A 598 gr Micro Pulse Tube Cryocooler

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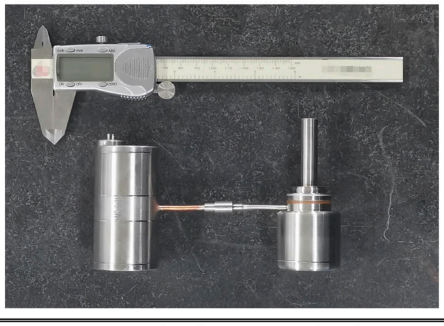
ABSTRACT

A novel coaxial micro pulse tube cryocooler has been developed for cooling on an infrared detector, which has the characteristics of low vibration, long life, and high reliability. Due to optimization of the linear compressor volume and cold finger with a diameter of 10 mm, it has a compact structure and an optimum frequency of 120 Hz. The entire cryocooler weighs 598 gr, including a 332 gr compressor. At 300 K reject temperature, the pulse tube cryocooler can obtain 1.2 W at 80K with an input electric power of 45 W, and it takes 3 minutes to cool down to 80 K with a 250 J heat capacity load. This paper describes the components and presents test data of this micro pulse tube cryocooler.

INTRODUCTION

The Key Laboratory of Technology on Space Energy Conversion has been working on micro pulse tube cryocooler since 2010[1] to create a micro-cryocooler with the characters of high efficiency, small size, and long lifetime[2-4], and developed a new micro pulse tube cryocooler recently. The external outline of it is shown in Figure 1. It has a spilt configuration, connecting the linear compressor with the cold finger via a transfer line to facilitate installation and placement, and combining the inertance



Component	Diameter (mm)	Length (mm)	Weight (g)
Compressor	40	62	332
Phase Shifter	40	38	160
Regenerator	10	42	106
Connecting Flange	30	10	

Figure 1. TSEC's Micro Pulse Tube Cryocooler.

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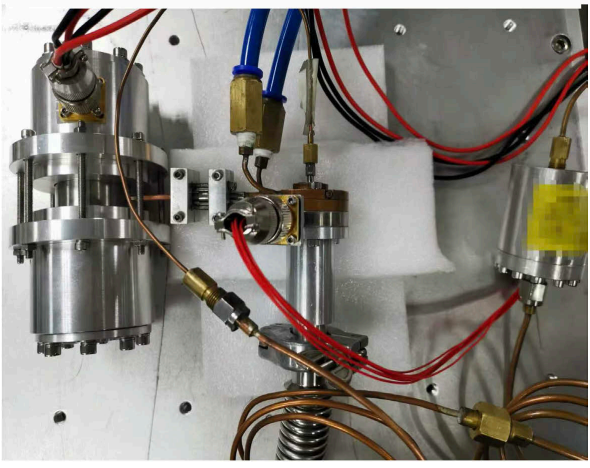

Figure 2. Test System.

tubes and reservoir as phase shifter. The cold finger part is coaxial, and the diameter and length of its regenerator are 10 mm and 42 mm respectively. The inertance tube is integrated in the reservoir to make the whole system more compact. The diameter of the phase shifter is 40 mm. The contour of vibrationally-balanced back-to-back linear compressor is designed as a standard cylinder, whose diameter is 40 mm and length is 62 mm. The compressor of this micro-cryocooler weighs 332 gr, and the cold finger weighs 106 gr, the phase shifter weighs 160 gr, which makes the whole system weighs 598 gr.

In this paper, experimental results on the cooling performance, vibration characteristics, and cooling down time with a heat capacity load at the cold end with different electric power inputs are presented.

CRYOCOOLER TESTS

The test system is shown in Figure 2. The testing of the cold finger and compressor are with a not completely welded assembly, and the phase shifter is placed separately. A transparent window is installed at the end of the compressor to monitor the movement of the compressor piston. A water-cooled flange is connected to the hot end heat exchanger to control the reject temperature.

