Experimental investigation of a helium sorption cooler operating below 1 K

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- Research Background
- Theoretical Analysis and Simulation
- Experiments and Results
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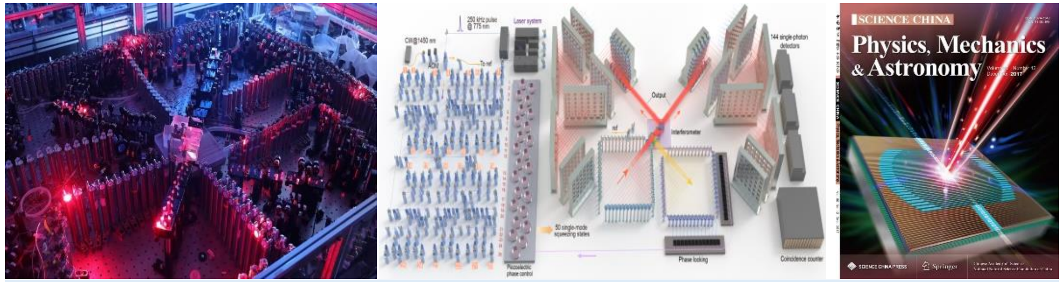
Research Background

Applications of the cooler operating below 1 K

- Superconducting Transition Edge Sensor (TES)
- Superconducting Nanowire Single-Photon Detector (SNSPD)
- Cryostat low-temperature physical property testing platform
- X-ray microcalorimeter cryogenic system
- Infrared and sub-millimeter wavelength detector
- ……

Ali CMB Polarization Telescope

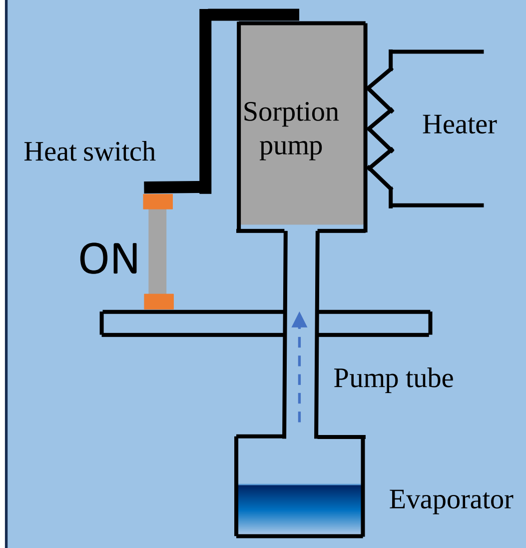


Jiuzhang 2.0 Photonic Quantum Computer

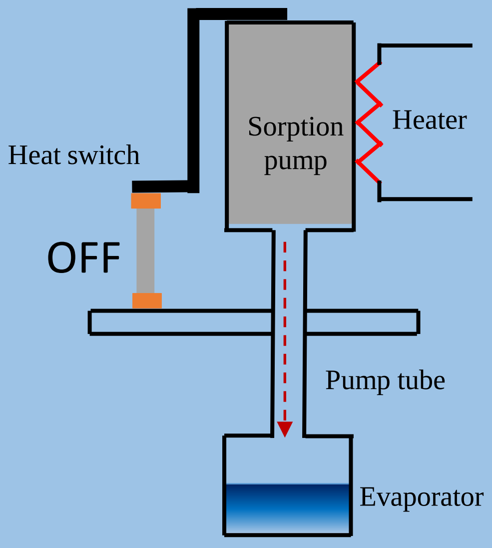
Micius Satellite for Quantum Science Experiments

Research Background

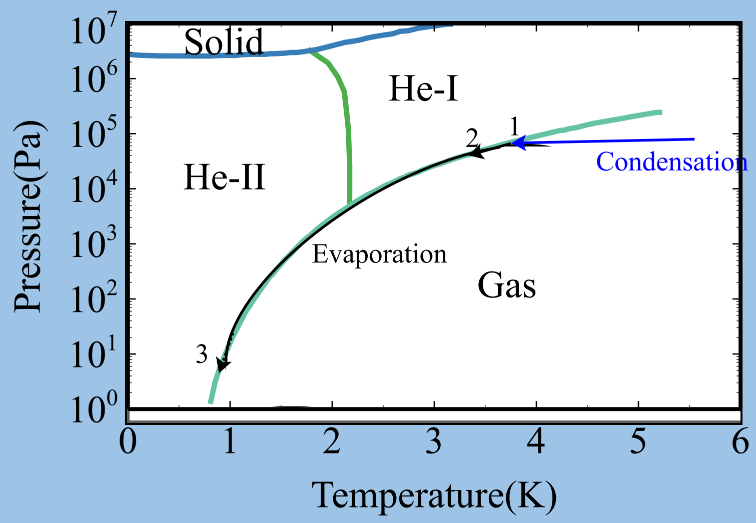
Advantages of the helium sorption cooler



Sorption



Desorption



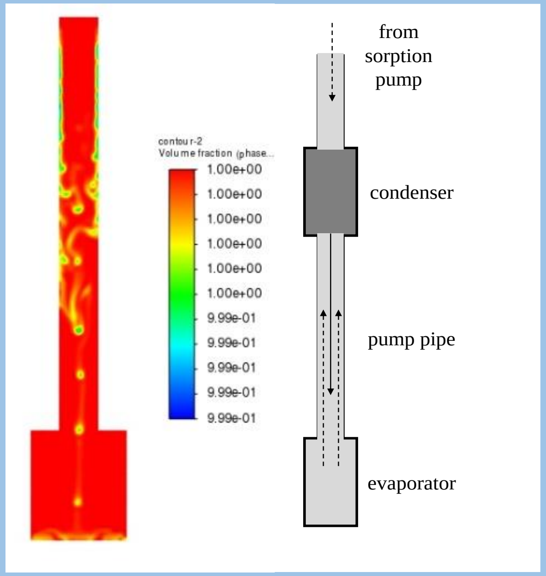
Saturated vapor pressure of helium

- **Advantages**
  - No moving parts
  - High reliability
  - Long lifetime
  - Low vibration
  - Low interference
  - Light weight

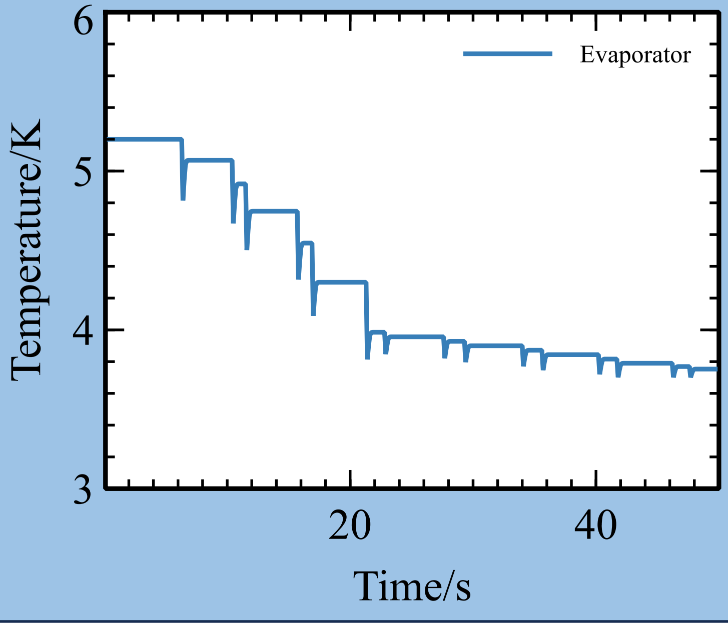
The sorption cooler operates based on the varying sorption capacities of the adsorbent at different temperatures and evaporative cooling

