

Pulse tube refrigerator cryostat with an intrinsic top-loading system

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Abstract. The authors have undertaken basic research and prototype developments of four-valve pulse-tube refrigerators (FVPTR) since several years. Two single-stage FVPTR in coaxial and U-shaped arrangement have been designed for maximum refrigeration power at cooling temperatures below 30 K. The heat flow through a thermal link between the pulse tube and the regenerator is the determining difference between the U-shaped and the coaxial configuration. The intrinsic heat flux has a complex influence on the cooler performance, e.g. the cooling power, the temperature distribution within the pulse tube and the dynamic losses. Based on these results we propose a design study of a coaxial FVPTR with an intrinsic top-loading system. This cryostat is most suitable for measurements and analytical applications with even low maintenance costs. The main advantage for the operator is the rapid sample exchange while the refrigerator is operating. The process takes only a matter of minutes. Thus the time to cool successive samples is greatly reduced over cold finger cryostats.

1. Introduction

During the last decades great efforts have been made in developing single stage pulse tube refrigerators for applications in which cooling to low temperatures less than 80 K is necessary, e.g. the cooling of sensors and devices for medical, scientific or industrial processing [2,3,4]. In comparison to other available commercial coolers, such as Gifford-McMahon (GM) coolers and Stirling coolers, the pulse tube refrigerator (PTR) has the great advantage of nonexistent moving parts inside the cold head. This aspect results in greater reliability and longer lifetime associated with reduced vibration levels and manufacturing costs. A coaxial structure has been designed, because this arrangement is the most compact and convenient one for actual applications.

2. Experimental set-up

A schematic diagram of the refrigerator and a picture of the real assembly are shown in figure 1. The diagram also illustrates the location of the various sensors used to study the gas temperature and pressure during operation [5]. A detailed cycle description is given in Ref. [6].

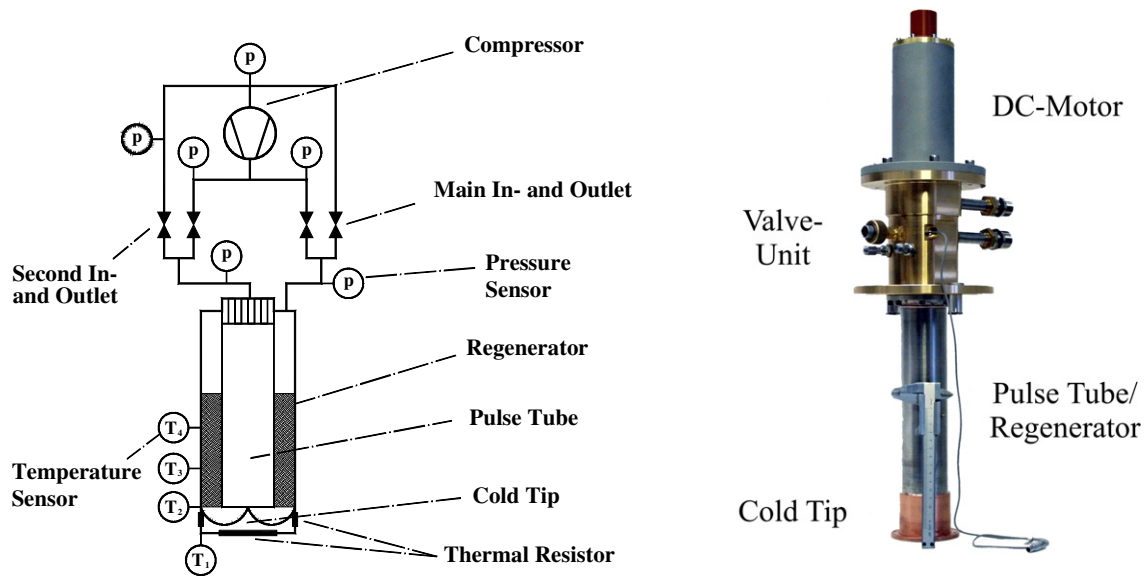


Figure 1. Schematic diagram (left) and a picture of the single stage FVPTR (right).

3. Experimental results

We achieved a cooling power of 120 W @ 76 K and 40 W @ 34 K with a filling pressure of 1.75 MPa. The no load temperature is 16 K. We are using a newly composite regenerator that is made of lead coated screens in the coldest part of the heat storage matrix. This higher heat capacity is linked with a smaller porosity of the screen stack. That guarantees a better cooling performance in the temperature range below 35 K. Figure 2 shows the performance of the single stage FVPTR. The effect of the filling pressure of the working gas helium inside the cryocooler system is parameterised. Higher system pressures improve the performance of the refrigerator but are limited by the compressor maximum pressure load.

