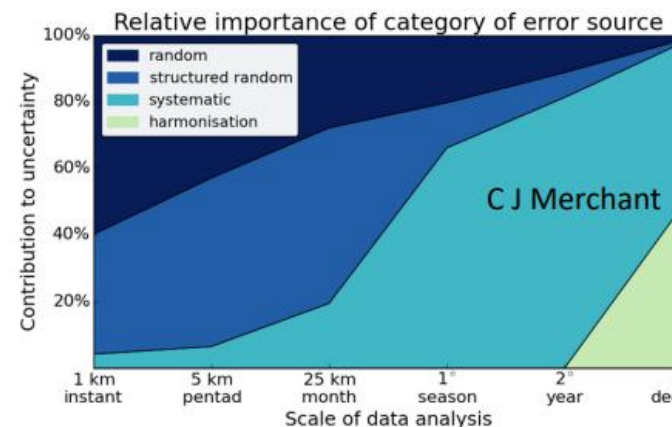


CrIS v.s. IASI

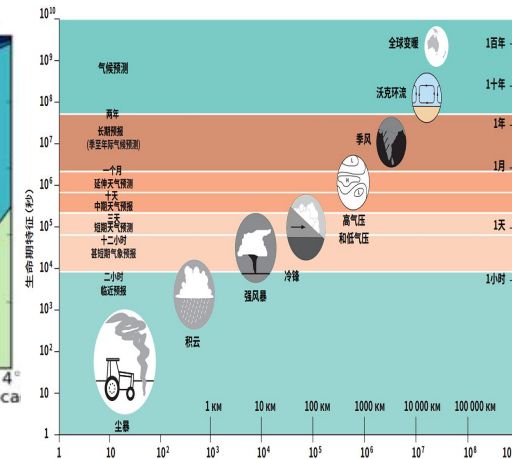
CrIS - IASI / CrIS



Global Operational Meteorological Satellite Observation System



As the time and space scales increase, systematic uncertainties become dominant



Meteorological events can be observed over a century

Climate change science data comes from different payloads

Large difference between payloads' absolute radiometric calibration

Cannot truly reflect the slight changes in climate observed

China, the United States and Europe:
 Lets get IR benchmark payloads!

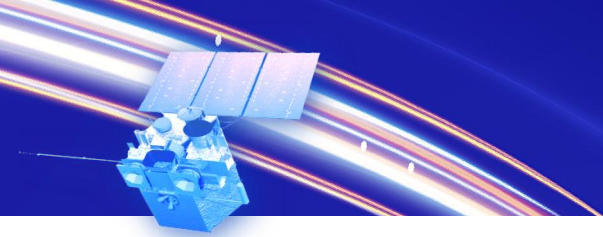
➤ Great significance:

❑ A common radiation benchmark

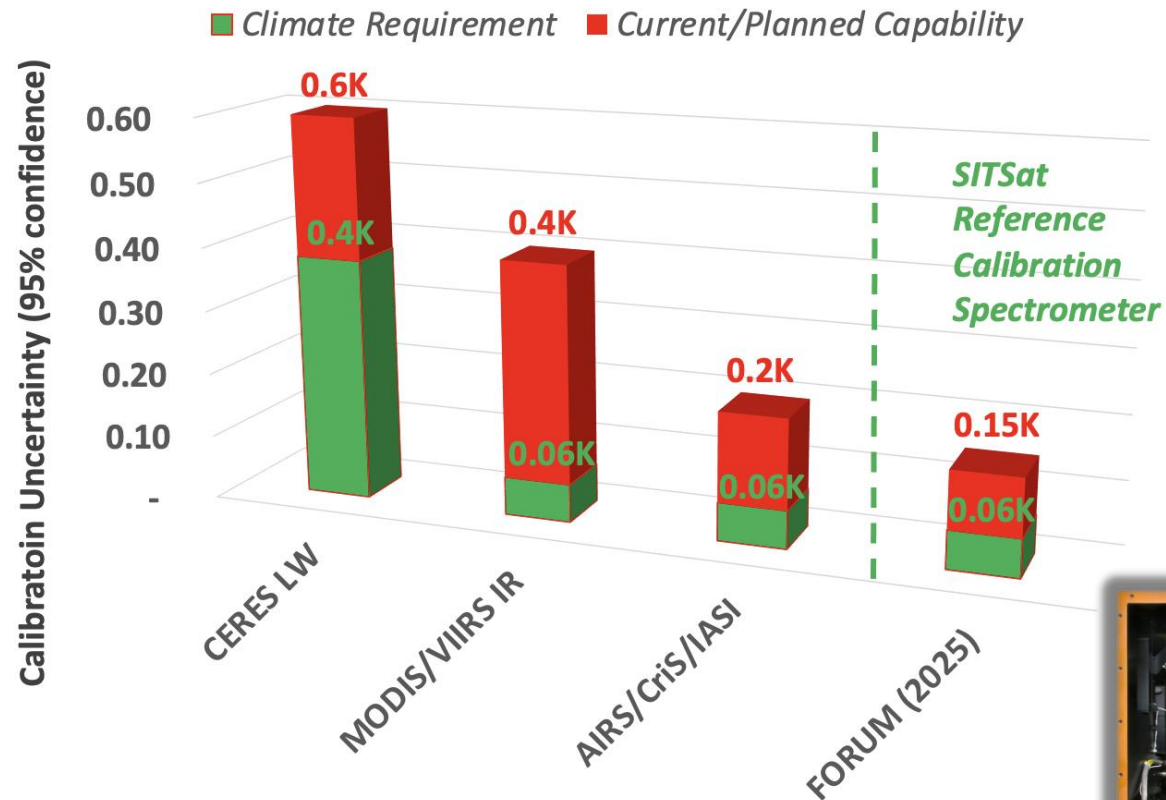
❑ Reduce the cost of remote sensing satellites

❑ Provide reliable data

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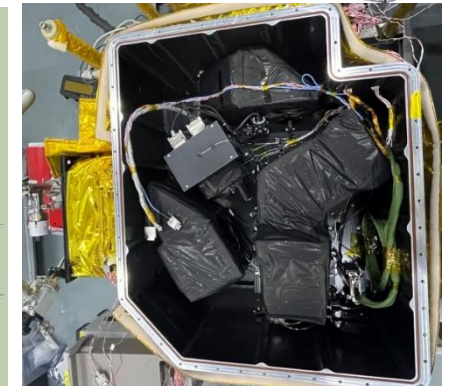
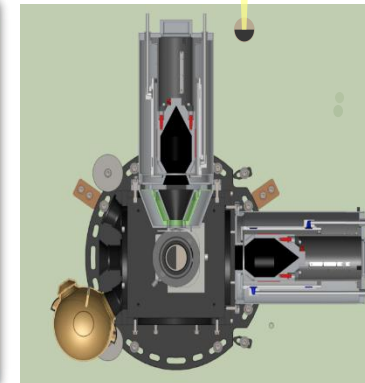
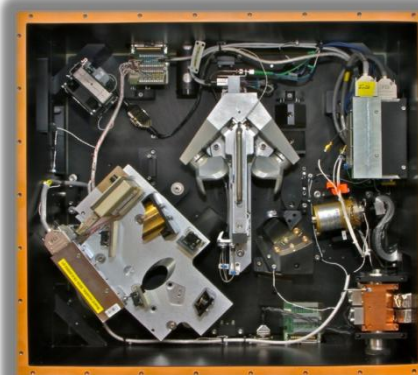
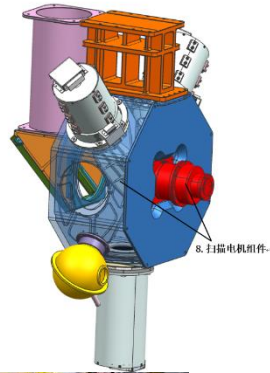


Infrared Current Capabilities versus SI Climate Requirement



➤ The infrared radiation quantification accuracy represented by meteorological satellite imaging and detection payloads has reached **0.2K**.

Still cannot meet the 0.06K climate change monitoring needs



Satellite Observation Type

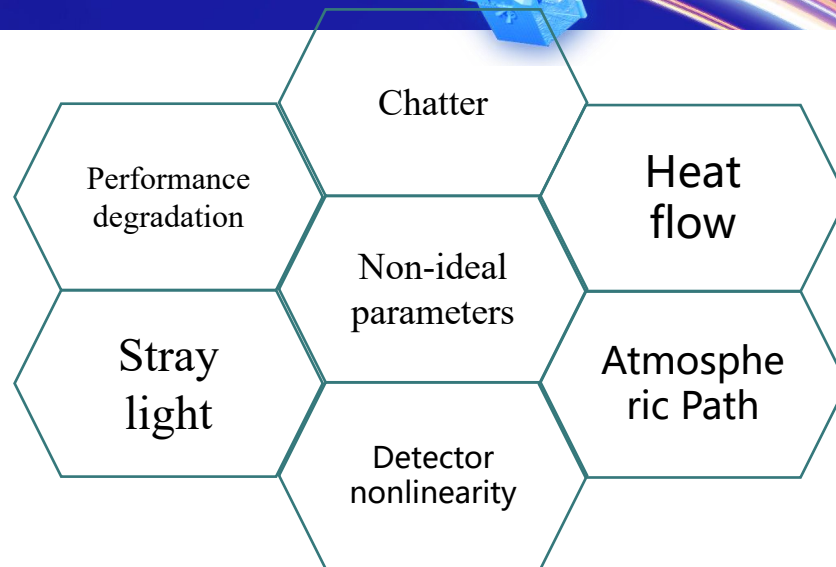
*: SI-traceable space-based climate observation system: a CEOS and GSICS workshop, National Physical Laboratory, London, UK, 9-11 Sept 2019.