Transient Analysis of the Condensation Process

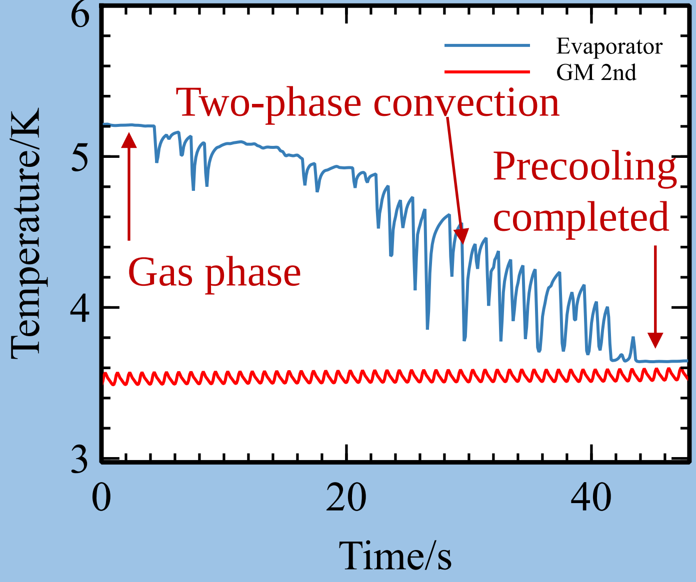
Simulation



Calculation



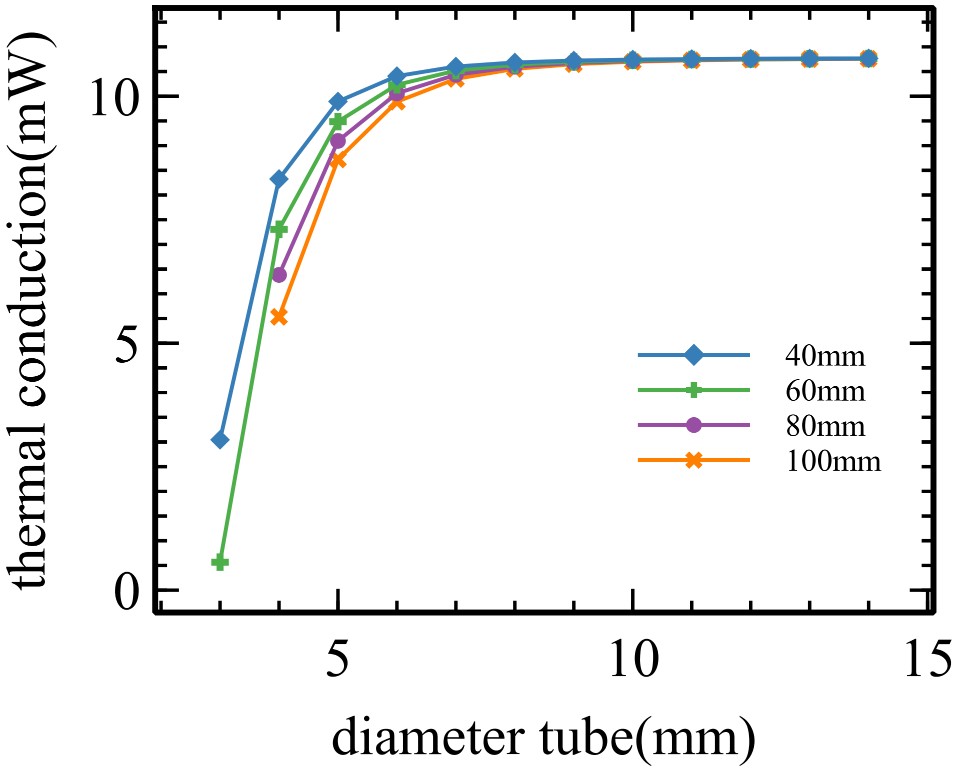
Experiment

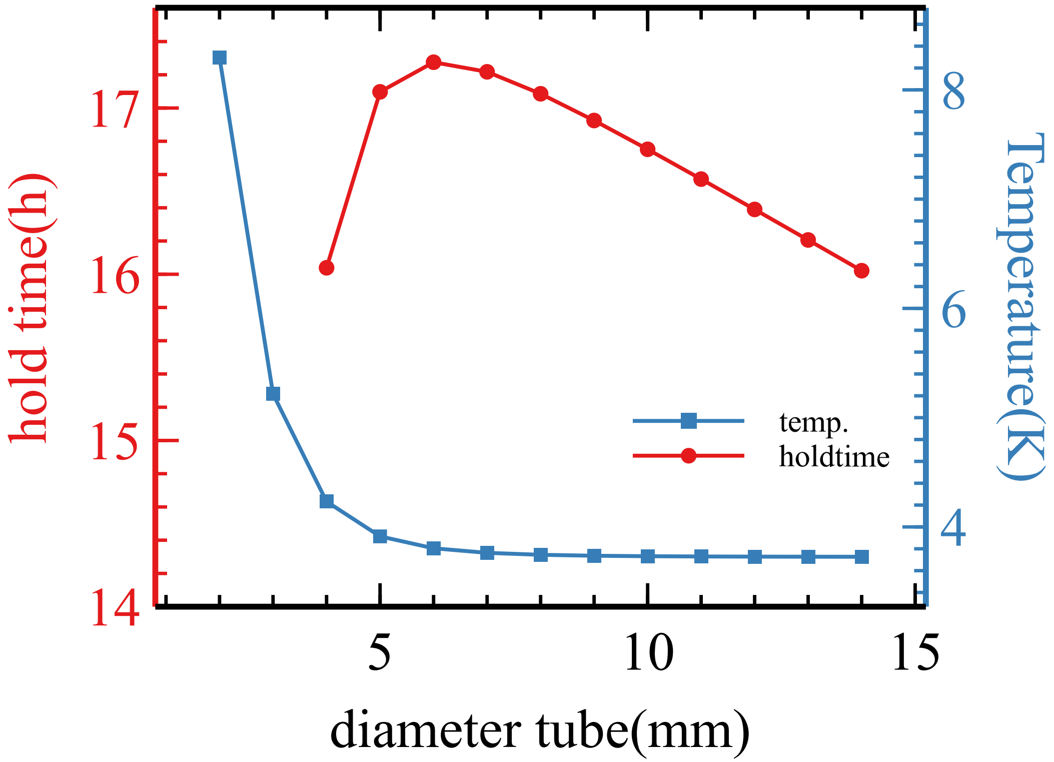


The diameter of liquid helium droplets is about 0.33 mm

Theoretical Analysis and Simulation