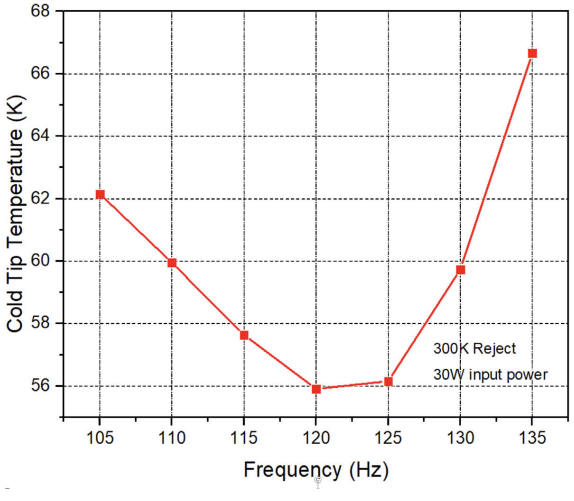

Figure 3. Cold Tip Temperature at Different Frequency.

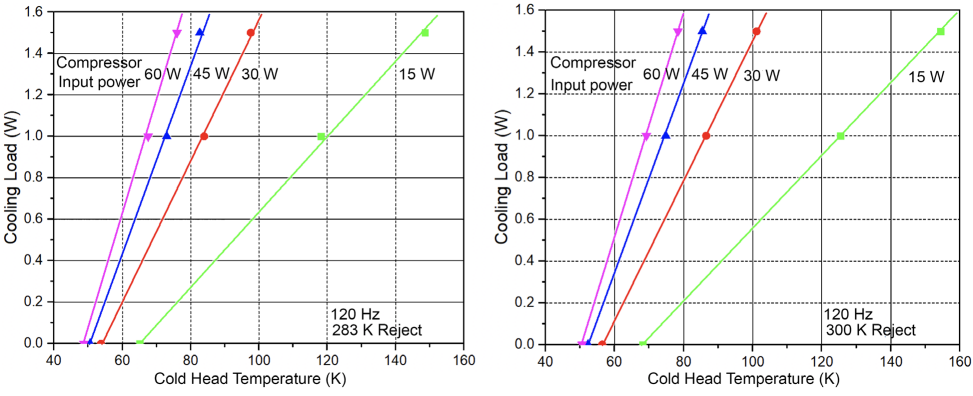

Figure 4. Cooling Performance at 300K and 283K Reject Temperature.

Optimal Frequency

The regenerator has small diameter, short length, and matrix with small hydraulic diameter and high heat transfer coefficient, so this micro pulse tube cryocooler is suitable for operating at a high frequency more than 100 Hz. The no-load temperature at different frequencies with the input power of 45 W is shown in Figure 3. According to the test, the cold tip can reach a lowest temperature at 120 Hz, which means the optimum frequency is 120 Hz. In further tests, 120 Hz is the default frequency.

Cooling Performance

The cooling performance with different input electrical powers are shown in Figure 4. As can be seen from the figure, at 283 K reject temperature, the micro pulse tube cryocooler can reach a lowest temperature of 50.5 K, and with 45 W electric power input, the cryocooler can obtain a cooling capacity higher than 1.3 W at 80 K, and at 300 K reject temperature, the micro pulse tube cryocooler can reach the lowest temperature of 52. 3K, and with 45 W electric power input, the cryocooler can obtain a cooling capacity higher than 1.2 W at 80 K.

Vibration and Piston Displacement

To analyze the reliability of this micro pulse tube cryocooler, the vibration characteristics and average piston displacement are given.

The vibration characteristics of the cryocooler are tested from X-axis and Y-axis. X-axis refers to the axial direction of compressor, where as Y-axis refers to the radial direction. In Figure 5, the vibration characters of two directions with different electric input powers are shown. The vibration amplitudes of both axes increase with the growth of input power. At all electric power inputs, the exported vibrations for all harmonics are less than 0.2 N in X-axis and 0.07 N in Y-axis.