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Development route
of Chinese infrared
benchmark payload

Complex environment

Non-idealization

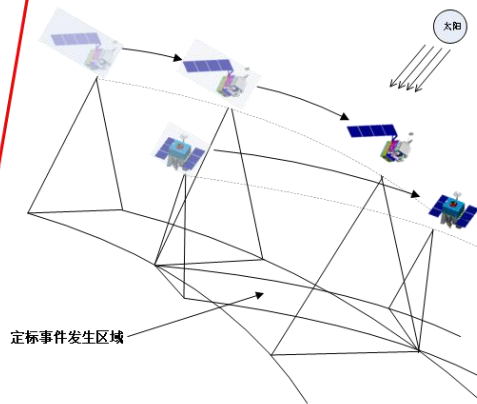


When it comes to on-orbit
engineering applications, **adapting
to the environment and non-ideal
parameters** become the main issues

Done

Done

We are here



**Infrared radiation
reference source**

Fixed phase change point &
emissivity on-orbit
measurement

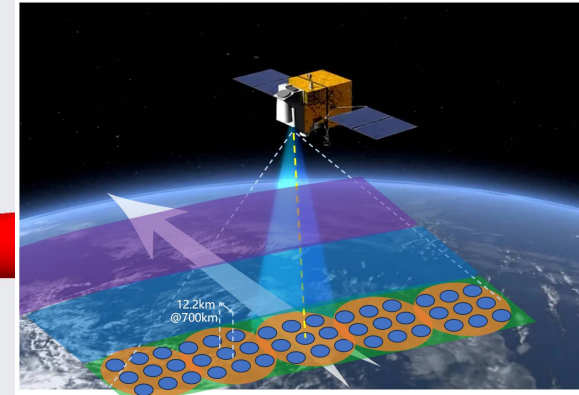
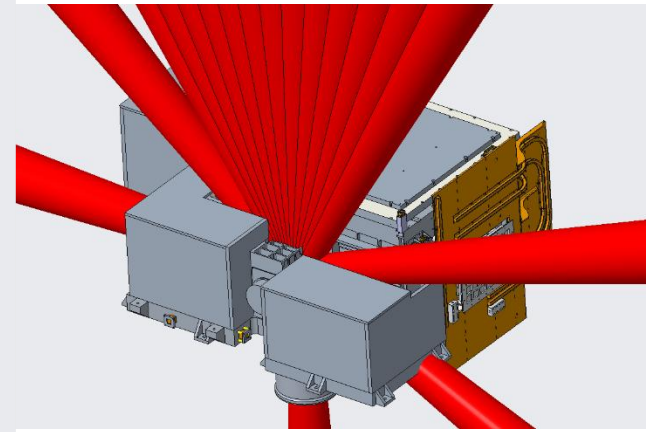
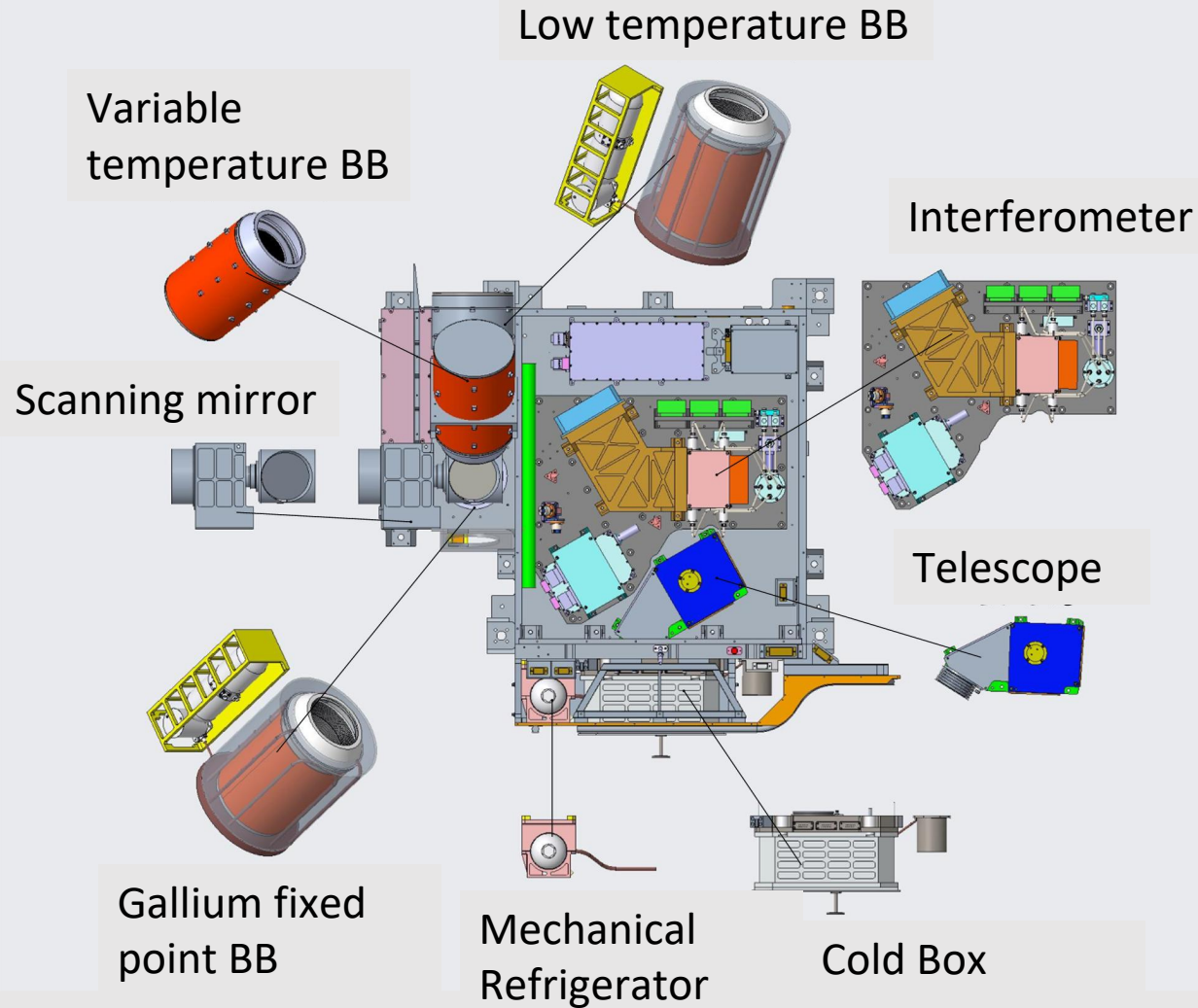
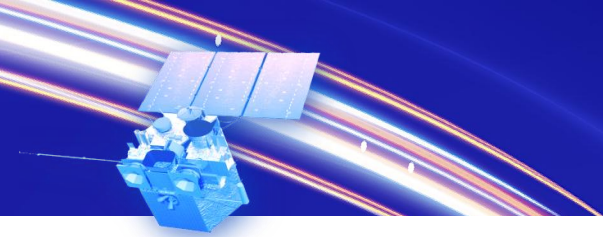
**Radiation benchmark
prototype**

Infrared hyperspectral, large-
aperture infrared radiation
source, SI-traceability

**IR benchmark
payload**

**On-orbit infrared
radiation
benchmark transfer**

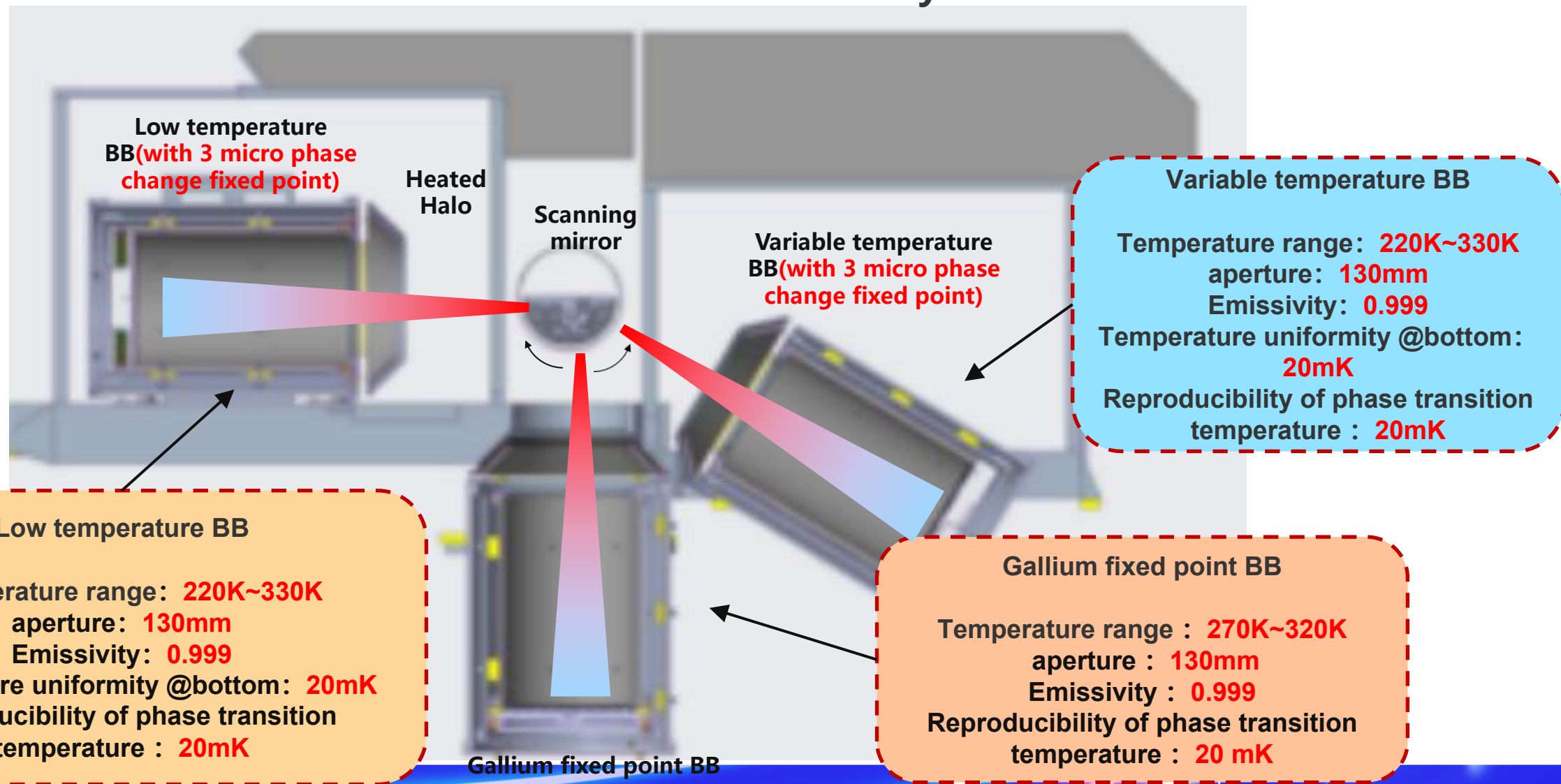
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- Key and difficult issues in high-precision SI-traceable radiation sources:
 - Engineering implementation
 - Long-term reliability verification
 - On-orbit radiation transfer method

