The Optimizations of a High Frequency Micro Pulse Tube Cryocooler

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Abstract

A micro coaxial pulse tube cryocooler has been developed to meet the requirements of high operating temperature infrared detection in space applications. To increase the efficiency of the cryocooler, the optimization experiments were designed. Driven by a double-piston opposed linear compressor with the mass less than 200 g, this cryocooler uses the inertance tubes and a reservoir as phase shifter and has the regenerator with a diameter of 10 mm. The effect of the operating frequencies and charging pressure on cooling performance were investigated through a series of experiments. This cryocooler can provide a cooling power of 0.61 W at 150 K with an input electric power of 10 W. This paper describes the optimizing processes and presents test data in detail.

Experimental System

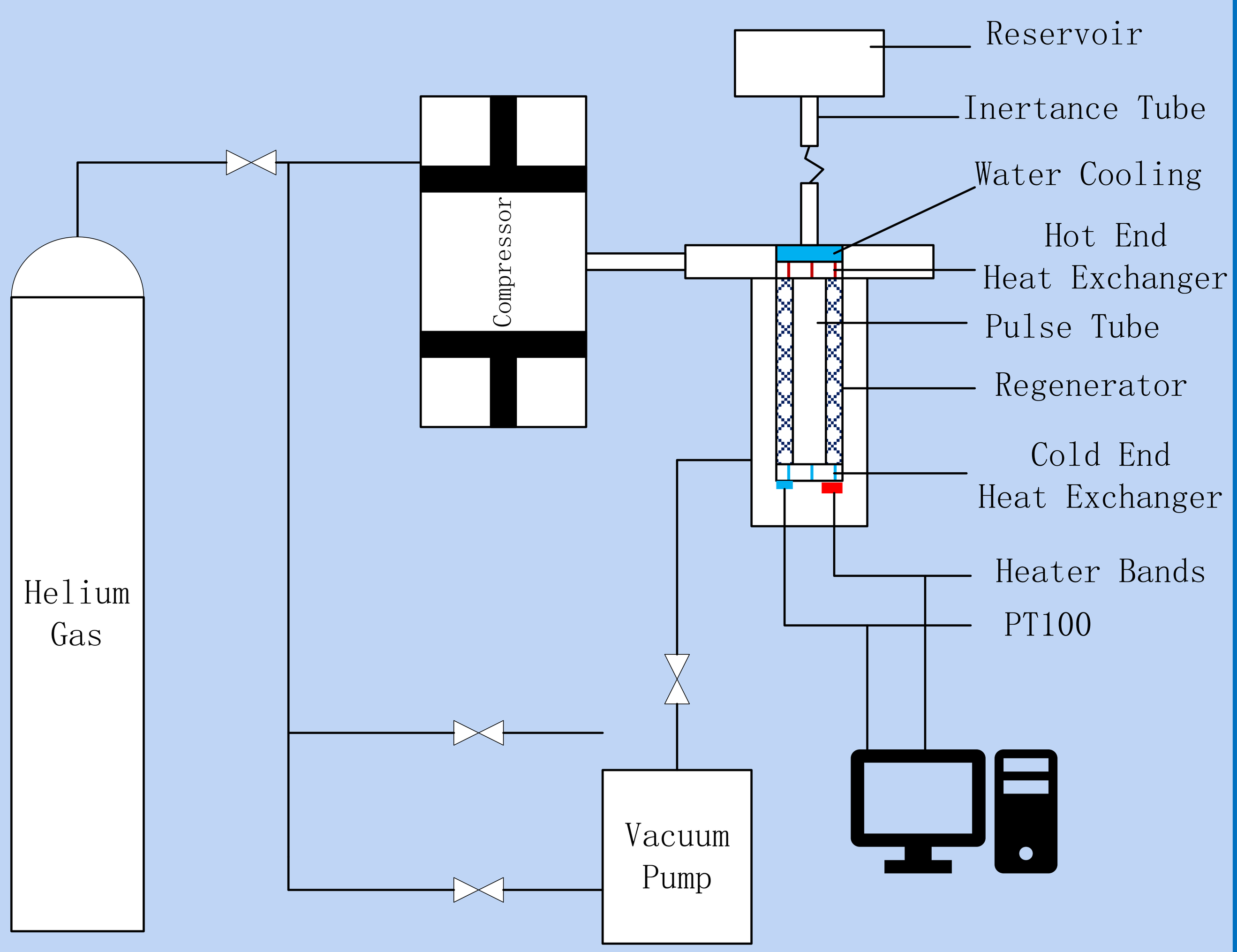

Fig. 1. Schematic of the experimental apparatus

Main parameters of the cryocooler

- Mass of compressor < 200 g
- Regenerator: ϕ10 mm x 35 mm
- Pulse tube: ϕ5 mm
- Matrix in regenerator: #500 and #635 stainless steel screens
- Volume of reservoir: 30 cc

Testing devices

- Working medium: pure helium
- Vacuum pump: reduce the radiant heat loss
- Reject temperature: 283 K
- Data collection: PT100 thermometer and the heater bands