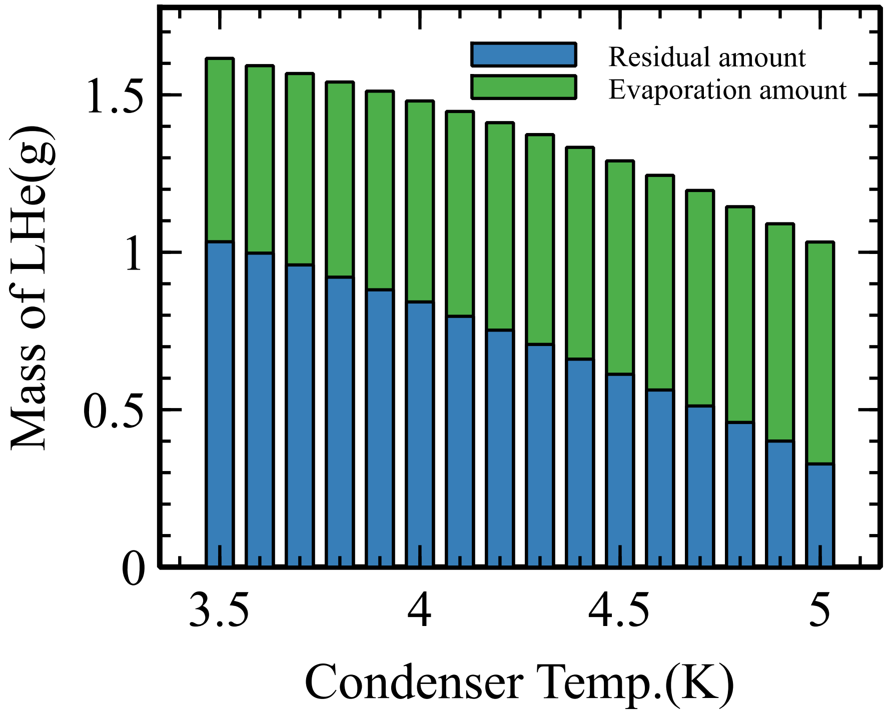
Influence of pump tube parameters



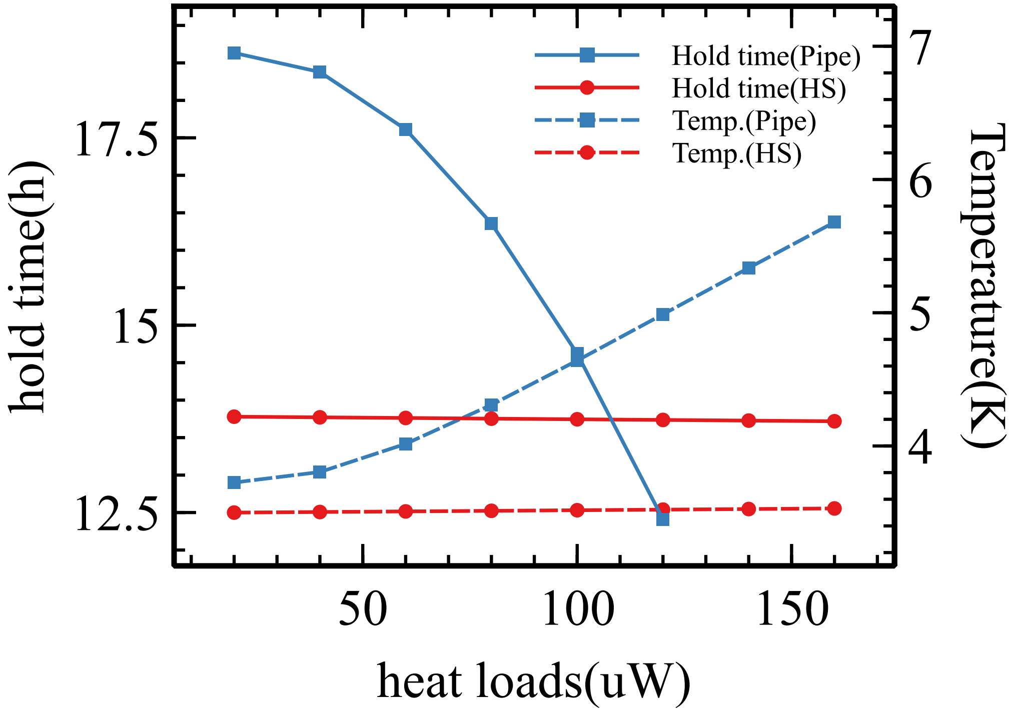


The optimal pump tube diameter is about 6 mm

Analysis of operating parameters

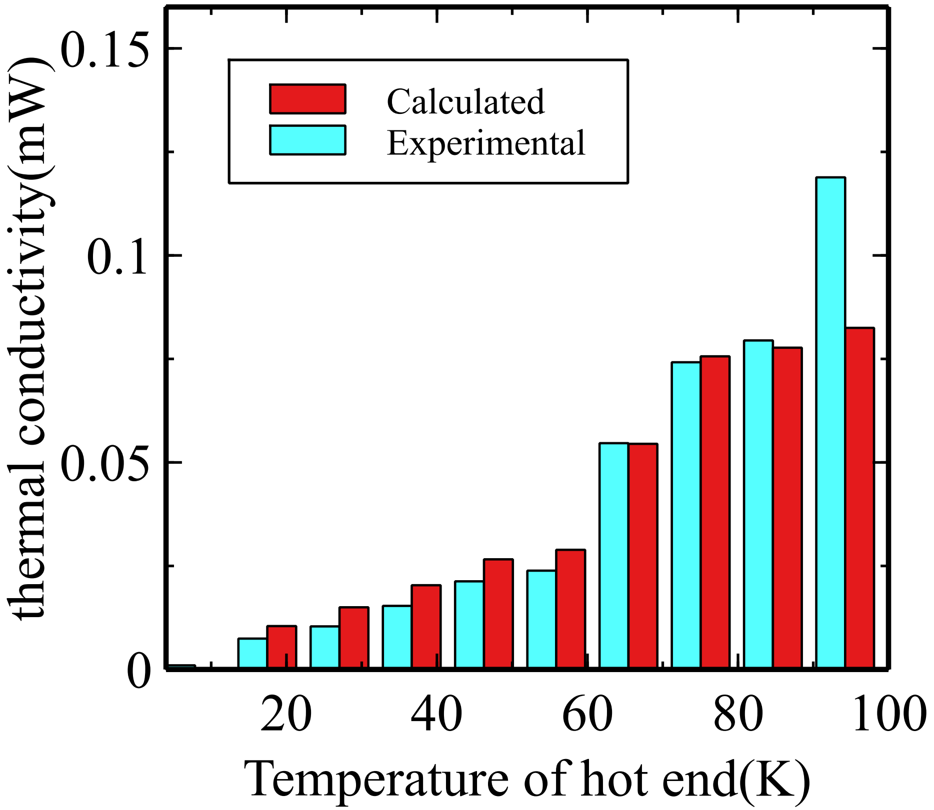


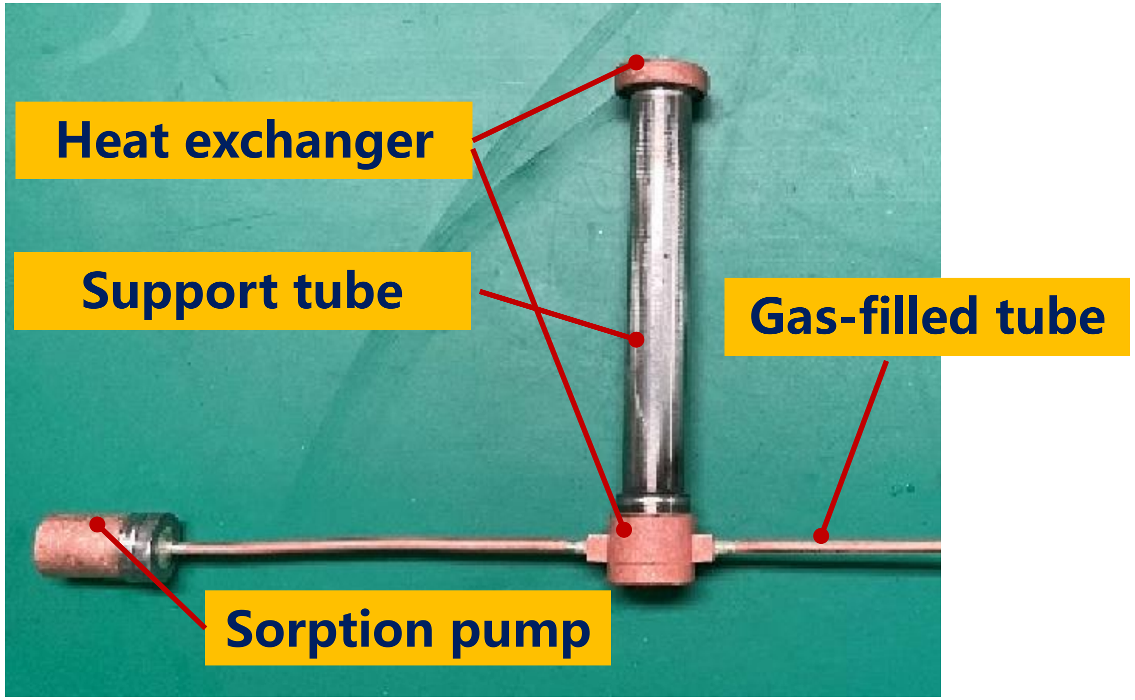
Amount of liquid helium vs Condenser temperature