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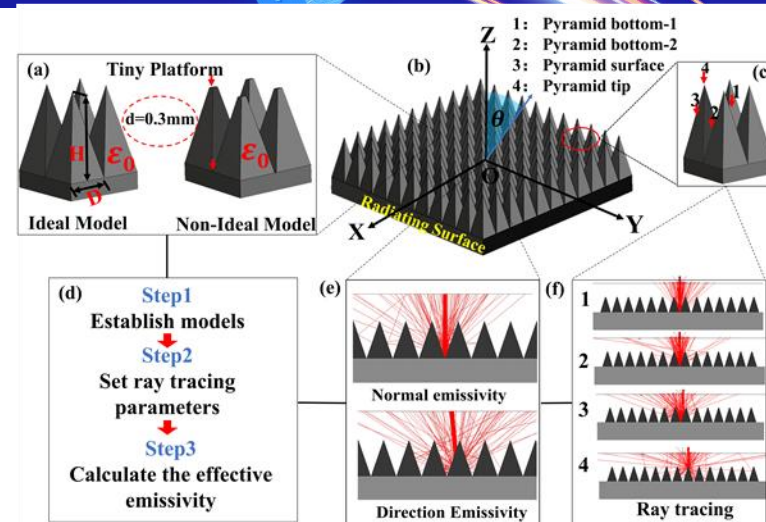
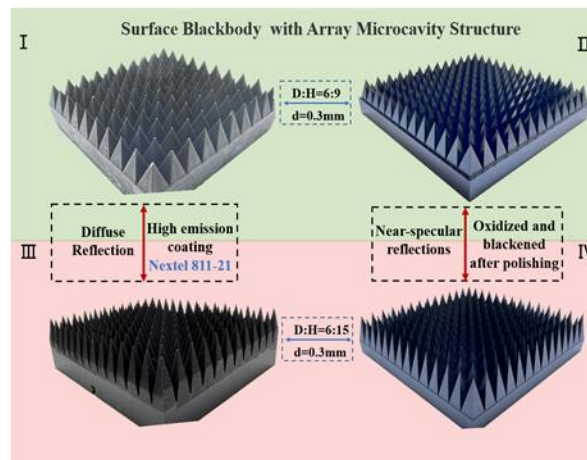
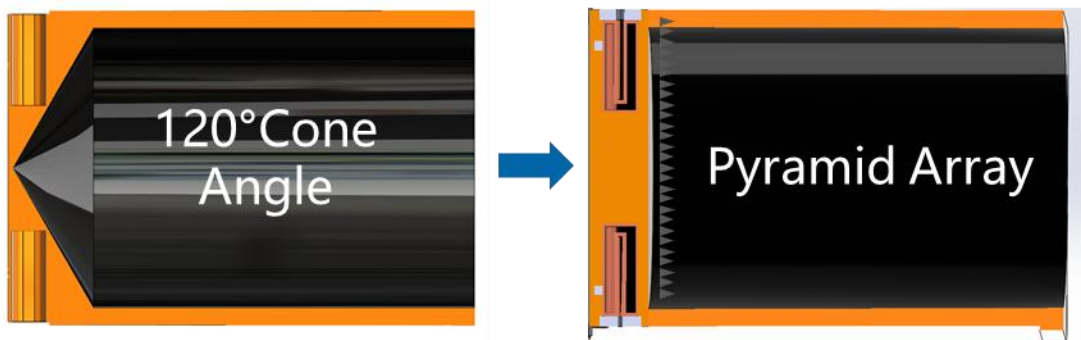
Overview of infrared radiation reference SI-traceable subsystem



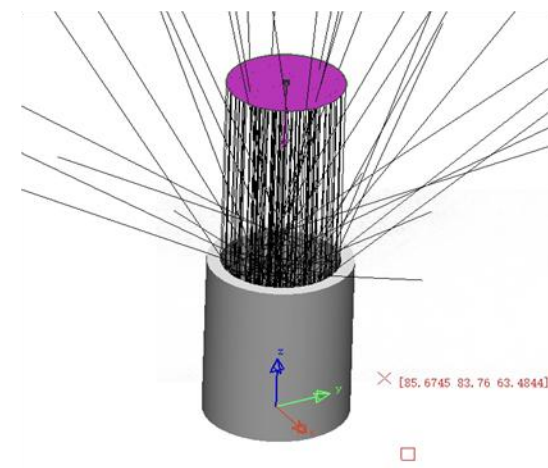
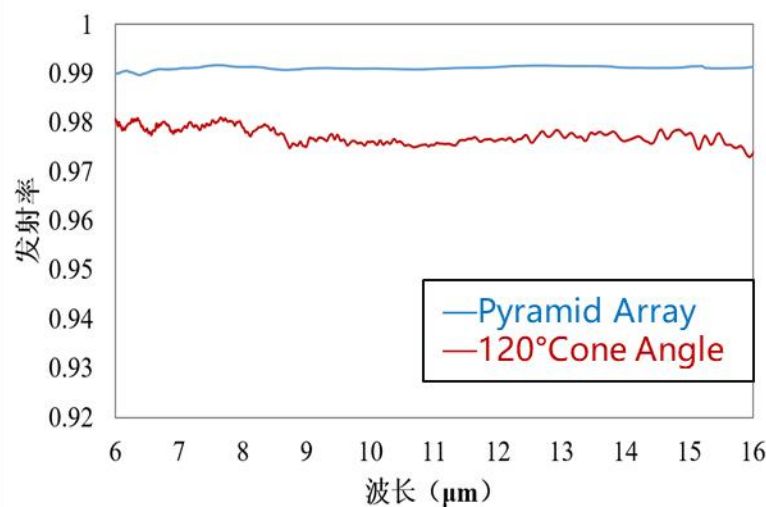
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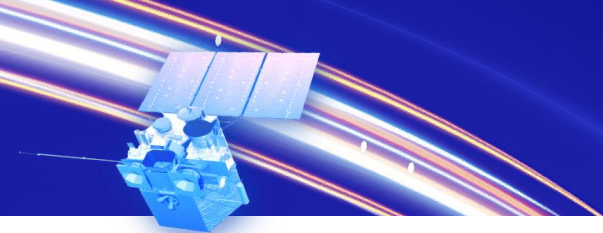
Large-aperture, high-emissivity blackbody lightweight design



	120° Cone Angle	Pyramid Array
aperture/mm	130	130
Blackbody cavity depth/mm	250	250
Weight/Kg	1.2	1.1
Emissivity	0.9976	0.9993



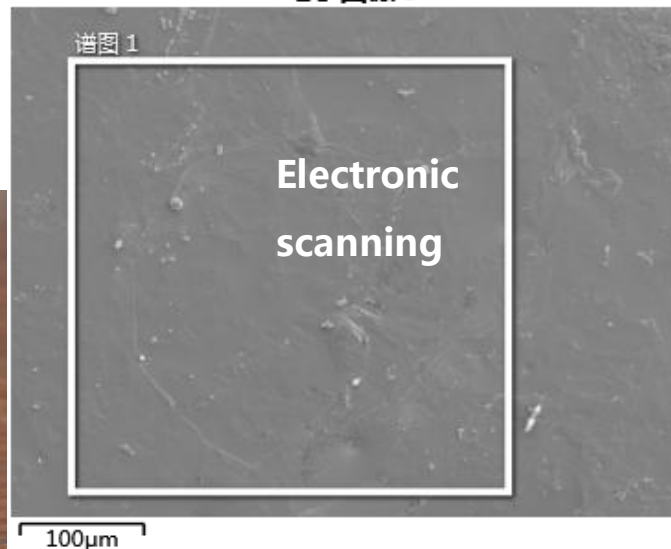
AOMSUC-15 2025 FYSUC



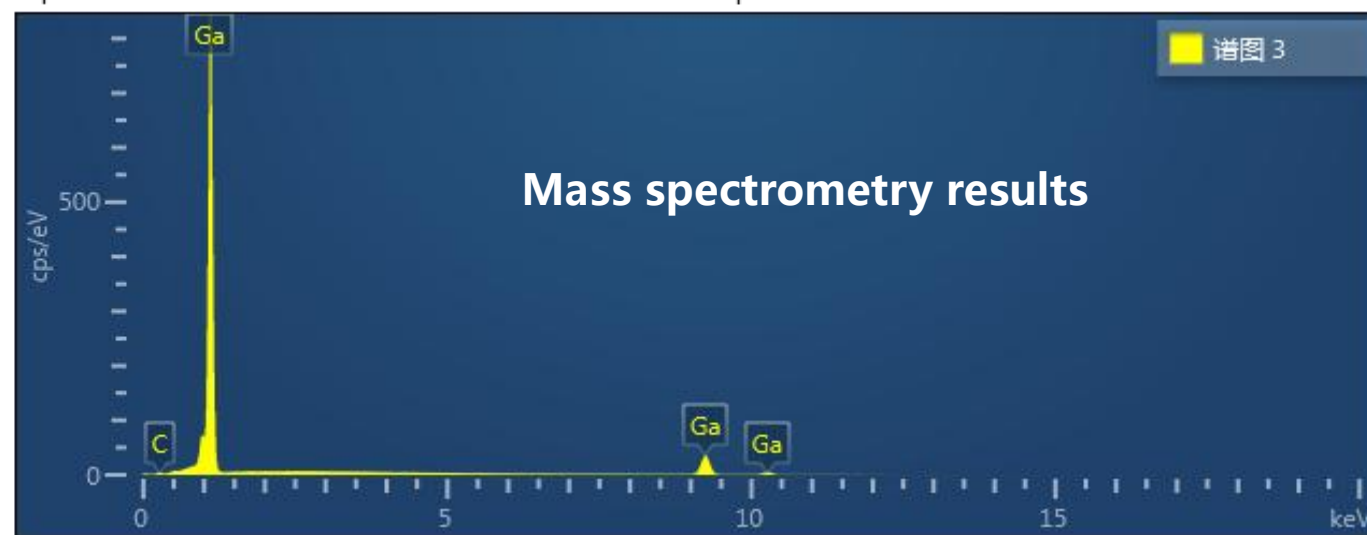
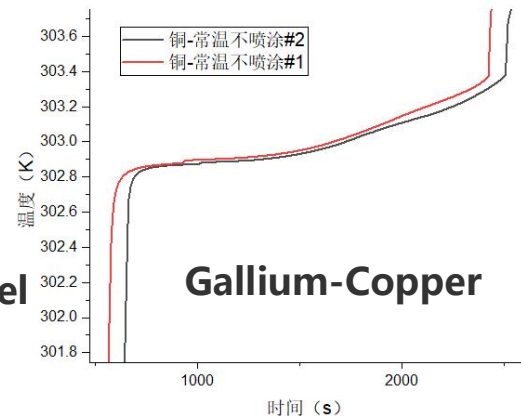
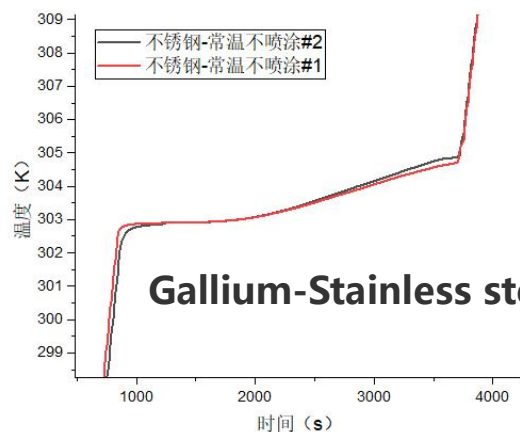
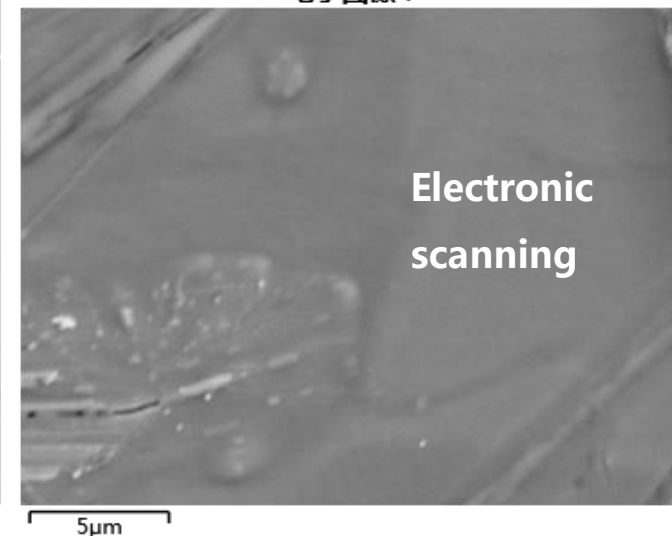
Micro phase change fixed point: package shell material study