Experimental results and discussion

Effect of the operating frequency

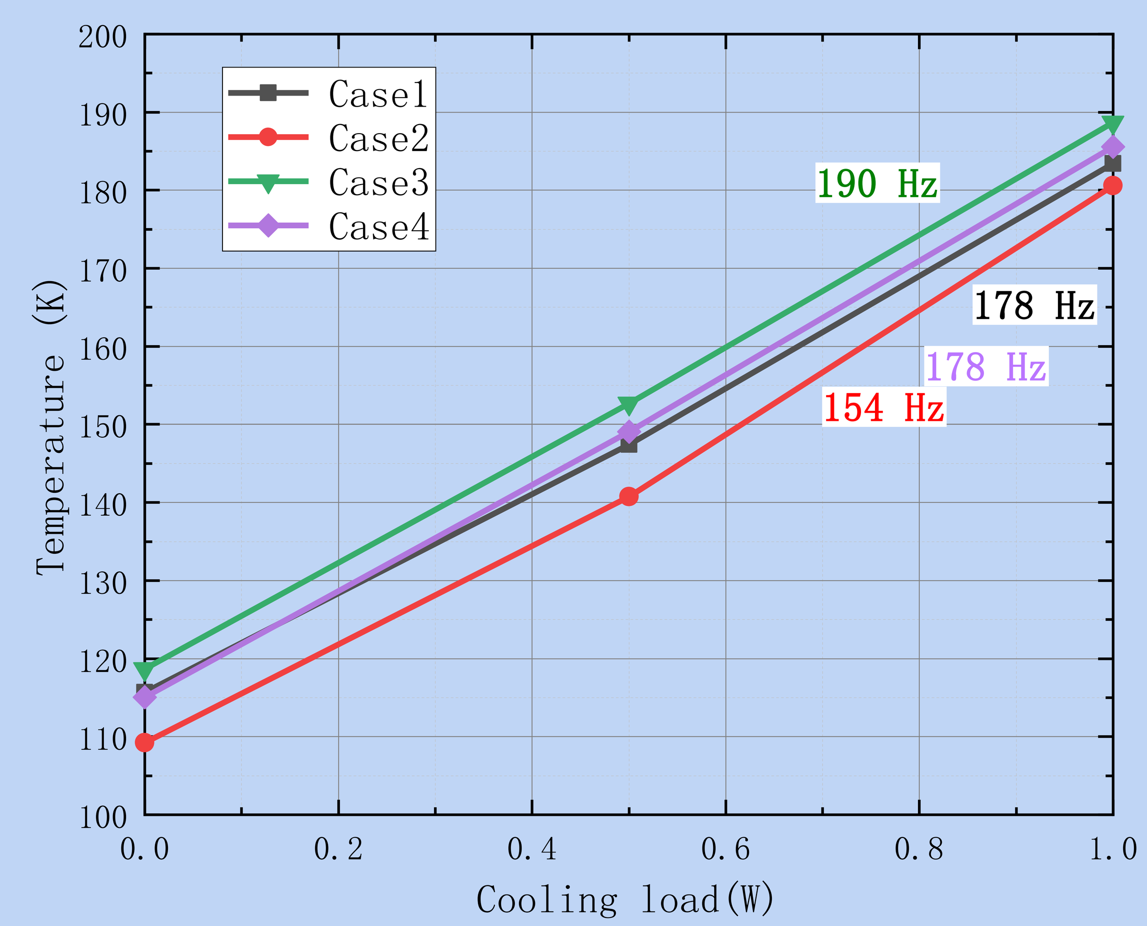

Fig. 2. The effect of the operating frequency

Different length and diameter of the inertance tubes can change the operating frequency of the cryocooler, then to affect the phase shift between mass flow and pressure wave at the hot end of regenerator. The phase distribution in the regenerator determines performance of the cryocooler.

Figure 2 shows the performance of cryocooler operating at different frequencies with 10 W electric power consumption. As can be seen from that, the best frequency is 154 Hz. The frequency decrease with the increase of the total length of inertance tubes. At 154 Hz, this micro pulse tube cryocooler can provide 0.61 W cooling power at 150 K.

