A PRELIMINARY CRYOGENIC PERFORMANCE TEST OF THE 4.8-M-LONG CRYOSTAT FOR SUPERCONDUCTING UNDULATORS

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ABSTRACT

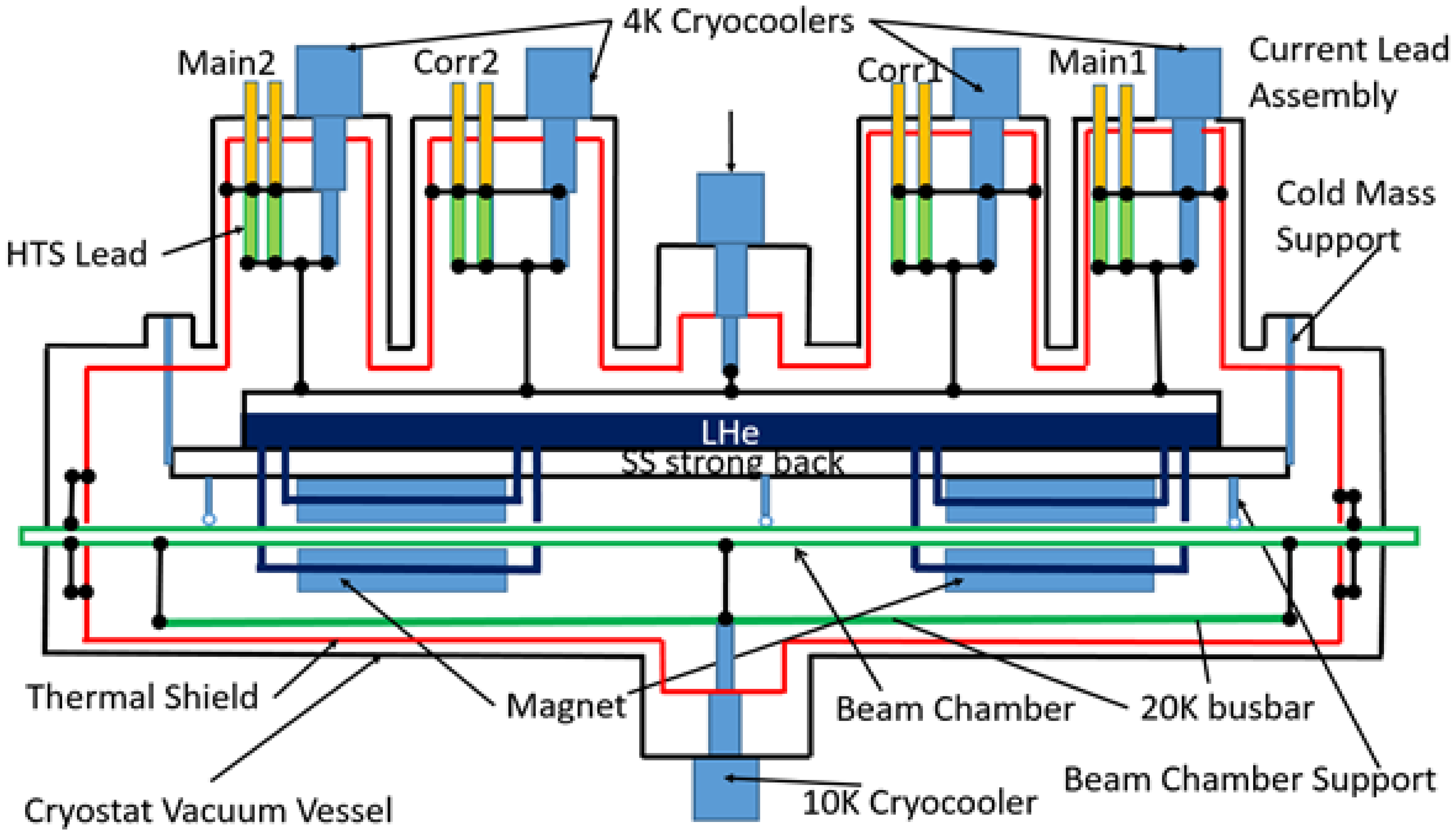
A 4.8-m-long cryostat has been developed to cool a pair of 1.9-m-long planar superconducting undulator magnets (SCUs). The final design and the thermal model of this cryocooler-cooled LHe-based cryostat has been completed [1, 2]. The cryostat is fabricated, and a preliminary cool-down test has been performed. This paper presents a comparison between measured and calculated thermal performance of the 4.8-m-long cryostat for the SCU.

