Operation test of new high-powered Gifford-McMahon Joule-Thomson (GM-JT) cryocooler

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The 28 GHz ECR superconducting ion source[1)] is equipped with several small helium refrigerators (cryocoolers) that operate continuously 24 hours a day to reduce the constant heat input to the cryostat and to recondense the evaporated helium. In particular, because the heat load from X-rays generated during ion source operation is large, GM-JT type cryocoolers (CG310SC by Sumitomo Heavy Industries, Ltd. (SHI)) with a refrigeration capacity of 3.5 W at 4 K are used. However, production of this type of cryocoolers was discontinued in 2016, and the supply of repair parts has also stopped since 2022. As a successor to this, a new cryocooler (SRJT100) with a rated output of 8.5 W at 4.2 K has been developed,[2)] and is in the commercialization stage at SHI. As the manufacturer only operates using heater heat load, we decided to install the cryocooler with a condenser in the reserve port of the cryostat of the SAMURAI[3)] superconducting magnet at RIBF to conduct a long-term operation test in recondensation mode

Figure 1 shows the schematics of the SRJT100 cryocooler. Approximately 2 MPa and 0.6 g/s helium gas generated by a JT-line compressor was cooled to approximately 10 K using a GM cryocooler and was liquified by Joule-Thomson expansion. Furthermore, this liquefied helium (refrigerant helium) was passed through a condenser (an evaporator when viewed from the refrigerator side) to condense the evaporated helium gas in the cryostat. Operation tests with the SAMURAI cryostat began in August 2023 and have been in operation for approximately 135 days till date. The pressure inside the cryostat was controlled by a heater placed in liquid helium, and the typical pressure was 6.5–8.5 kPa, and the helium condensation temperature was 4.29–4.31 K. Figure 2 shows the relationship between the temperature difference between the refrigerant helium and the condensation temperature at the condenser and the refrigeration capacity. The refrigerant helium temperature was measured by the temperature sensor A in Fig. 1 and was changed by the return pressure of the JT-line compressor. However, in principle, the return pressure cannot be changed by users. The refrigeration capacity was calculated by subtracting the surplus refrigeration capacity of 1.5–1.8 W of a CG308SC (2.5 W @ 4.2 K) cryocooler operated simultaneously from the heater power. Figure 2 shows that the refrigeration capacity was approximately proportional to the temperature difference at the condenser, and that when the helium liquid level in the cryostat was high, the refrigeration capacity decreased for unclear reasons. In addition, the refrigeration system was stable during the over 100 days test period. From this result, it can be expected that even when installed in the 28 GHz ECR ion source, a refrigeration capacity of 8 W or more can be obtained stably by considering a temperature difference of 0.15–0.2 K in the condenser.

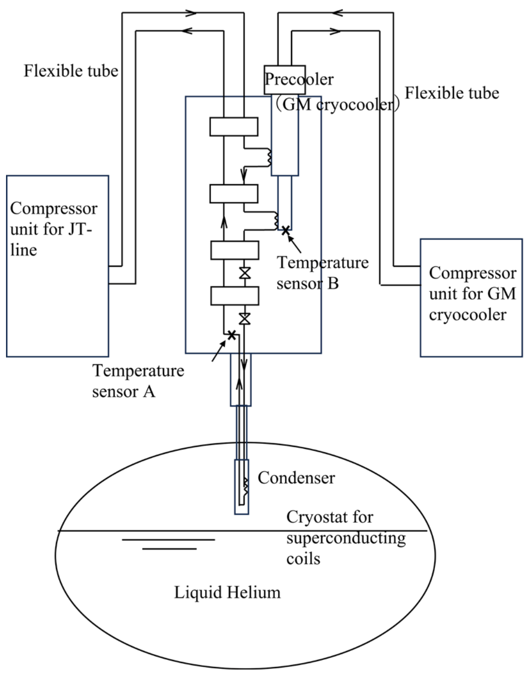

Fig. 1. Schematics of SRJT100 cryocooler system.

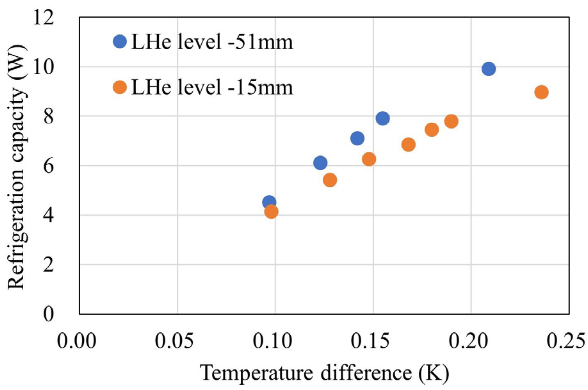

Fig. 2. Temperature difference at the condenser vs cooling capacity. Level of the liquid helium is based on the bottom of the condenser.

References
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