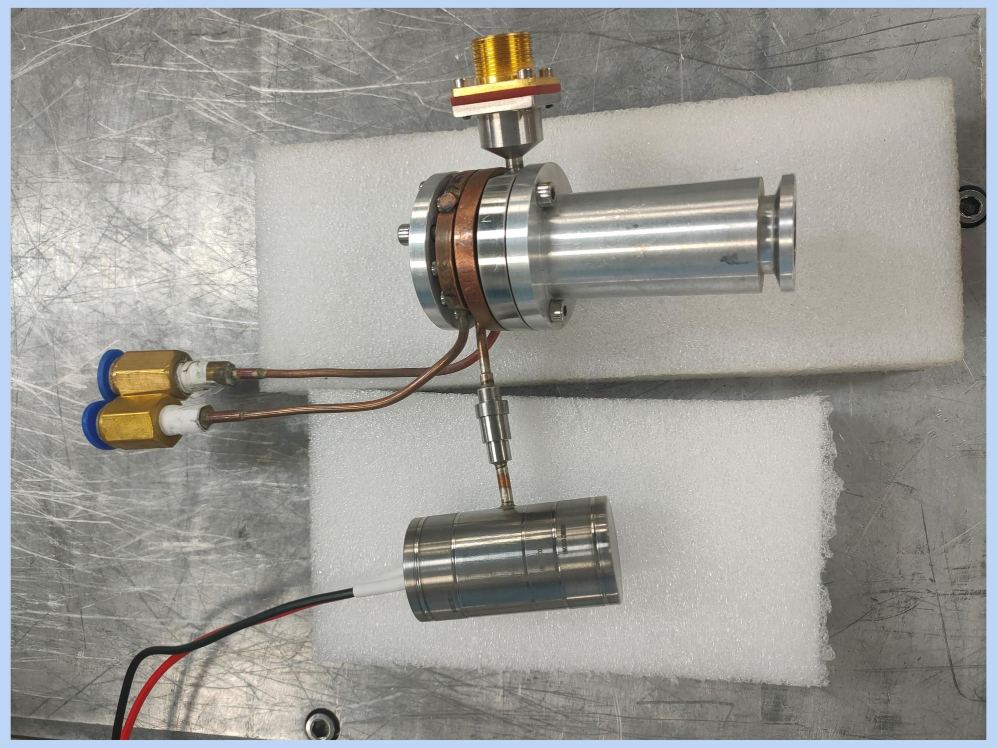

Fig. 5. The micro pulse tube cryocooler

Effect of the charging pressure

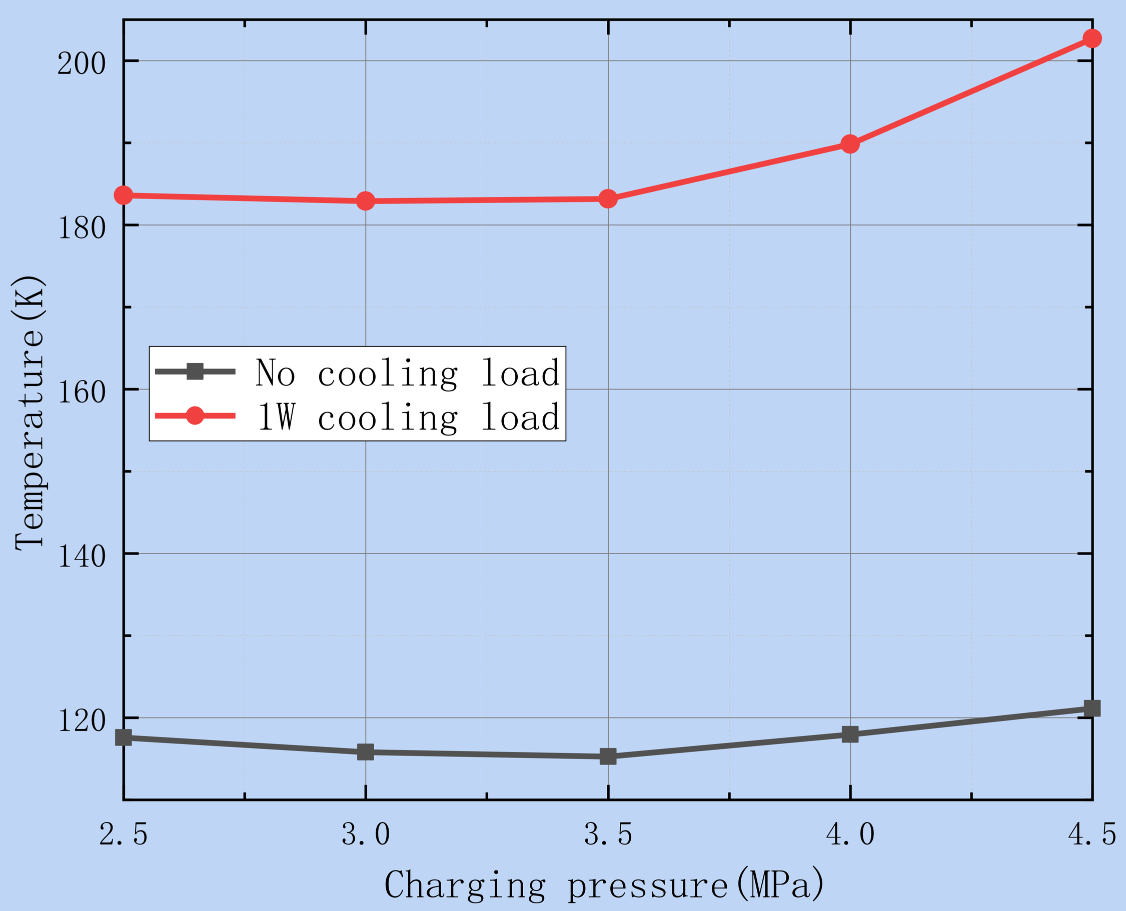

Fig. 3. The effect of the charging pressure

Figure 3 shows the temperatures with no cooling load and with a cooling load of 1 W as the charging pressure changed from 2.5 MPa to 4.5 MPa. The cryocooler reaches the best performance when the charging pressure is 3.5 MPa.

When the 1 W cooling load was added on the cold tip, the temperatures are close below 3.5 MPa. It illustrates that 2.5-3.5 MPa pressure range can provide sufficient mass flow above 180 K, and the performance is worse if the charging pressure continues to increase.