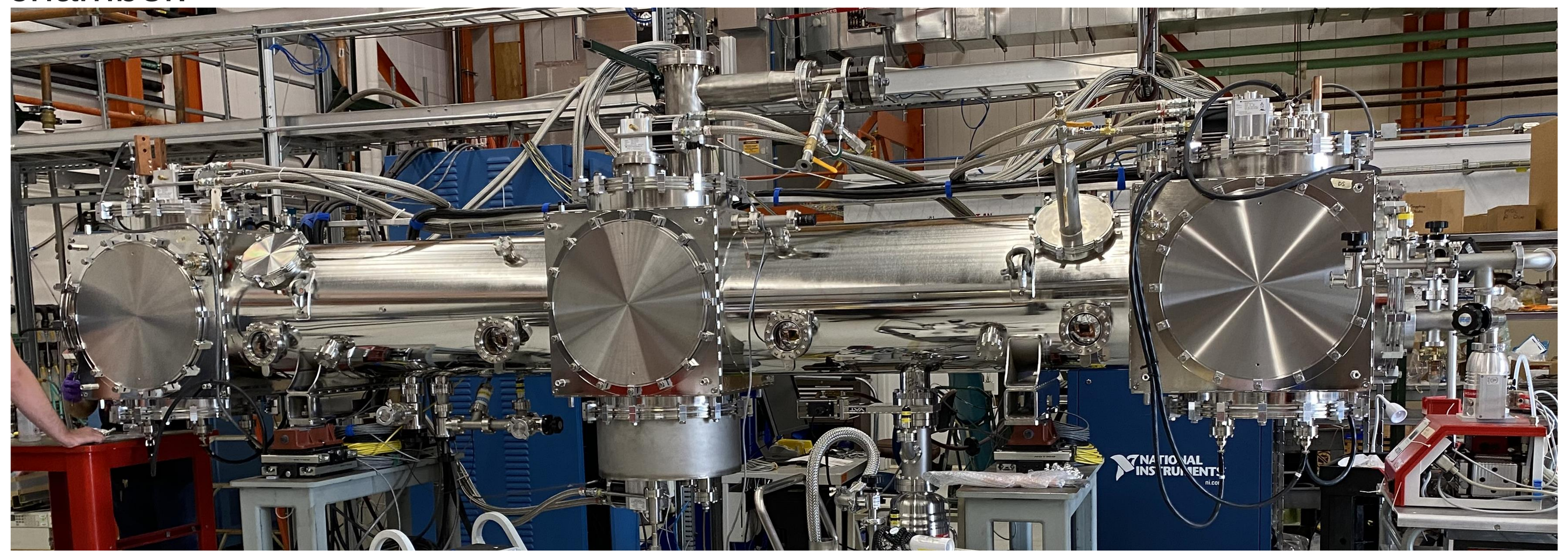
2. CRYOSTAT

The overall assembly of the cryostat: At the end turret assembly, there are two cryocoolers (Sumitomo 418D) to cool the HTS part of magnet leads and LHe Tank. At the center turret assembly, there are the one 4K cryocooler at the top to cool the LHe Tank and the one 10K cryocooler (Sumitomo 408S) at the bottom to cool the beam chamber.