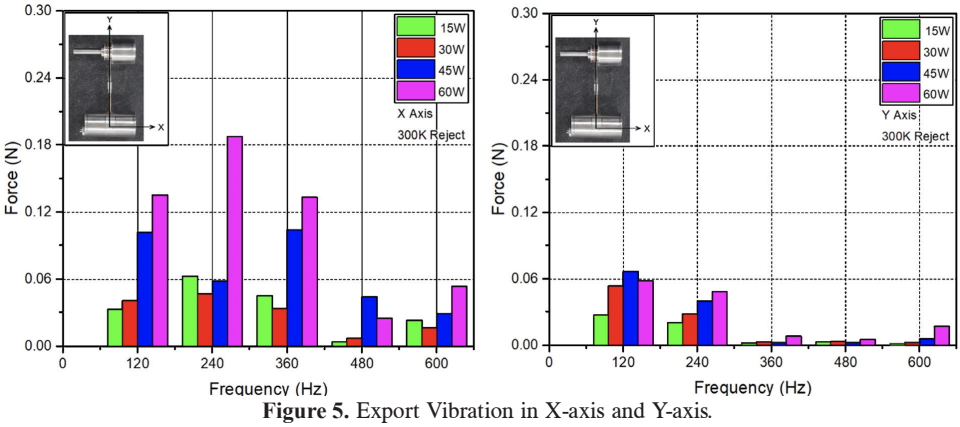

Figure 5. Export Vibration in X-axis and Y-axis.

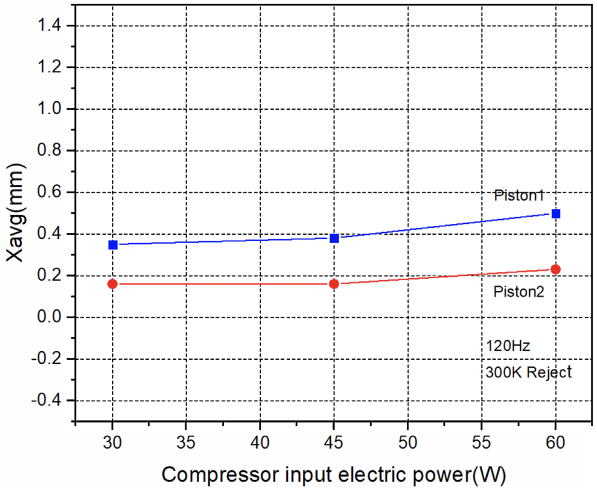

Figure 6. Piston Average Displacement.

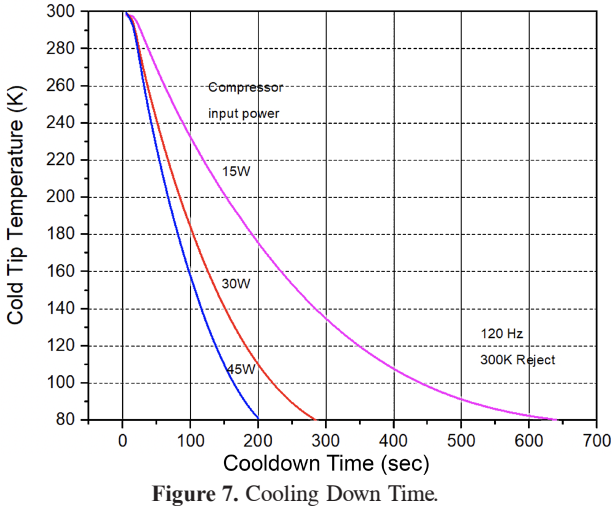

Figure 7. Cooling Down Time.

The piston displacements on both sides of the compressor with different electric power input are monitored by a laser displacement sensor. The average piston center shifts with different input powers are shown in Figure 6. With different electric power inputs, all the average values are less than 0.5 mm, which indicates that the piston is running with high symmetry.

Cooling Down Time

A copper cap as dummy load with a heat capacity of 250 J is installed on the cold tip of the micro-cryocooler to test the cooling down time. The test results are shown in Figure 7, the cold tip temperature can be reduced from 300 to 80 K in 3 minutes with 45 W electric power input.

CONCLUSION

This micro pulse tube cryocooler has the characteristics of high cooling performance, fast cooling down speed, small volume and mass, and good reliability. It can obtain 1.2 W cooling power at 80 K with 45 W electric power input, and takes 3 minutes to cool a 250 J heat capacity load down to 80 K at 300 K reject temperature. The micro cryocooler is suitable for avionics and space infrared sensors, and other cold-optics applications.

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