Effect of the different compressors

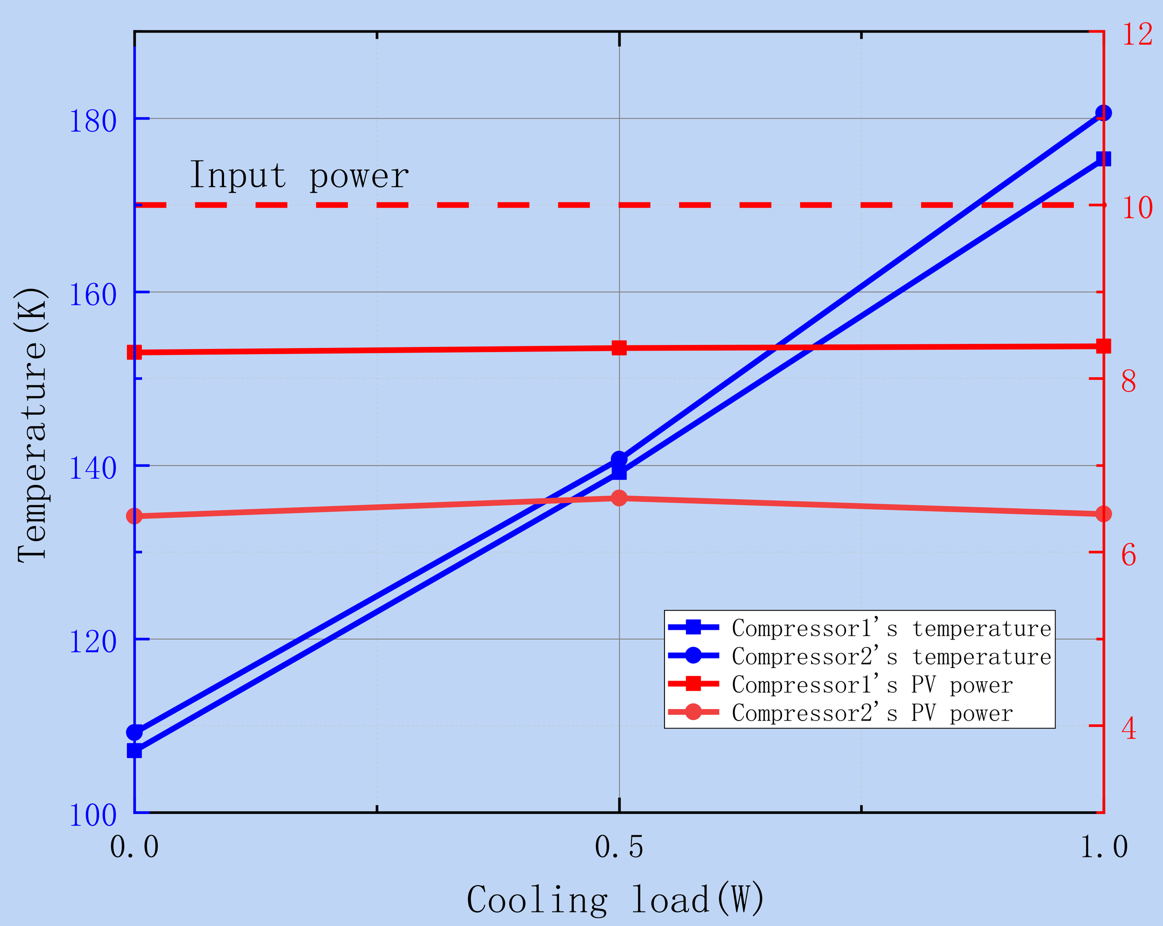

Fig. 4. The effect of the different compressors

Figure 4 shows the performance comparison of these two compressors with the same cold finger. The cooling capacity of compressor1 is slightly worse than compressor2. The PV power at the entrance of the cold finger is defined as the value of input electric power minus Joule heat losses. The results indicate that under the same input power, the bigger current of the compressor1 increase the Joule heat losses and decrease the PV power which leads to less cooling capacity.

Conclusion

- To optimize the performance of cryocooler by changing the operating frequency and charging pressure.
- The cooling capacity remains close after reducing the weigh and size of the compressor.
- It can provide more than 0.6 W cooling power at 150 K with 10 W input power.