Hold time and temperature vs Heat loads

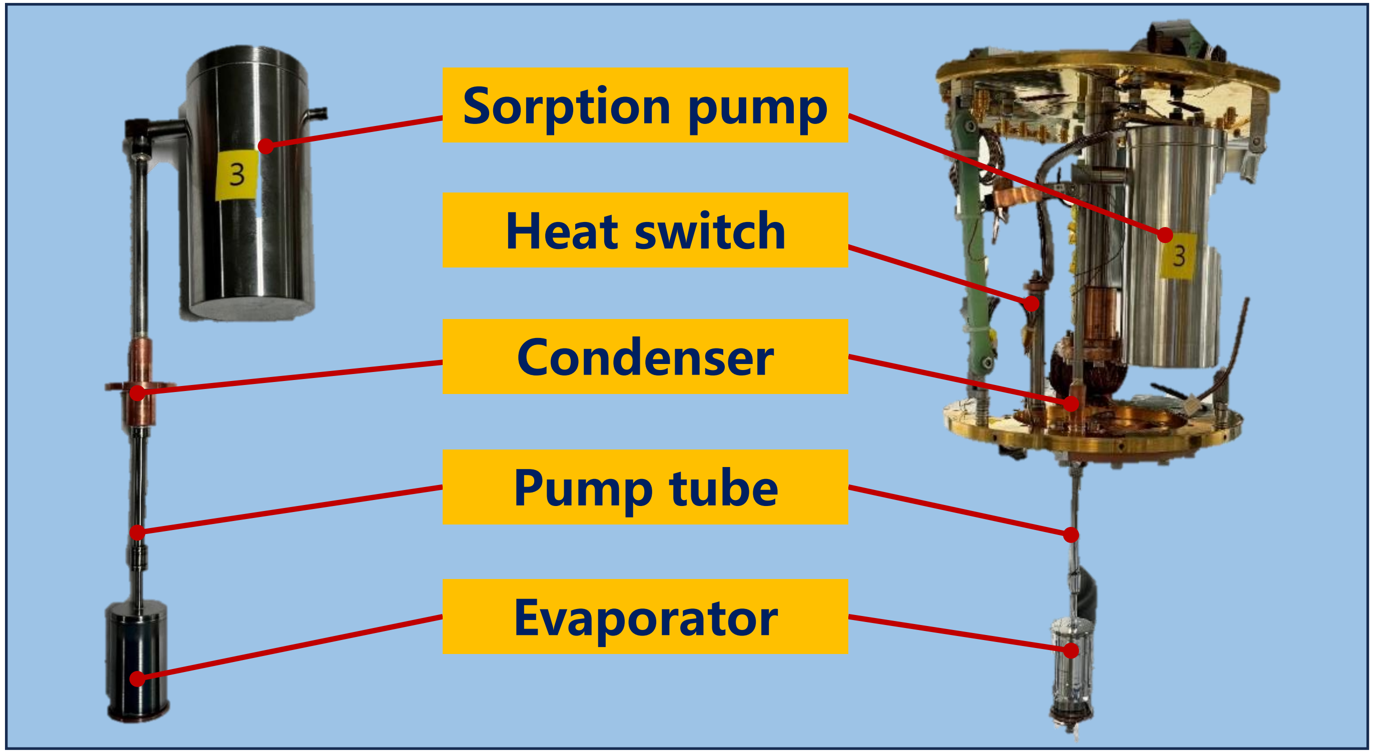
Analysis of heat switch characteristics

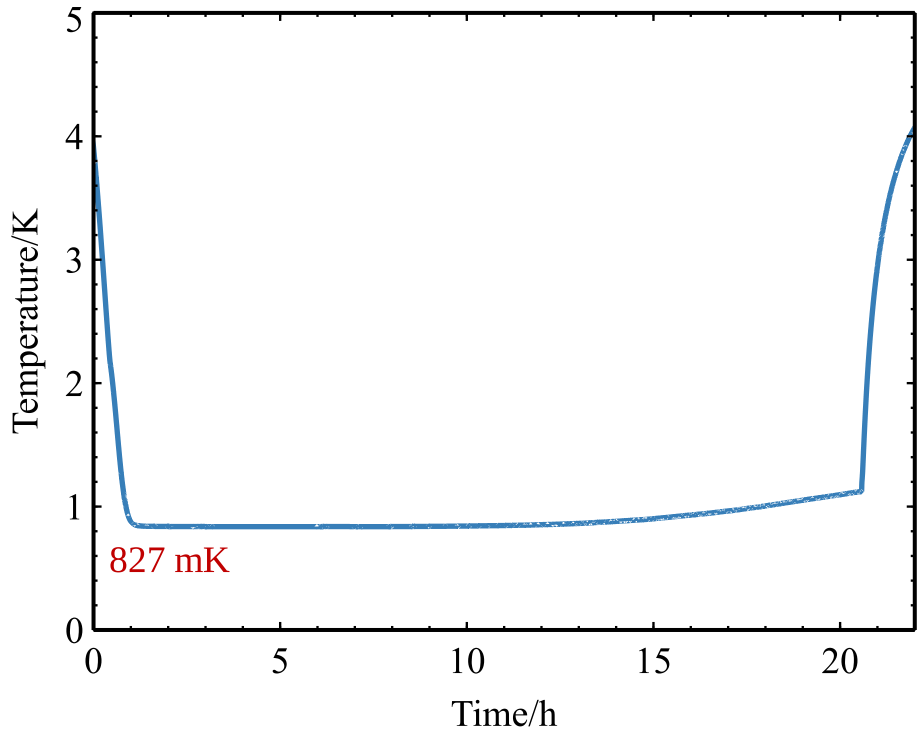




Within the temperature range of 4 K to 20 K, the switching ratio is 1007

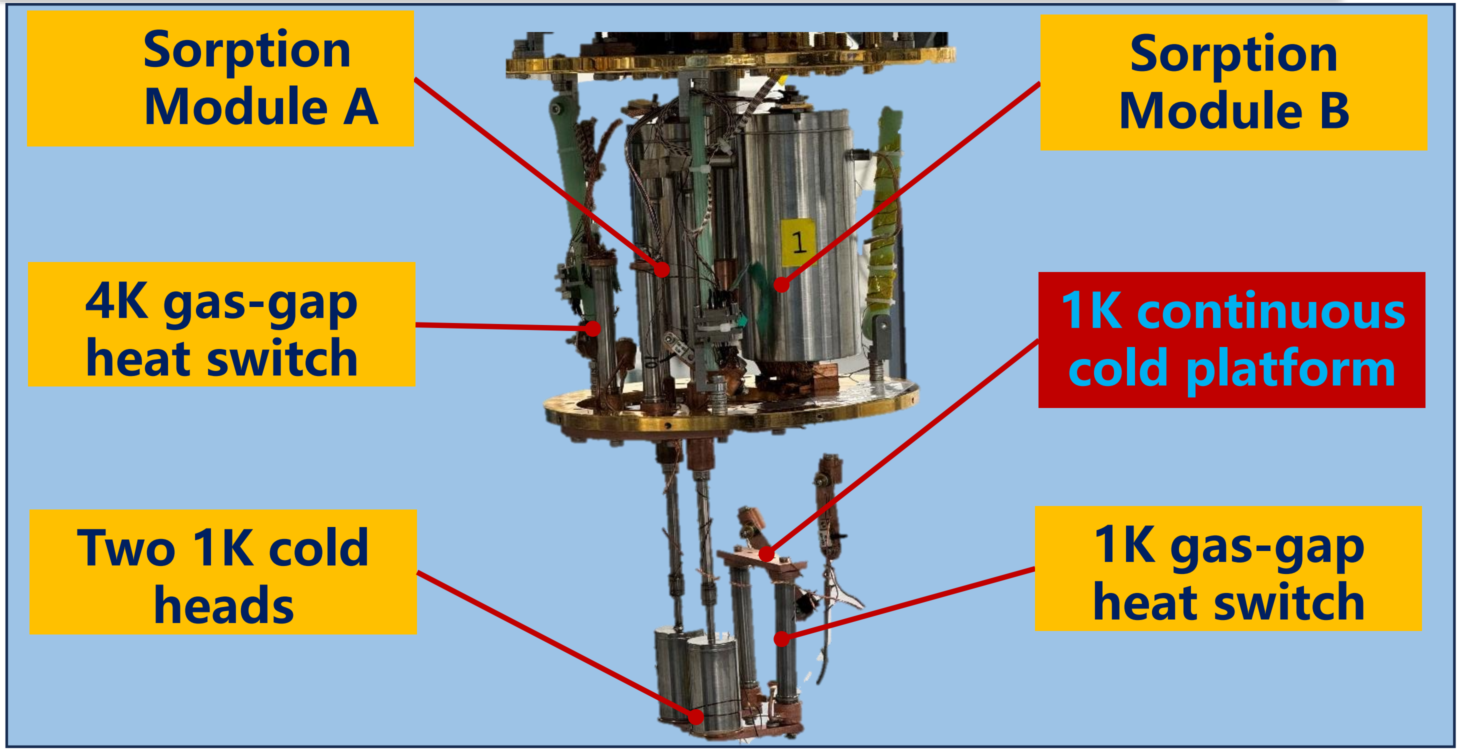
Single-stage helium sorption cooler

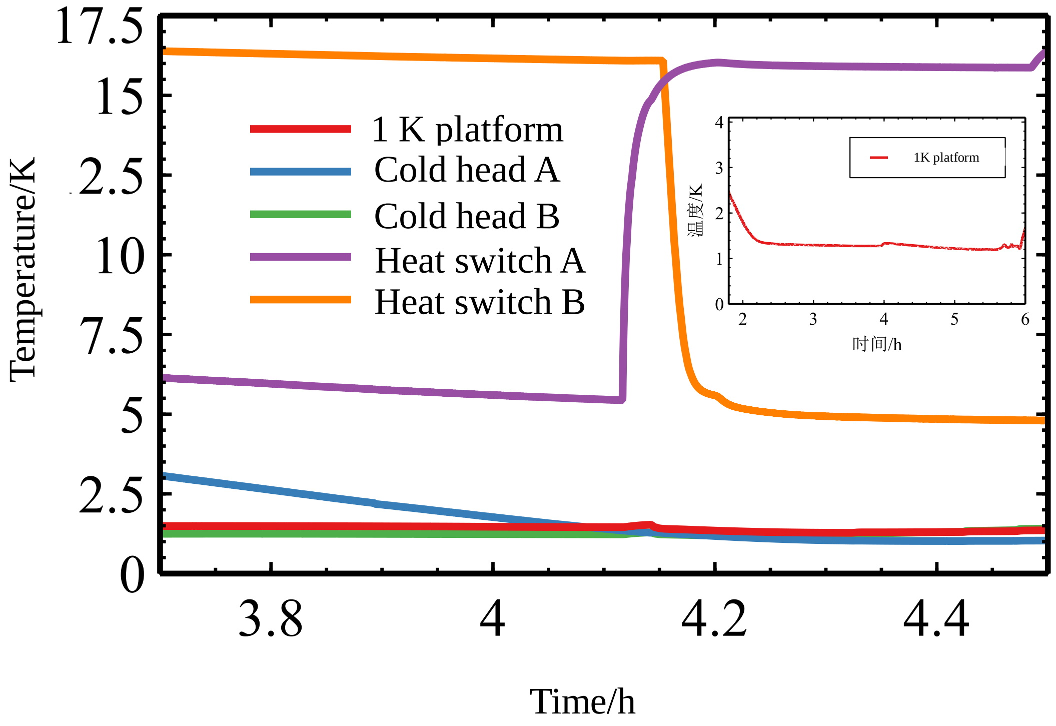




Experimental results: **The total cooling capacity is 13.23 J, the hold time