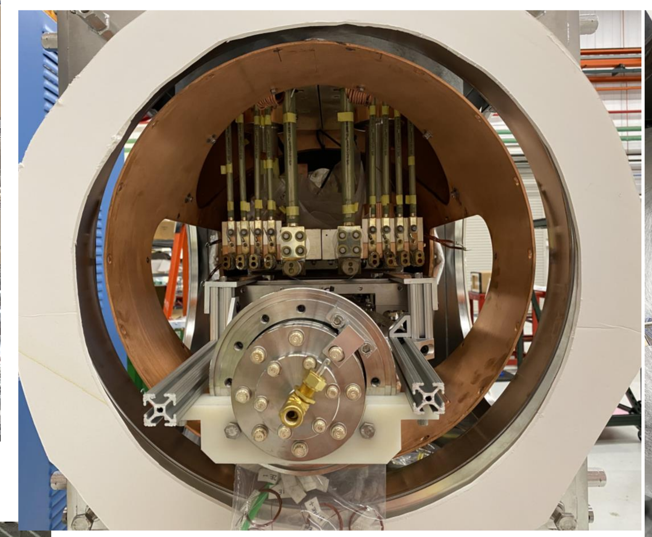
1. COOLING SCHEMATIC

The cryogenic system of the long SCU is based on our design modification of planar SCUs which is in operation in Advanced Photon Source (APS) [3]. The cooling schematic of the APSU-SCU cryostat is shown [1, 2]. The cooling is provided by six cryocoolers arranged in three thermal circuits. The thermal shield and warm parts of current leads are cooled by the 1st stages of all six cryocoolers. The 4 K circuit, which includes a LHe tank and magnets are cooled by the 2nd stages of five cryocoolers (418D). The 10 K cryocooler (408S) located at the bottom center, cools the beam chamber through the copper busbar and an array of thermal links.