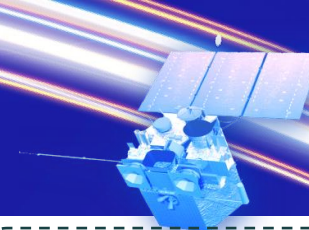


电子图像 5

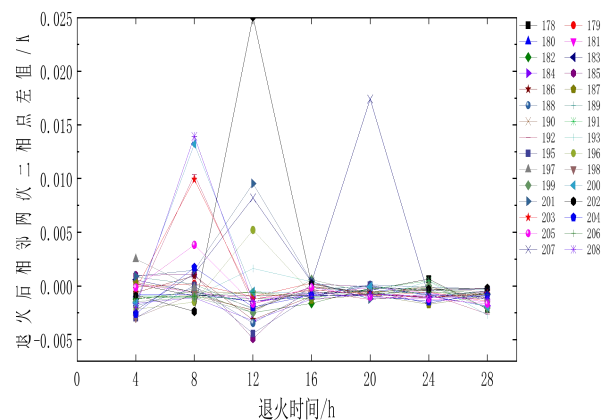


电子图像 7

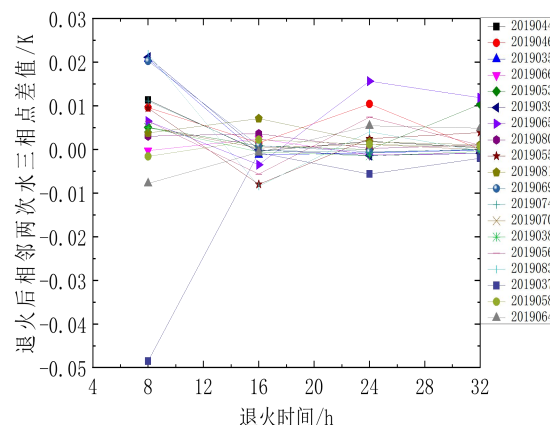




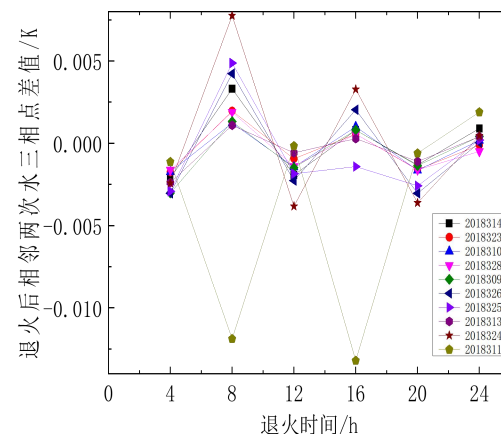
Effect of Annealing on Precision Platinum Resistance Temperature Sensor



4 hours@353 K, 4hours@233K
Temperature change of thermometer at
triple point of water

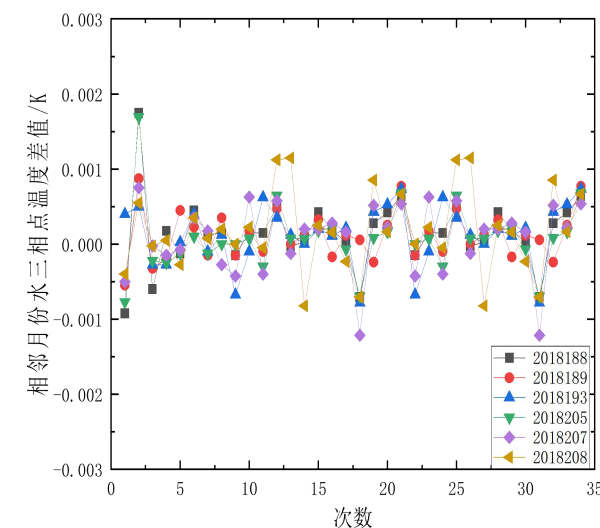


4 hours@353 K, 4hours@213K
Temperature change of thermometer at
triple point of water



2 hours@353 K, 2 hours@77K
Temperature change of thermometer at
triple point of water

Long-term stability:

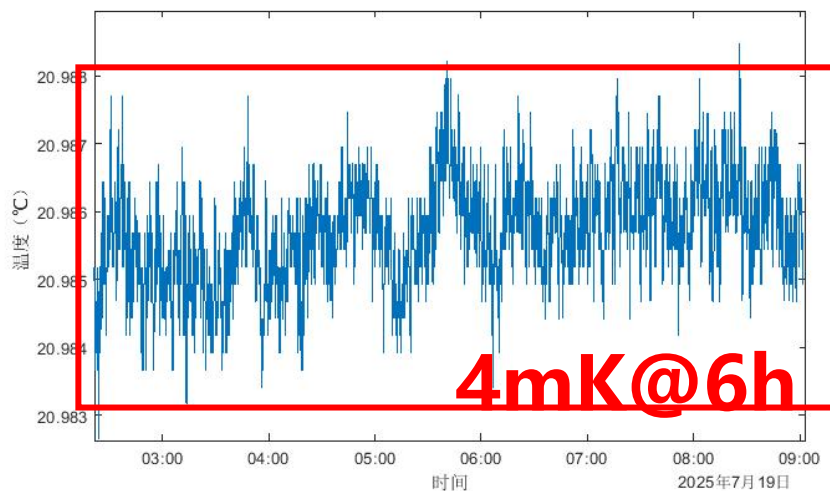
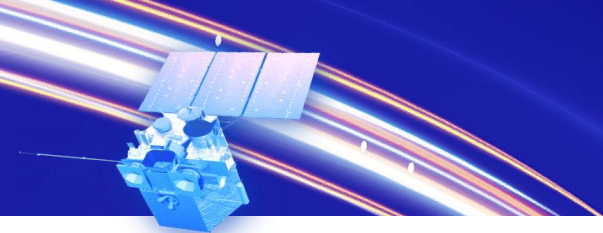


Adequate annealing is very important for the stability of the precision platinum resistance thermometer.

The stability of the thermometer at the water triple point temperature after annealing is also the basis screening a large number of thermometers.

➤ 3-year long-term stability results:

- 4.7mK@273.16K
- 4.3mK@341.15K
- 2.7mK@234.32K



Parameter	Current	New
Topology	14-bit ADC Calibration depends on stability of entire circuit	24-bit ADC Calibration depends only on stability of reference resistor
Readout accuracy	~20mK	< 5mK
Readout resolution	5mK	100 μ K

Stepper
Motor

Gold plated
bezel

Support
structure

Heated
halo

Gallium fixed
point BB

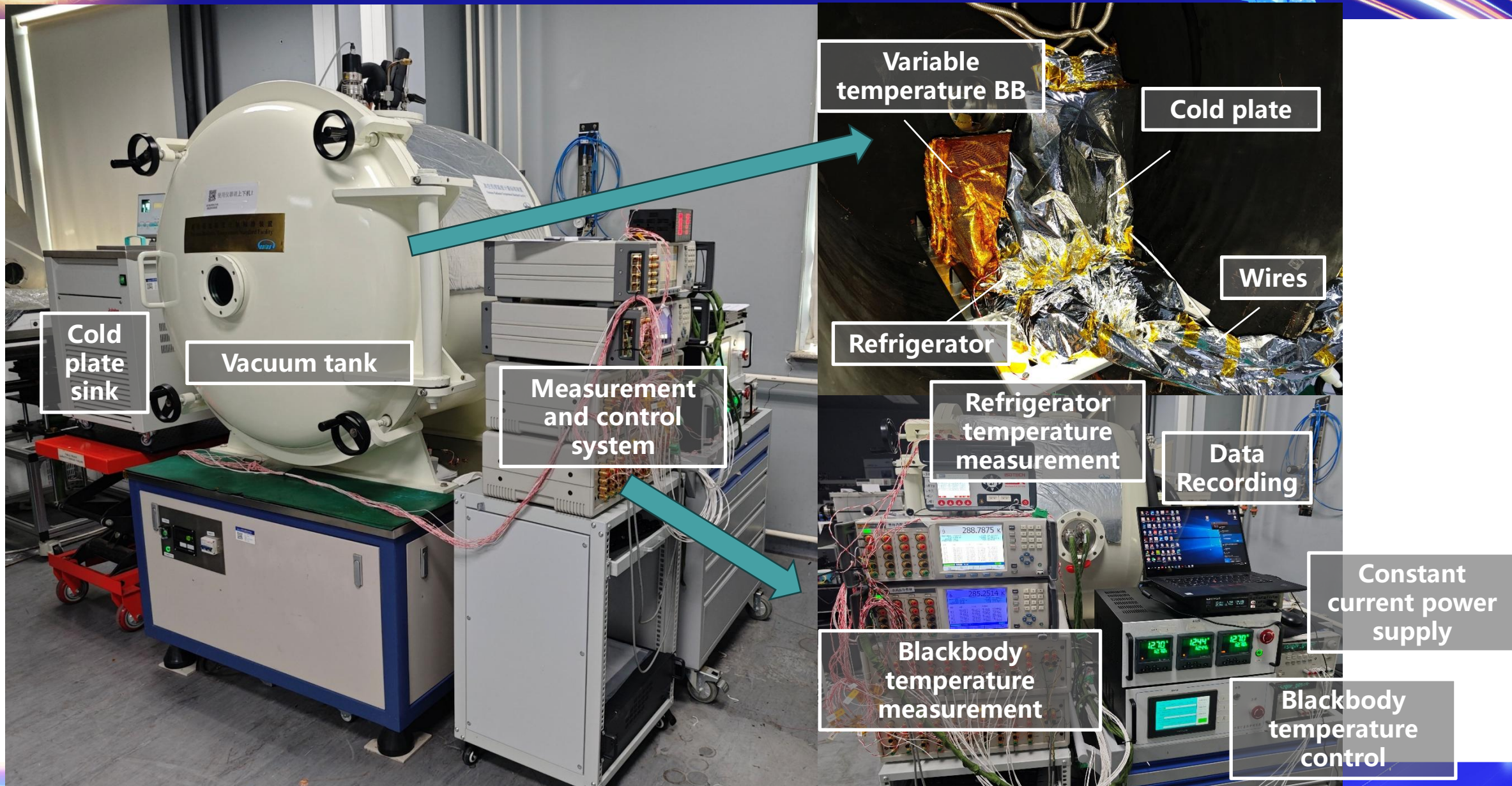
Stepper
Motor

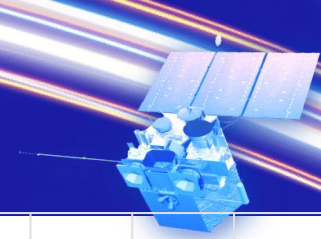
Support
structure



- Each blackbody has a gold plated bezel and heated halo:
 - Isolate external heat flow
 - Maintain phase change process stability
 - Measure emissivity