without load is approximately 20 hours, the lowest temperature is 827 mK, and a cooling capacity of 351 μW@1 K**

Continuous helium sorption cooler



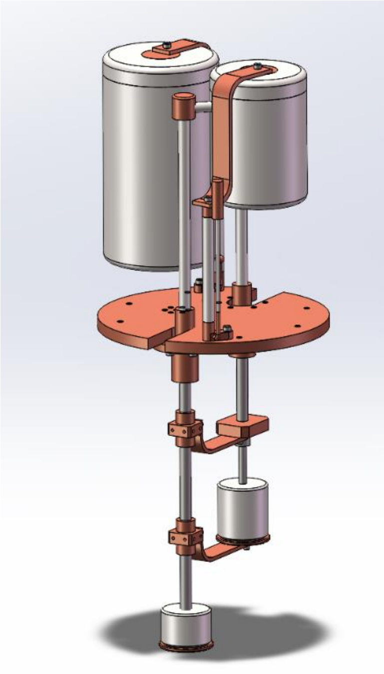


Experimental results: **The 1K platform has a lowest temperature of 1.21 K and can provide a maximum cooling capacity of 1 mW.**

Other Work

Two-stage helium sorption cooler

Discontinuous

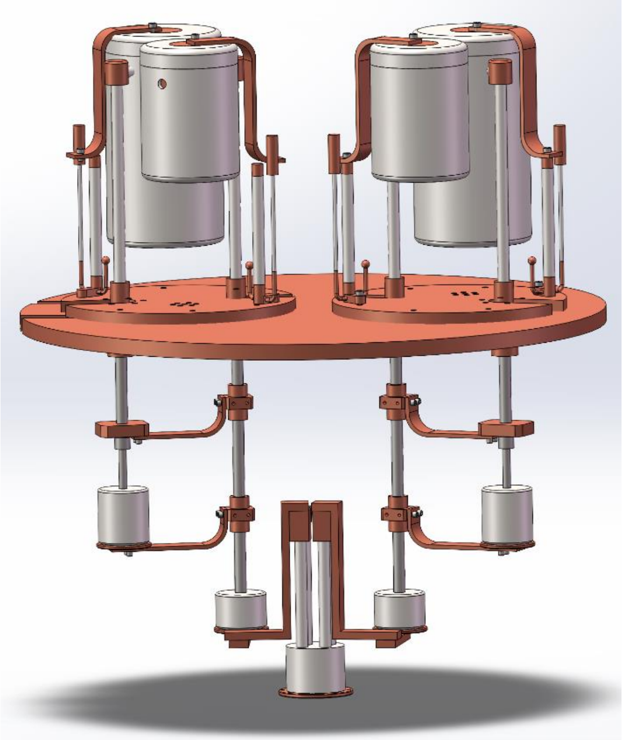


Simulation results:

Cooling capacity: 500 μW@0.3 K

Holding time: 0.3K 10h

Continuous

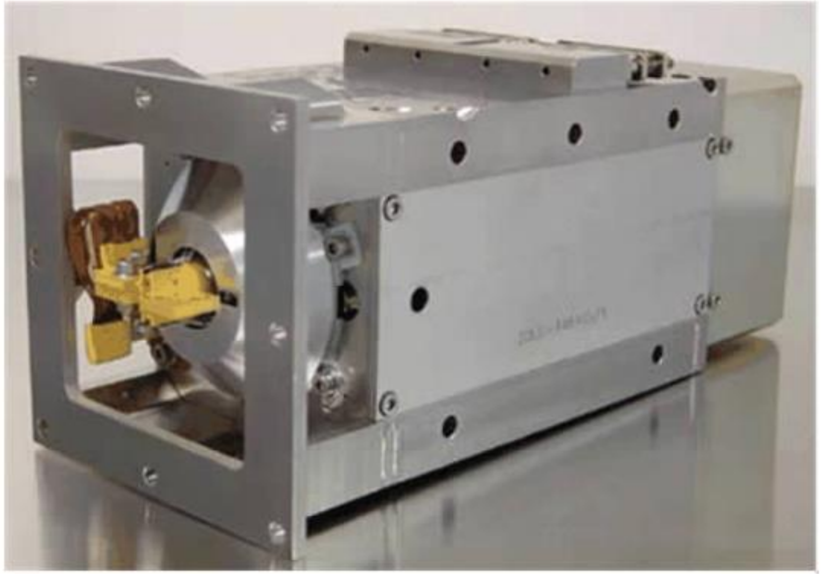


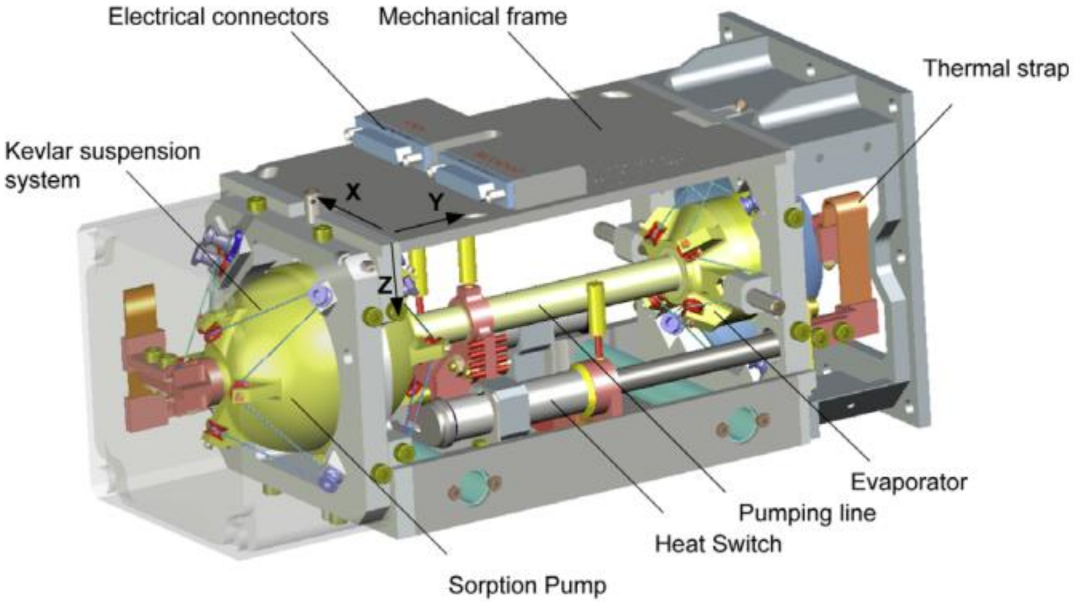
Simulation results:

Cooling capacity: 200 μW@0.3 K

Holding time : 0.3K continuous operation

Precooler for sorption cooler in space



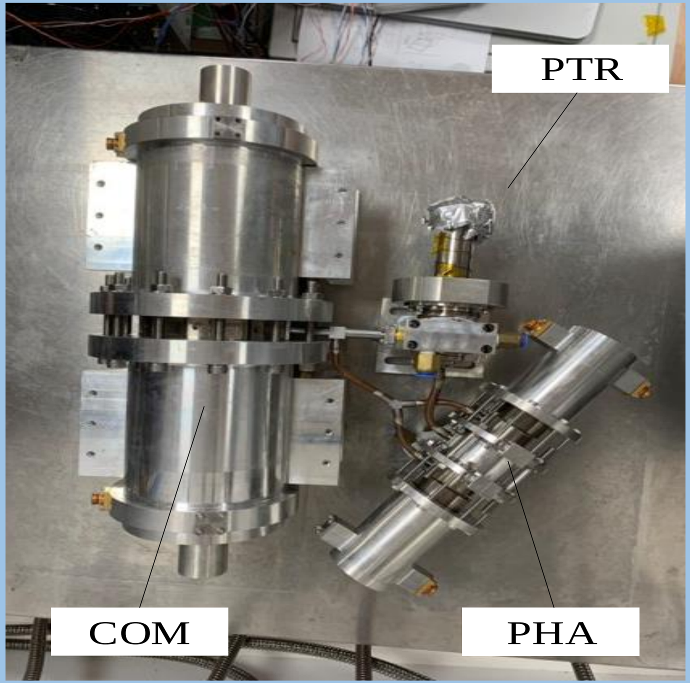


Herschel sorption cooler[1]

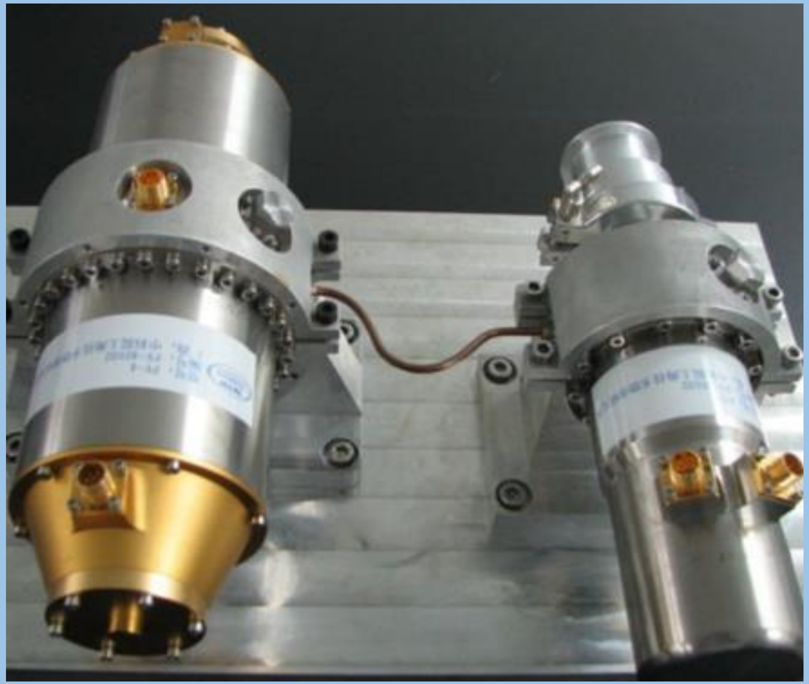
[1] DUBAND L, CLERC L, ERCOLANI E, et al. Herschel flight models sorption coolers [J]. Cryogenics, 2008, 48(3-4): 95-105