The end turret assembly with current leads. Thermal links are at the back



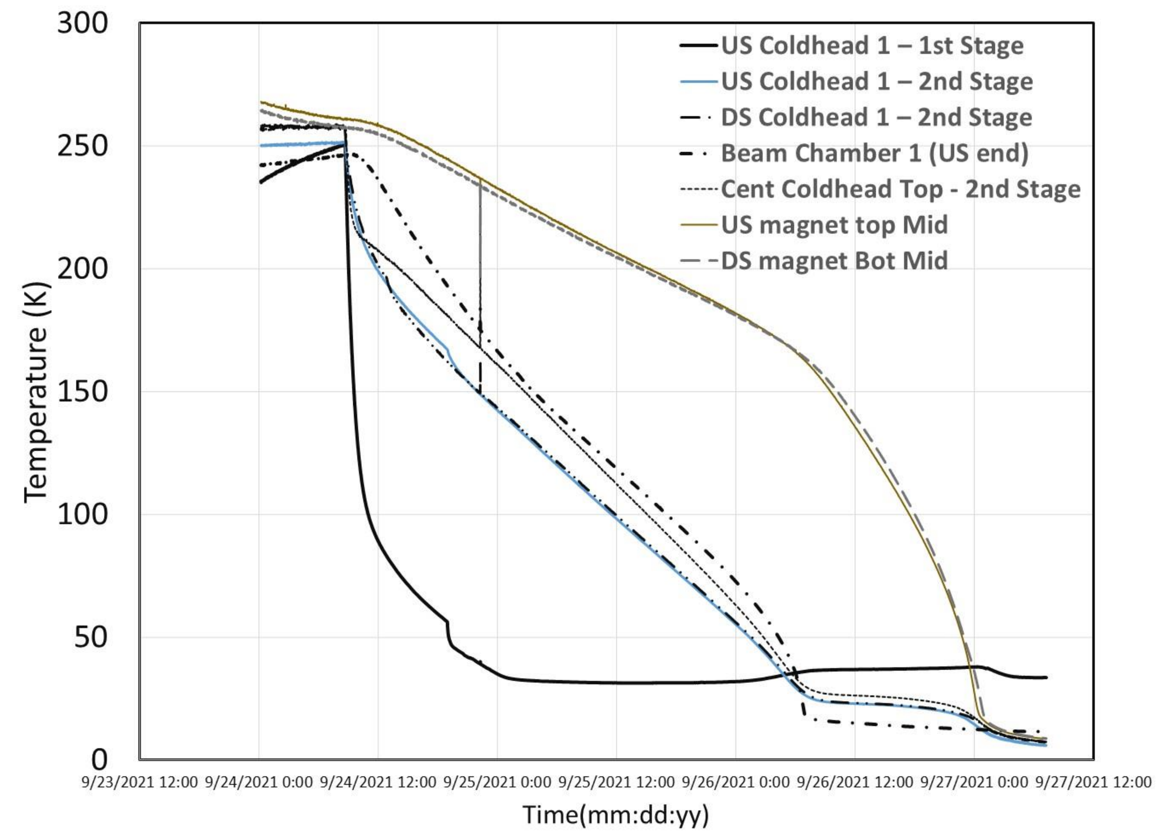
the center turret and thermal link

The thermal shield is cooled by all cryocooler 1st stages

The cold mass: The cold mass consist of the two 1.9m superconducting undulators (four magnets) and the beam chamber between the magnets.