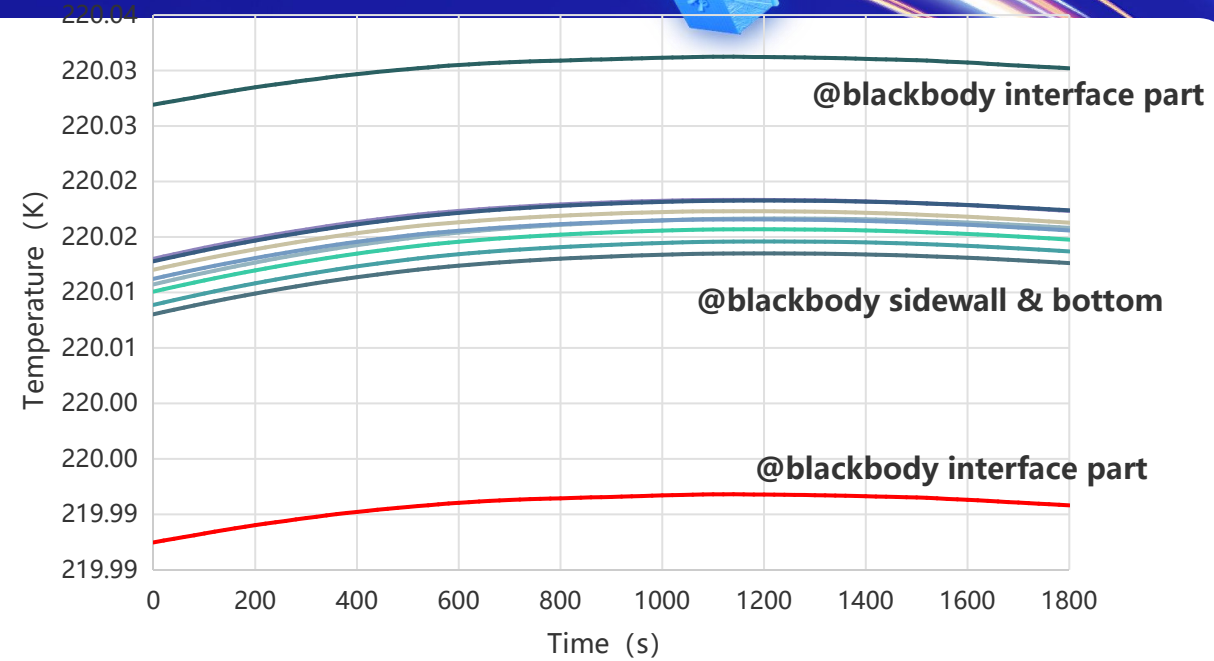
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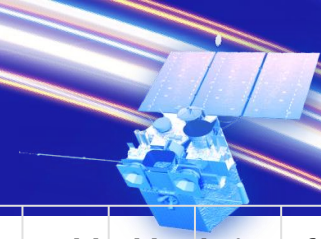
Experimental Status

- **BlackBody**(use PID): **220 K**
- **Middle Layer**(use PID): **217 K**
- **Outer shell**(no control): **205 K**



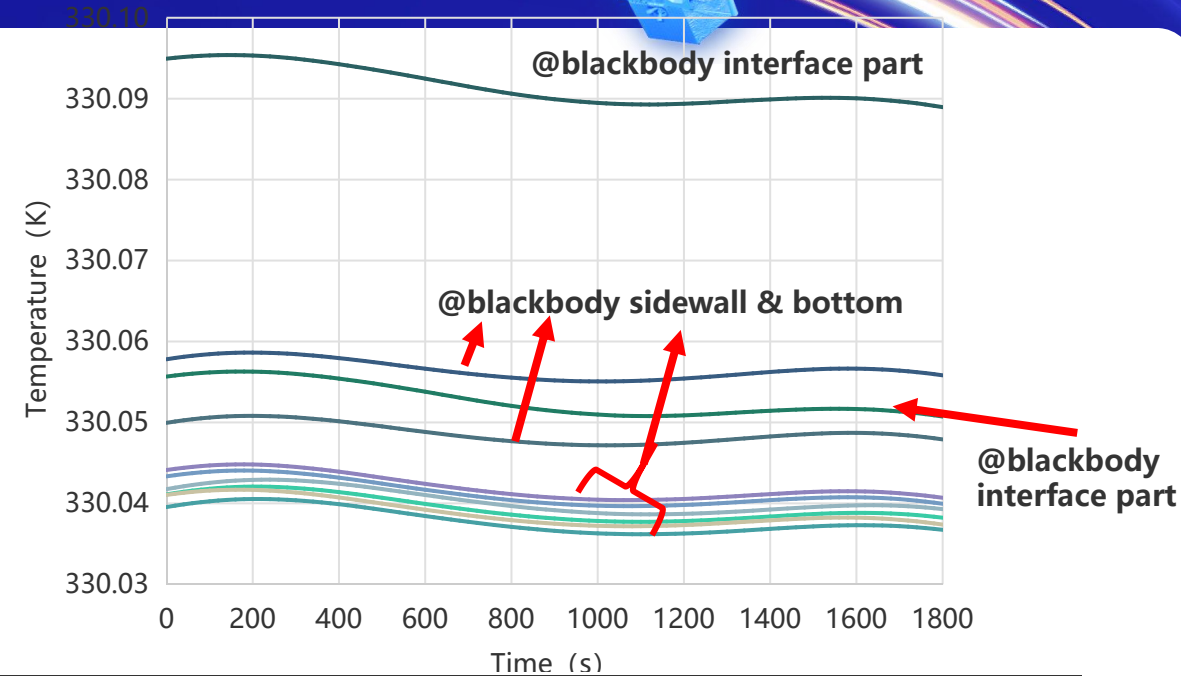
Temperature uniformity and stability within 30 minutes(Unit: K)

ID code	S1-1	S1-2	S1-3	S1-4	S1-5	S1-6	S1-7	S1-8	S1-9	S1-10
Name	Bottom 1	Bottom 2	Bottom 3	Bottom 4	Bottom 5	Bottom 7	Sidewall 1	Sidewall 2	Sidewall 3	Sidewall 4
Position	In the crucible	In the crucible	In the crucible	Bottom	Bottom	Middle of the bottom	Top of sidewall	Top of sidewall	Under of sidewall	Under of sidewall
Mean temperature	220.0133	220.0144	220.0153	220.0154	220.0172	220.0161	220.0303	219.9908	220.0123	220.0170
Stability (standard deviation)	0.0016	0.0015	0.0017	0.0015	0.0014	0.0014	0.0011	0.0012	0.0015	0.0015
Max temperature difference of bottom: 0.0038			Standard deviation of bottom: 0.0013			Max temperature difference of blackbody: 0.0394			Standard deviation of blackbody: 0.0096	



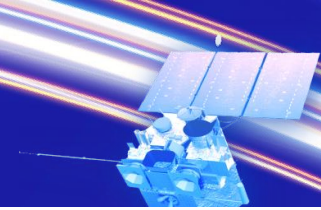
Experimental Status

- **BlackBody**(use PID): **330.0 K**
- **Middle Layer**(use PID): **327.0K**
- **Outer shell**(no control): **326 K**



Temperature uniformity and stability within 30 minutes(Unit: K)

ID code	S1-1	S1-2	S1-3	S1-4	S1-5	S1-6	S1-7	S1-8	S1-9	S1-10
Name	Bottom 1	Bottom 2	Bottom 3	Bottom 4	Bottom 5	Bottom 7	Sidewall 1	Sidewall 2	Sidewall 3	Sidewall 4
Position	In the crucible	In the crucible	In the crucible	Bottom	Bottom	Middle of the bottom	Top of sidewall	Top of sidewall	Under of sidewall	Under of sidewall
Mean temperature	330.0379	330.0394	330.0404	330.0413	330.0421	330.0389	330.0915	330.0529	330.0487	330.0566
Stability (standard deviation)	0.0015	0.0015	0.0015	0.0015	0.0015	0.0016	0.0023	0.0020	0.0012	0.0012
Max temperature difference of bottom: 0.0042			Standard deviation of bottom: 0.0016			Max temperature difference of blackbody: 0.054			Standard deviation of blackbody: 0.0162	



Experimental procedures

1. **Middle Layer**(use PID):

231.3K

2. **Blackbody**(use PID):