Other Work

Single-stage Stirling & pulse tube cooler



- 40 K pulse tube cooler
- Active piston
- rCOP 10.4%

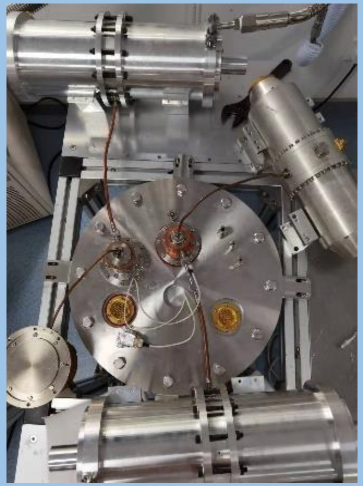


- 60 K long-life Stirling cooler
- Operating for more than 2 years on FY-4 satellite
- 2.3 W@60 K with 67.5 Wac

Other Work

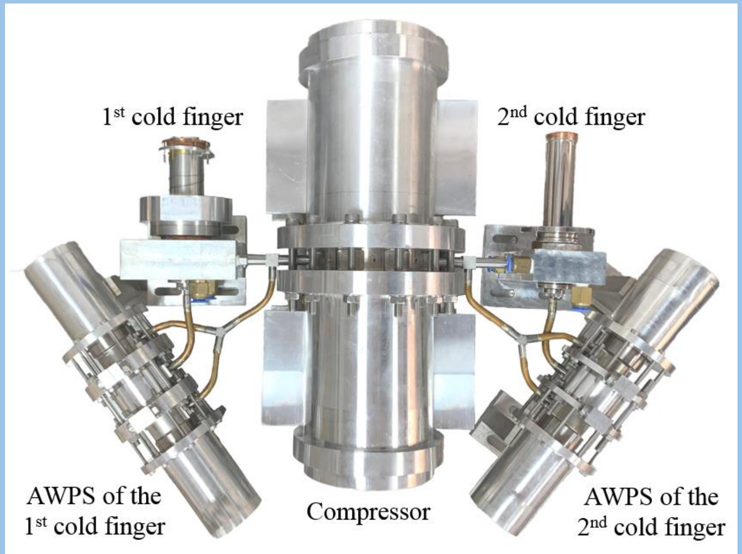
Two-stage pulse tube cooler

Thermally coupled Two-stage PTR



- **Experimental performance**
  - **1.19 W@15 K (with 398 Wac), lowest temperature 8.96 K (with 348 Wac)**

Two-stage PTR driven by one compressor

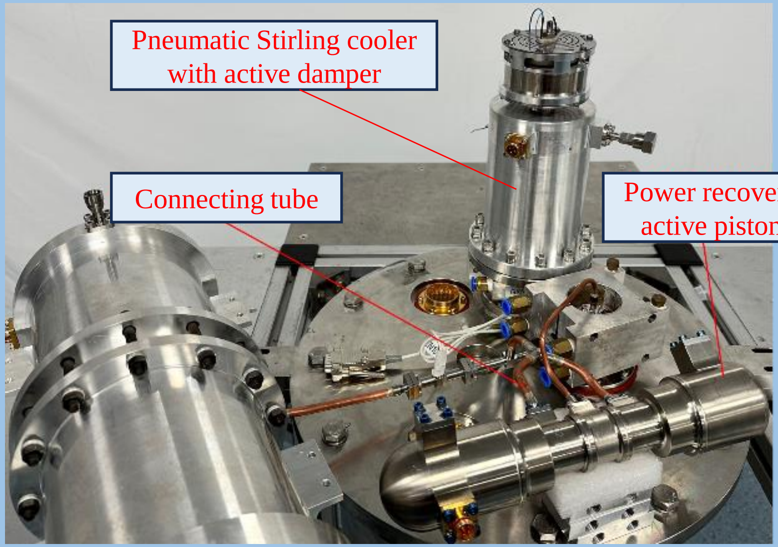


- **Experimental performance**
  - **20 W@80 K and 4 W@40 K (with 440.5 Wac), 19.5% rCOP**

Other Work

Stirling / pulse tube cooler

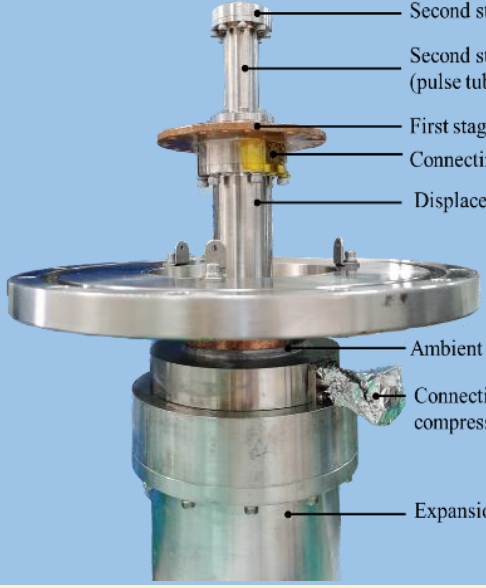
Thermally coupled hybrid cooler



Experimental performance

- 1.12 W@15 K (with 357 Wac)