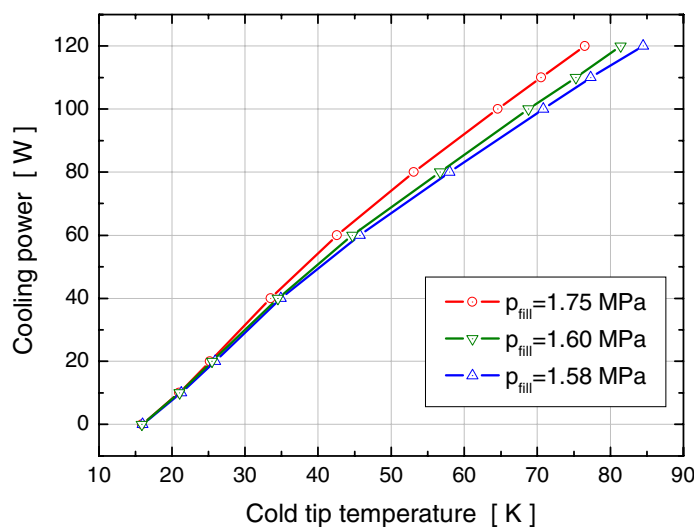


Figure 2. Performance of the FVPTR for different filling pressures. Compressor Leybold RW 6000, nominal input power 6.2 kW.

Based on the consolidated findings of the single stage coaxial FVPTR, we designed a two stage FVPTR. The coaxial arrangement is chosen too. The presented top-loading system can be integrated in both coaxial refrigerators. The nonexistent moving part inside the pulse tubes permits a sample holder system on the symmetry axis. The main advantage to the operator will be the rapid sample exchange while the refrigerator is operating. The process takes only a matter of minutes. Thus the time to cool successive samples is greatly reduced over cold finger cryostats. Breaching the vacuum and removing the radiation shield is not necessary. We demonstrate the principle arrangement of a two stage coaxial refrigerator including a top-loading system in figure 3.

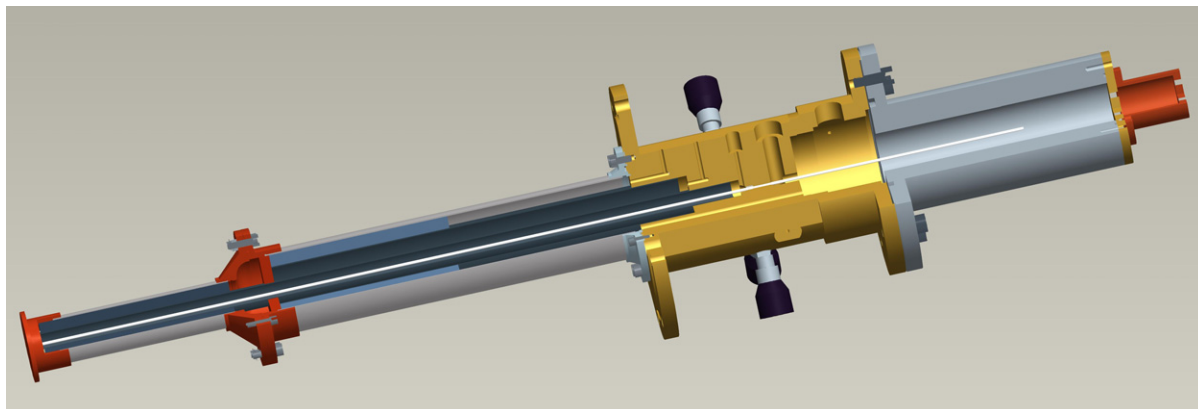


Figure 3. A two-stage pulse tube refrigerator in coaxial configuration, permitting an intrinsic top-loading system. The possible sample mounting is highlighted at the centreline of the coaxial configured FVPTR.

4. Conclusions

A single stage FVPTR in coaxial arrangement has been designed and constructed. The minimum no-load temperature achieved is 16 K. This temperature is reached with an inhomogeneous regenerator made of stainless steel and lead coated screens. The refrigerator provides a cooling capacity of 120 W @ 80 K or 40 W @ 35 K. These values can be achieved without any readjustment of the refrigerator. The cryocooler works stable and unattended over a long period of operation.

A two stage PTR in coaxial arrangement has been designed. The nonexistent moving part inside the cold head allows the integration of a sample holder system.

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