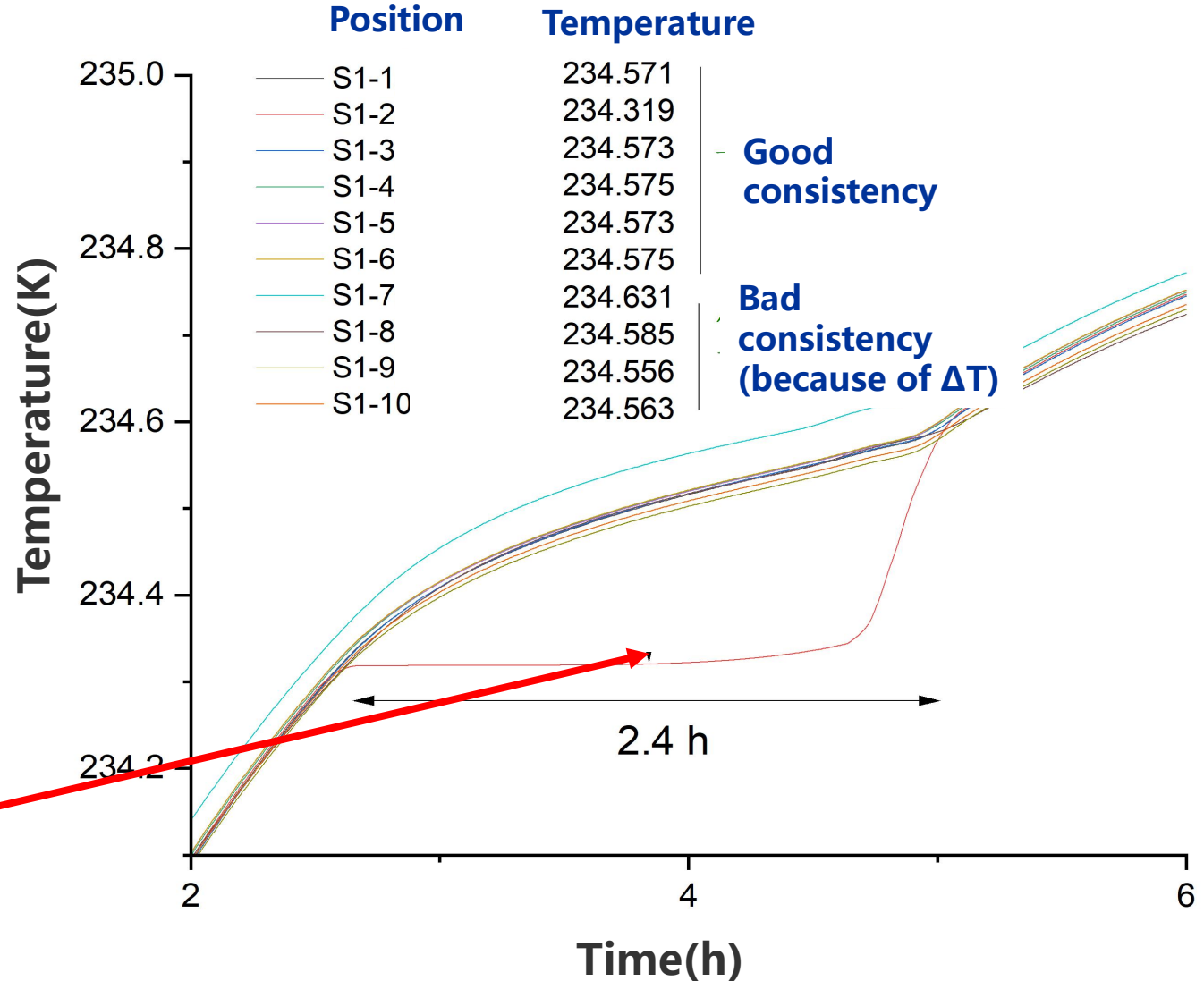
233.8K

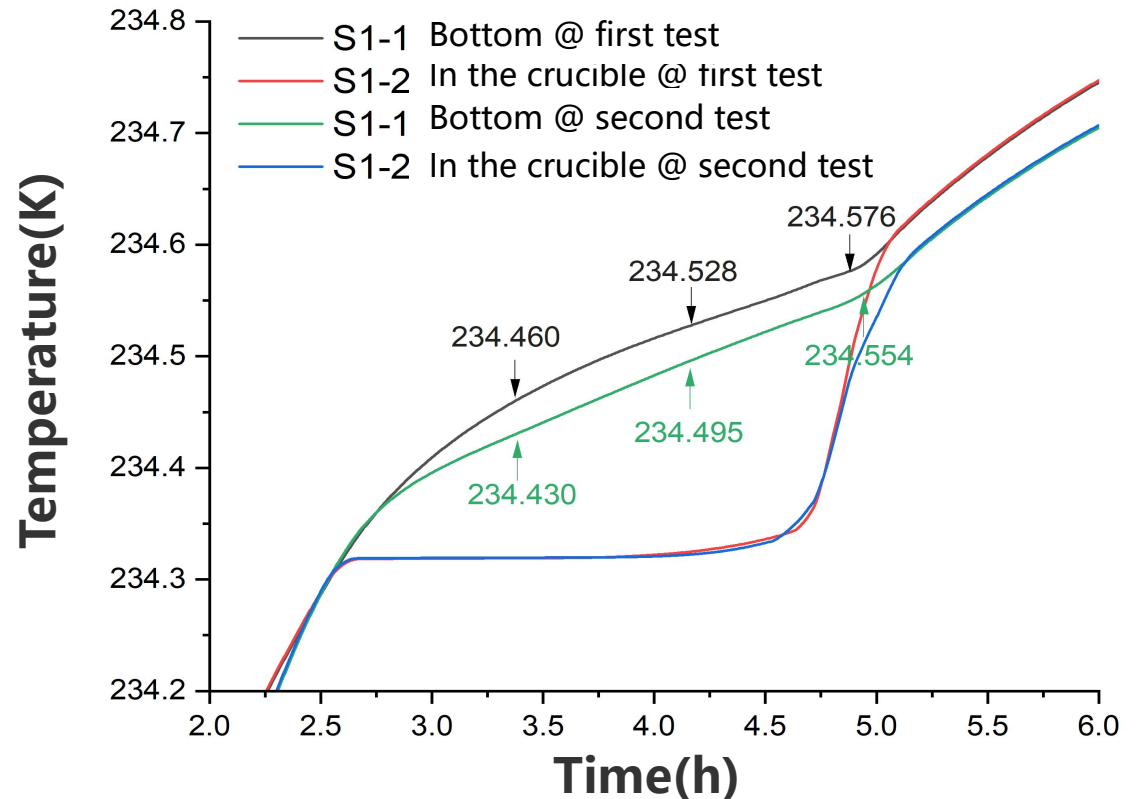
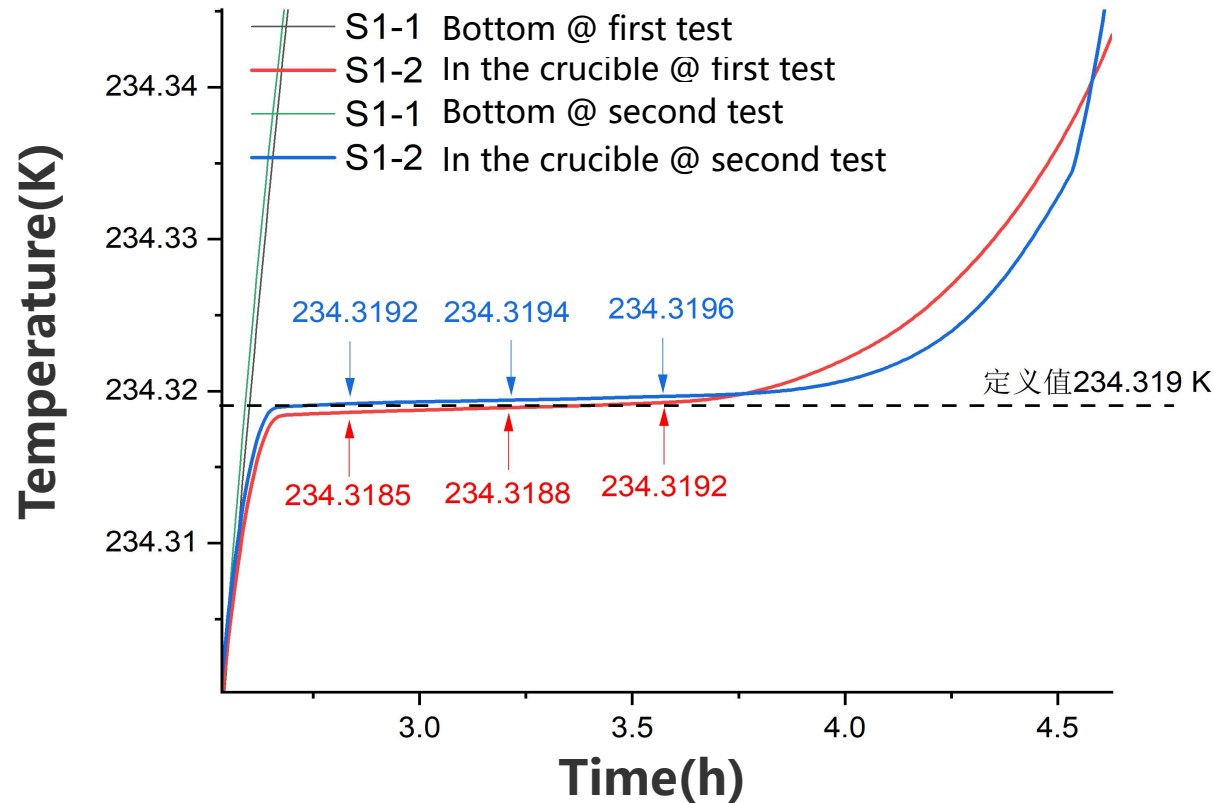
3. **Blackbody**(net power):