Gas coupled hybrid cooler

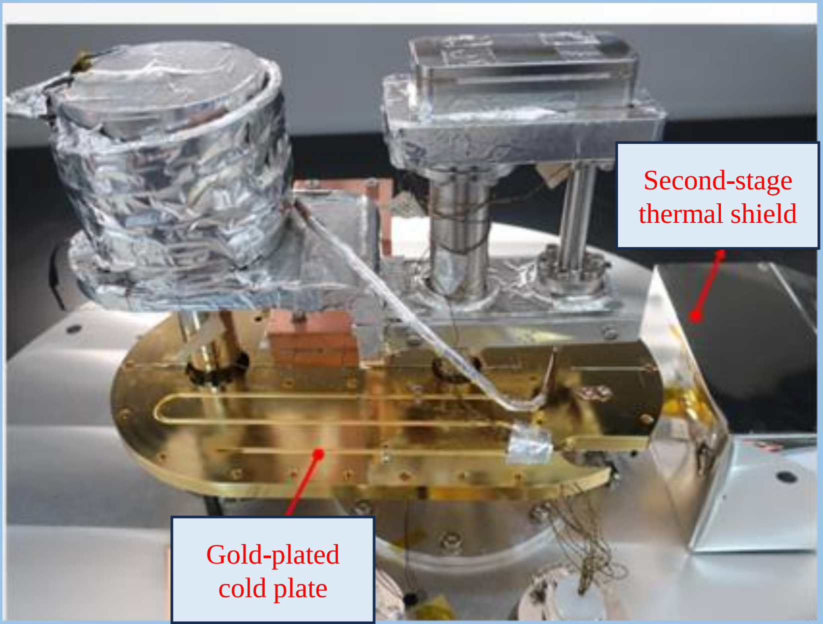


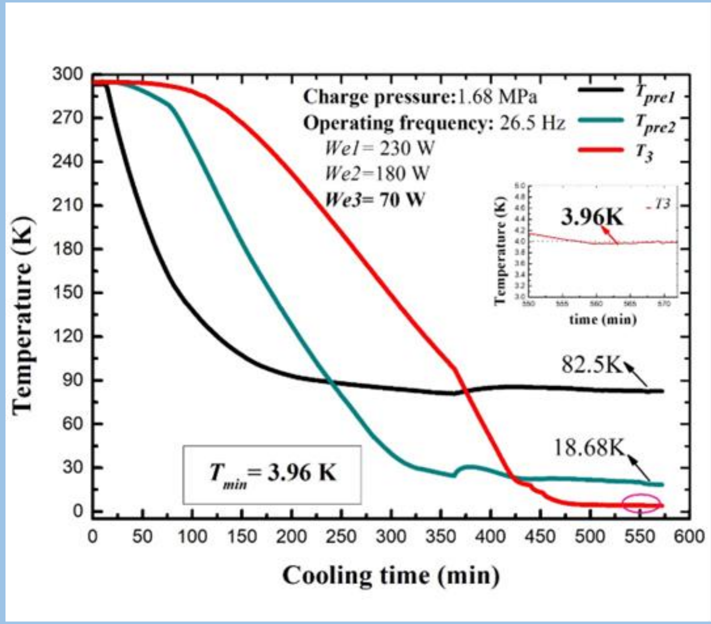
Experimental performance

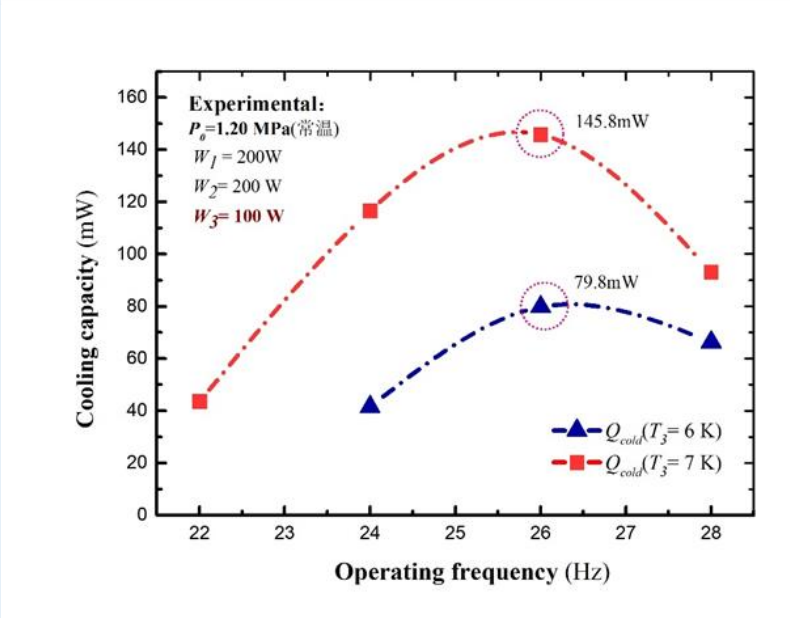
- 0.45 W@20 K and 2.5 W@70 K (with 200 Wac)

Three-stage pulse tube cooler

Thermally coupled Three-stage PTR

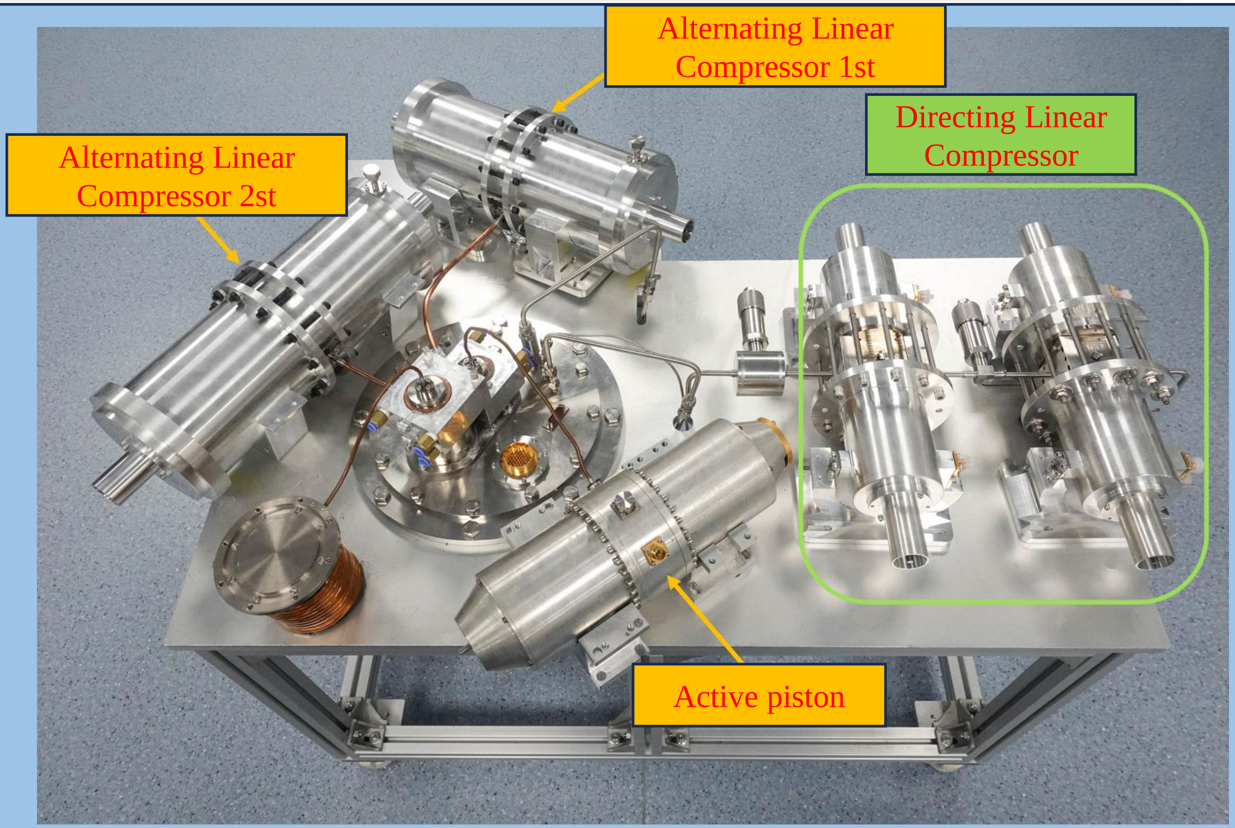






- Experimental performance
  - 145.8 mW@7 K (with 522 Wac), lowest temperature 3.96 K (with 500 Wac),

4K cryogenic system



- **Precooling by a two-stage pulse tube cooler**
- **400 mW@4.5 K**

Summary

☐ Sorption cooler

- The lowest temperature is 827 mK and the hold time without load is approximately 20 hours for single-stage
- The 1K platform has a lowest temperature of 1.21 K and can provide a maximum cooling capacity of 1 mW for continuous cooler

☐ Precooler

- We have developed space-usable high-efficiency single-stage pulse tube coolers, two-stage pulse tube coolers, Stirling/pulse tube hybrid coolers, three-stage pulse tube coolers, and 4K cryogenic system, offering a reliable precooling solution for space sorption cooler

Thank you for your attention!

Welcome to communicate!

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