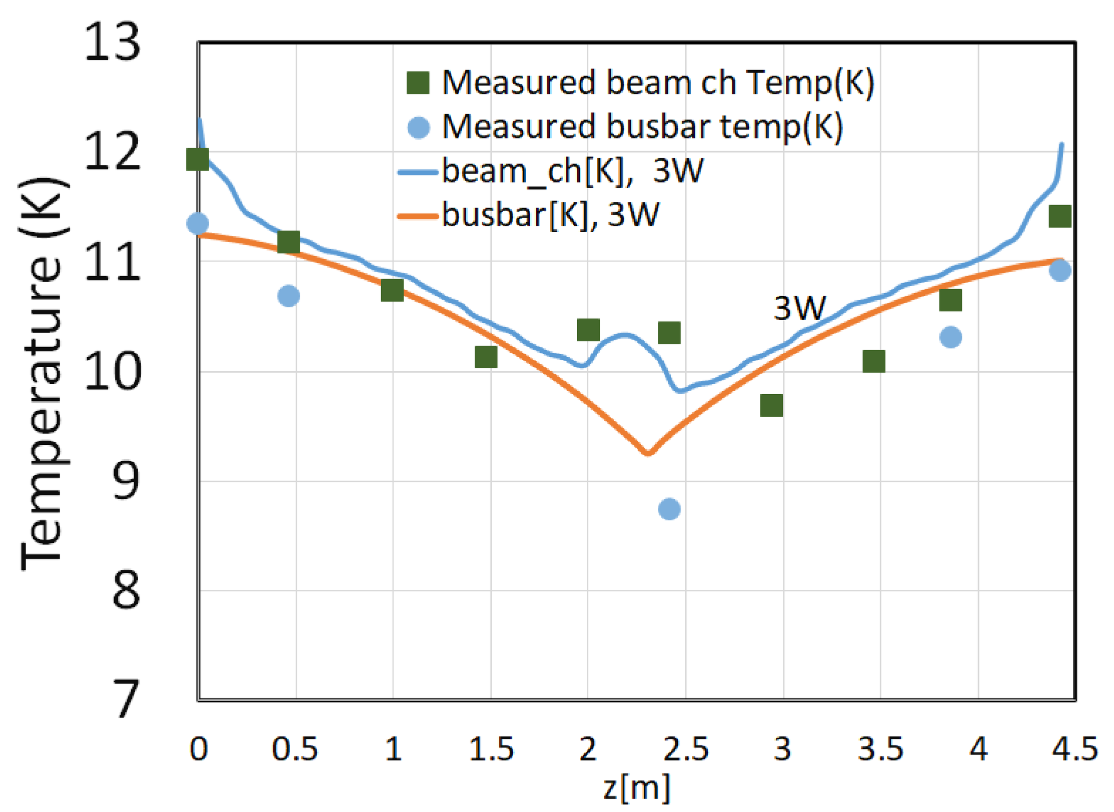
3 COOLDOWN CURVE

The cooldown took ~4 days. Three thermal circuits are clearly observed. The cryocooler 1st stages were cooled down first and reached ~40K at 25hrs. The beam chamber reached ~15K at 55hrs. The 4K cryocooler 2nd stages and magnets reached ~6 K at 80 hrs. LHe was successfully transferred on the 5th day. After LHe is transferred, the system was operated for 14 days in zero boiloff mode.



4. BEAM CHAMBER TEMPERATURE

- The beam chamber temperatures at a function of locations in the longitudinal direction are shown. The measured temperatures match with the calculated temperatures with 3W applied to the beam chamber from the measurement system [4].
- The temperature difference between the beam chamber and the copper busbar is ~0.5 K



5. MAGNET COOLING CIRCUIT AND EXCESS COOLING POWER

A comparison between observed and calculated heat load at the 2nd cryocooler stages is shown. The observed total cooling power is 6 W based on the measured 2nd stage temperatures and the cryocooler load lines. A trim heater power to maintain the LHe tank at slightly above atmospheric pressure is 1.8 W which gives a good margin to operate magnets in zero-boiloff mode.

Cooling Power (W)	Calculated (W)	Measured (W)
Total 4K Stage Cooling Power	5.60	6.0
Excess Cooling Power	4.76	1.8
4K Stage Heat Load	0.84	4.2

Thermal conductance of the five 4K stage thermal links are shown. An average temperature drop across the 4K links is 0.14 K. Thermal conductance across the copper links is 6W /0.14K/ 5 =~8 W/K. Therefore, the thermal conductance does not limit the performance of the cryocoolers.

	T(K)	Q(W)	dT (K)	Q/dT (W/K)
US1	3.48	1.12	0.14	8.0
US2	3.48	1.12	0.14	8.0
DS1	3.51	1.16	0.11	10.54
DS2	3.51	1.16	0.11	10.54
Center Top	3.75	1.45	0.21	6.90

6. DISCUSSION AND NEXT STEP

The first 4.8m long cryostat including two 1.9m SCUs has been built and its thermal performance was tested stand alone. The cooldown time is ~4 days. Excess cooling capacity with "simulated beam heat" was 1.8 W which is large enough to operate magnets at 450A in zero boiloff mode stably. The total 2nd stage heat load is 6.0 – 1.8= 4.2 W, which is higher than the calculated heat load of 0.84W. There is 3.3 W more heat leak and possible sources of this discrepancy can be thermal radiation through the gaps in the thermal shield or heat leak due to an incidental contact between the beam chamber and the magnet.

REFERENCES

[1] Anliker, E., J. Fuerst, Q. Hasse, Y. Ivanyushenkov, M. Kasa and Y. Shiroyanagi. "A New Superconducting Undulator Cryostat for the APS Upgrade." 2020 IOP Conf. Ser.: Mater. Sci. Eng. 755 012126

[2] Shiroyanagi, Y., E. Anliker, Q. Hasse, Y. Ivanyushenkov, M. Kasa and Joel Fuerst. "Thermal Analysis of a Superconducting Undulator Cryostat for the APS Upgrade", 2020 IOP Conf. Ser.: Mater. Sci. Eng. 755 012125.

[3] Y. Ivanyushenkov et al., "Development and operating experience of a 1.1-m-long superconducting undulator at the Advanced Photon Source," Phys. Rev. Accel. Beams, vol. 20, no. 10, p. 100701, Oct. 2017, doi: 10.1103/PhysRevAccelBeams.20.100701.

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ACKNOWLEDGEMENT

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