0.60W

Phase transition temperature
of Hg: **234.318K**

Measured temperature:
234.319K



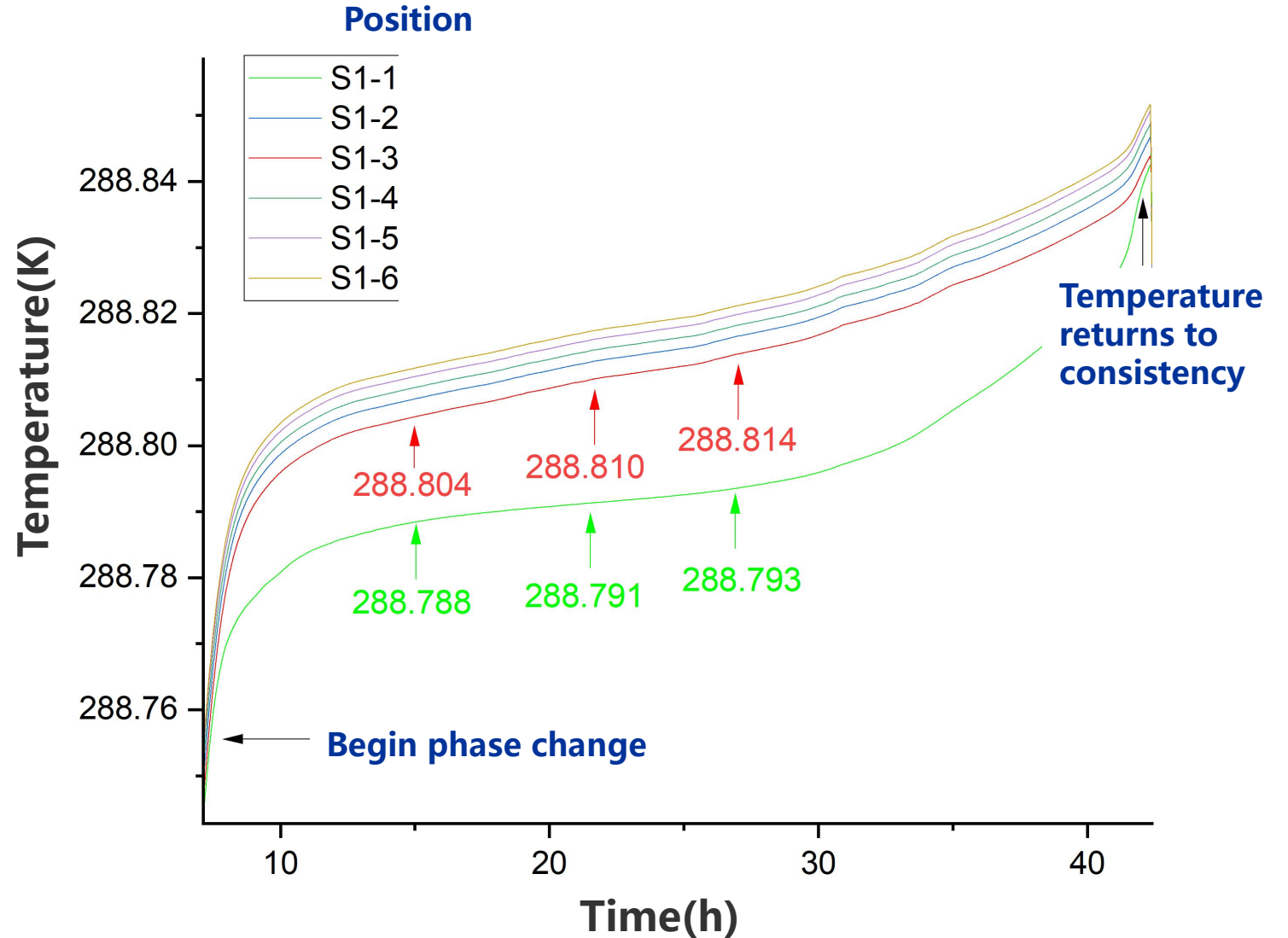


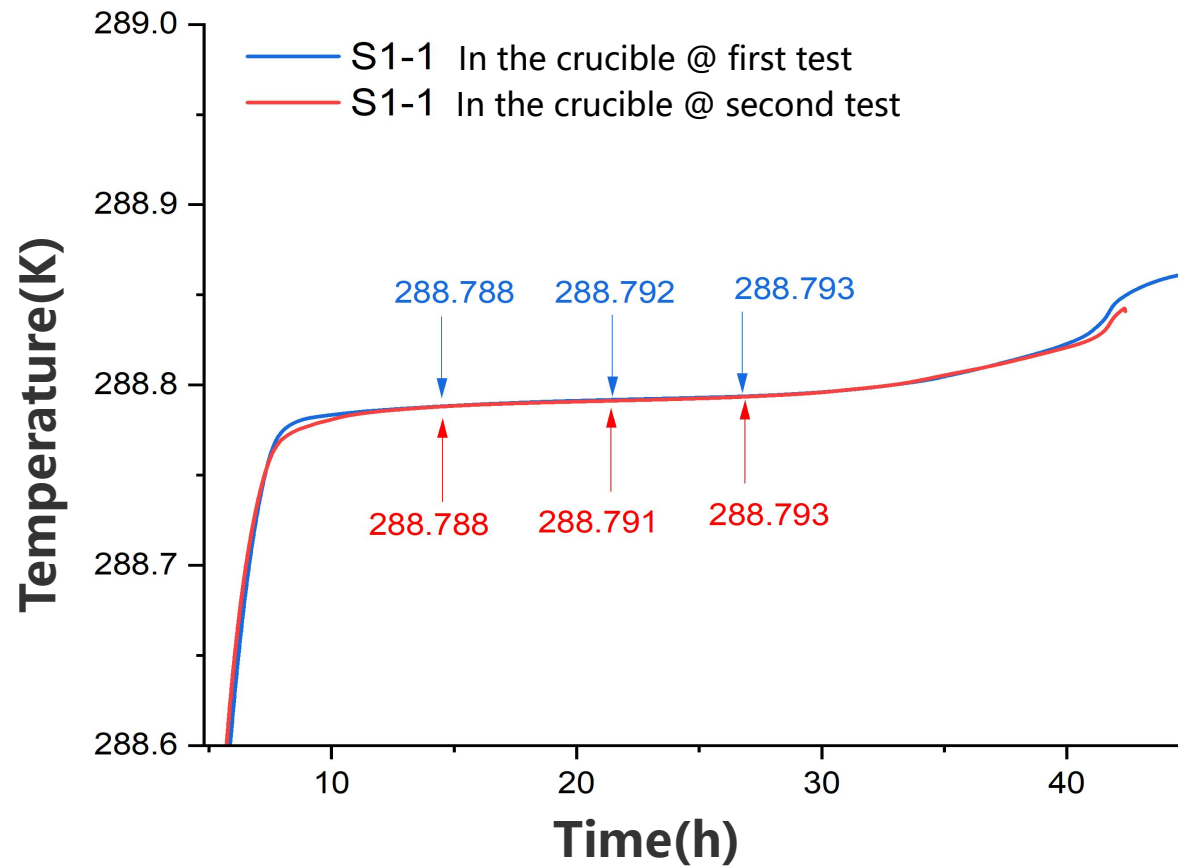
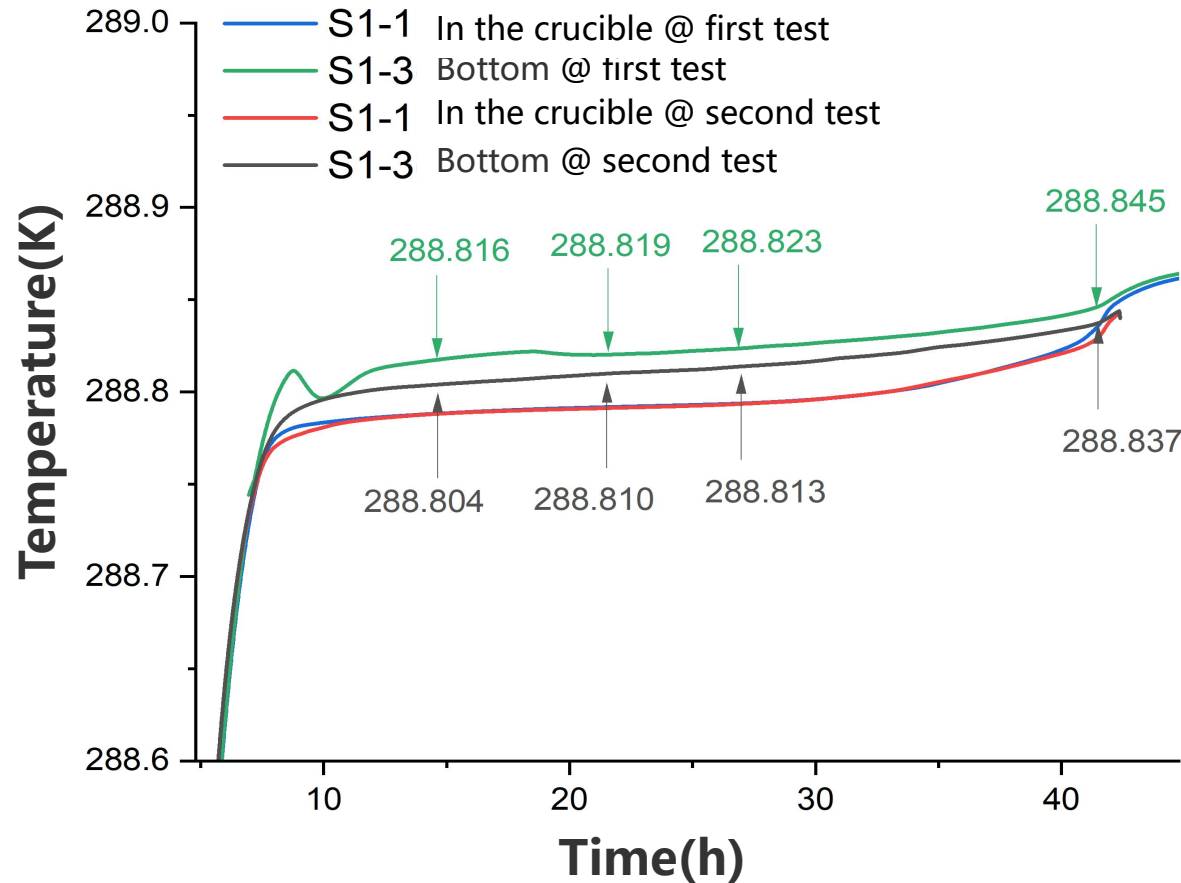
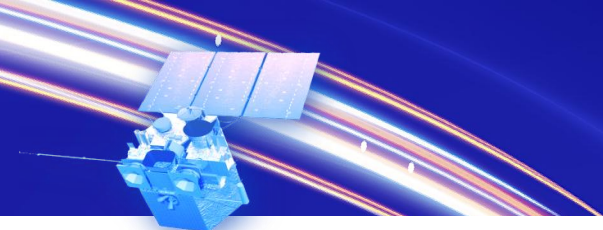
**Difference between phase transition temperature of Hg
and thermometer in crucible: $\leq 1\text{mK}$**
Reproducibility of thermometer in crucible: $\leq 1\text{mK}$

Experimental procedures

1. **Middle Layer**(use PID):
285.25K
2. **Blackbody**(use PID):
288.25K
3. **Blackbody**(net power):
0.49W

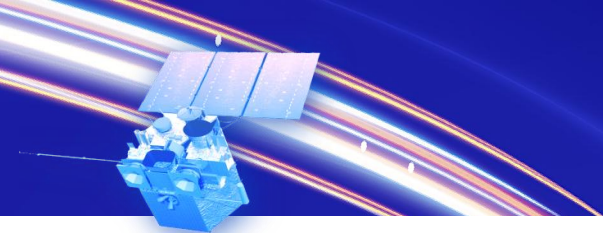
Gallium & Indium mixture





Max difference within whole phase change: **5mK**

Reproducibility of thermometer in crucible: **$\leq 1\text{mK}$**



Experimental procedures

1. **Middle Layer**(use PID):

299.4K

2. **Blackbody**(use PID):

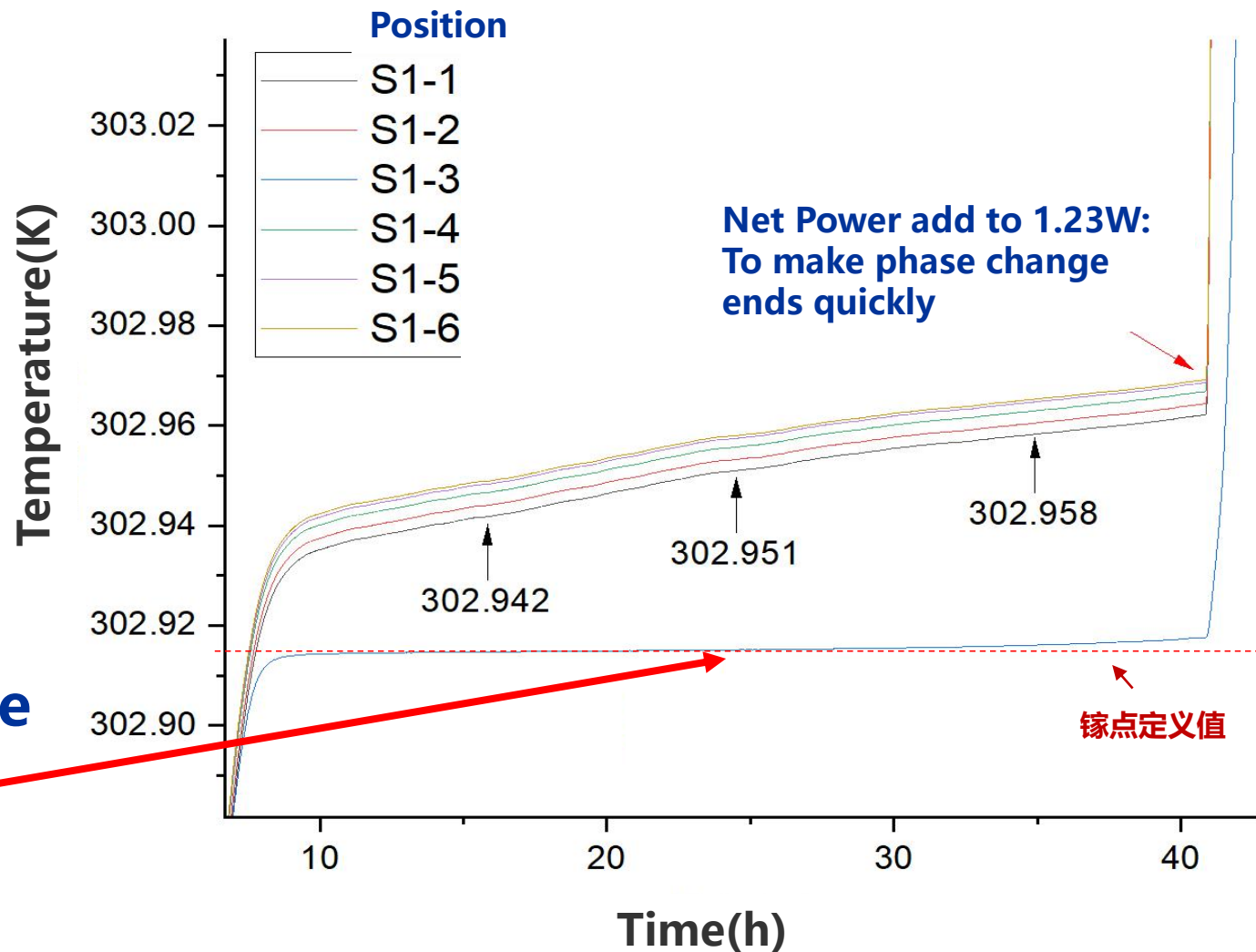
302.4K

3. **Blackbody**(net power):

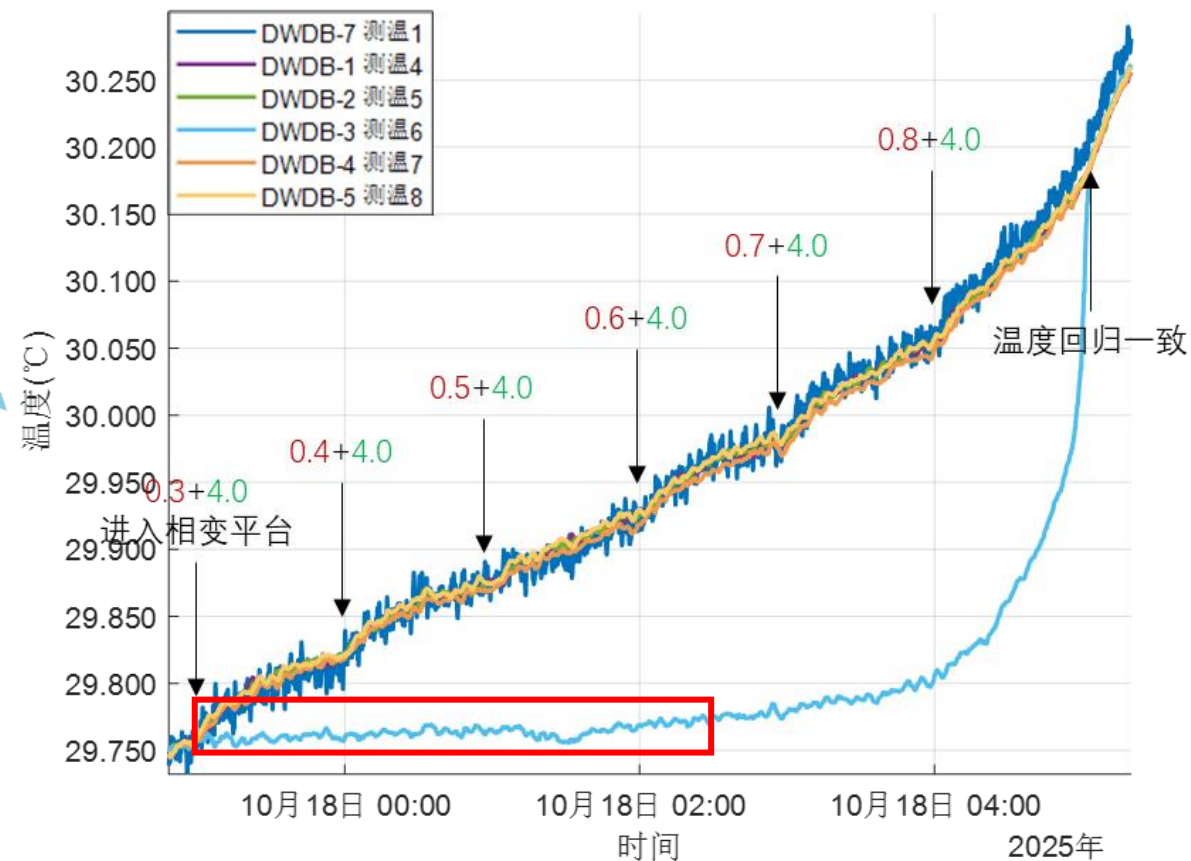
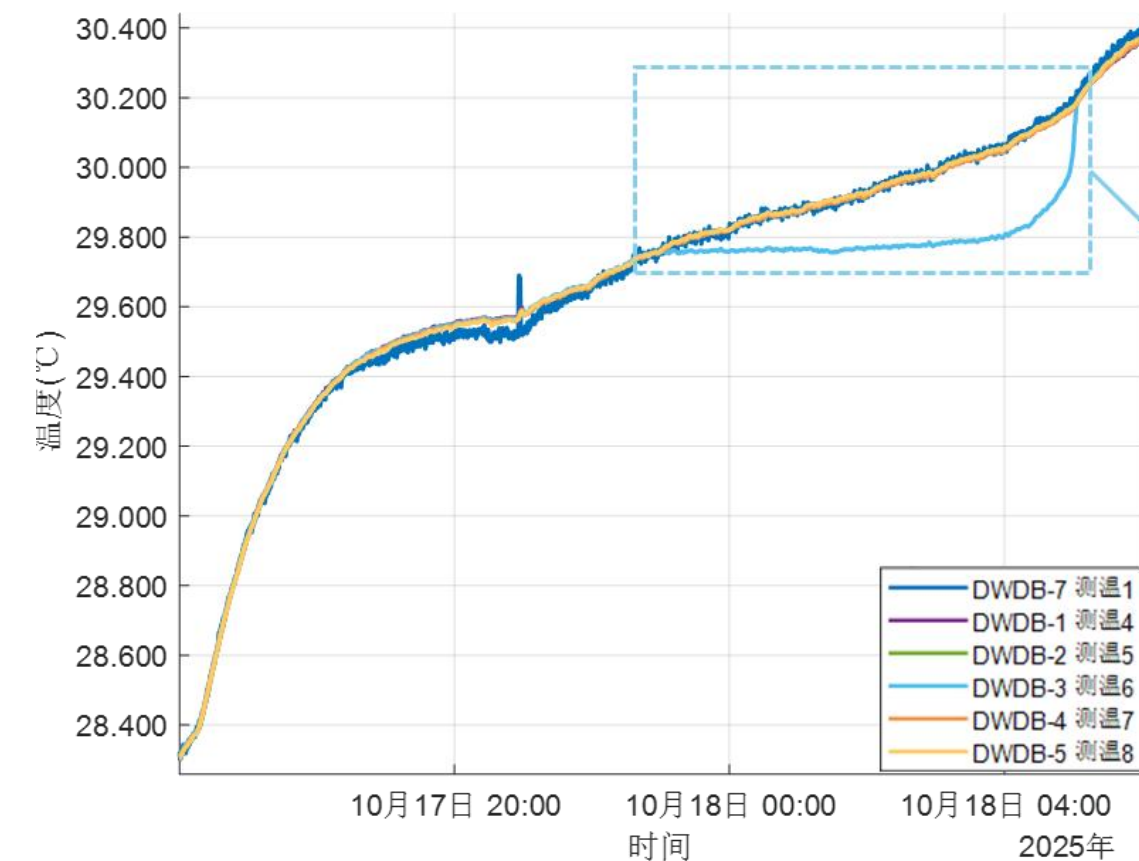
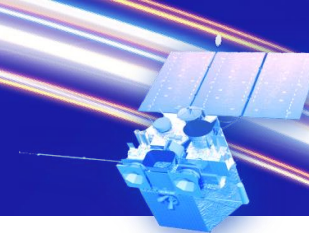
0.57W

Phase transition temperature
of Ga: **302.9146K**

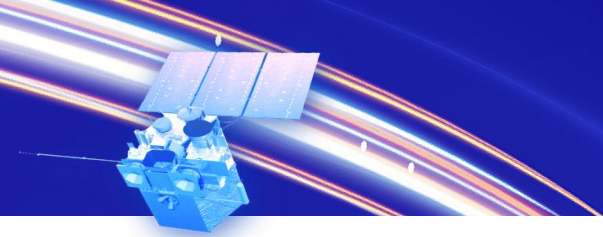
Measured temperature:
302.9150K



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Max temperature difference: 14mK
Standard deviation: 3.3mK



➤ Three blackbody design:

- Gallium fixed point BB **provides radiation benchmark** at gallium phase transition temperature
- Low temperature BB provides Earth observation radiation source **for daily use**
- Variable temperature BB provides **nonlinear calibration** radiation source

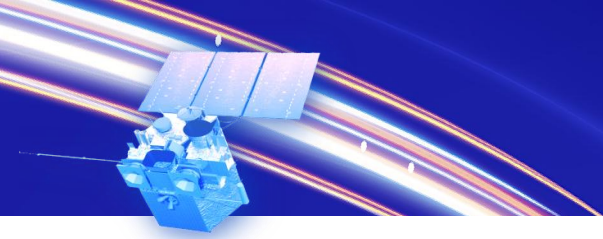
As a backup

➤ Each blackbody has a gold plated bezel and heated halo:

- Isolate external heat flow
- Maintain phase change process stability
- Measure emissivity

➤ Temperature uniformity and phase change test results show that the blackbody has good performance

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THANK YOU!!

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