Integrated Detector Cooler Assembly for Space Applications

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ABSTRACT

Integrated detector cooler assemblies are widely used in tactical military applications to integrate coolers with an infrared focal plane into an evacuated dewar. Because the space environment is already evacuated they have rarely been used in space payloads despite their test advantage prior to launch. In this paper we report on the design, fabrication and test of an Integrated Detector Cooler Assembly (IDCA) that was designed for space around our micro cryocooler; it can be easily modified to accommodate a wide variety of MWIR and SWIR focal planes. The IDCA is a hermetically sealed evacuated dewar containing an optical window, a cold shield, provision for a cold filter, a 640x480 pixel InSb focal plane, wiring to a 41 pin hermetic connector, and cooled by the integrated pulse tube cold finger. The IDCA is a variant of previous devices that have been built in quantity for tactical applications whose environmental requirements exceed those typically found for space optical hardware. Since the typical focal plane dissipation (including this InSb focal plane) is much less than 100mW, and the parasitic loads are much less than the cooler's rated capacity at 80K, this IDCA subsystem could also be used for some LWIR systems if the reject temperature is lowered.

INTRODUCTION

We designed, fabricated and tested an engineering model Integrated Dewar Cooler Assembly (IDCA) intended for use in space instruments. The IDCA incorporated and integrated four key components; the dewar, focal plane, pulse tube cold finger, and long life flexure bearing compressor. The dewar assembly, manufactured by TEMO Corporation[1], is a hermetically sealed evacuated dewar containing an optical window, a cold shield, provision for a cold filter, a 640x480 pixel InSb focal plane, wiring to the 41 pin hermetic connector, and the pulse tube cold finger as shown in Figure 1. The IDCA is a variant of previous devices that have been built in quantity for tactical applications whose environmental requirements exceed those typically found for space optical hardware. This short wave infrared (SWIR) focal plane was chosen for demonstration purposes. In fact, the design could accommodate a variety of other focal planes operating into the mid wave infrared (MWIR) regime and even in to the long wave infrared (LWIR) regime, if the cooler performance operating conditions allow the focal plane's chosen operating temperature. The dewar incorporates the second key component, a coaxial configuration pulse tube cold finger that cools the focal plane. This cold finger is shown in Figure 2A together with its micro compressor. The Northrop Grumman space micro pulse tube cooler (micro) is a split configuration cooler that incorporates a coaxial

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Figure 1. Integrated Dewar Assembly

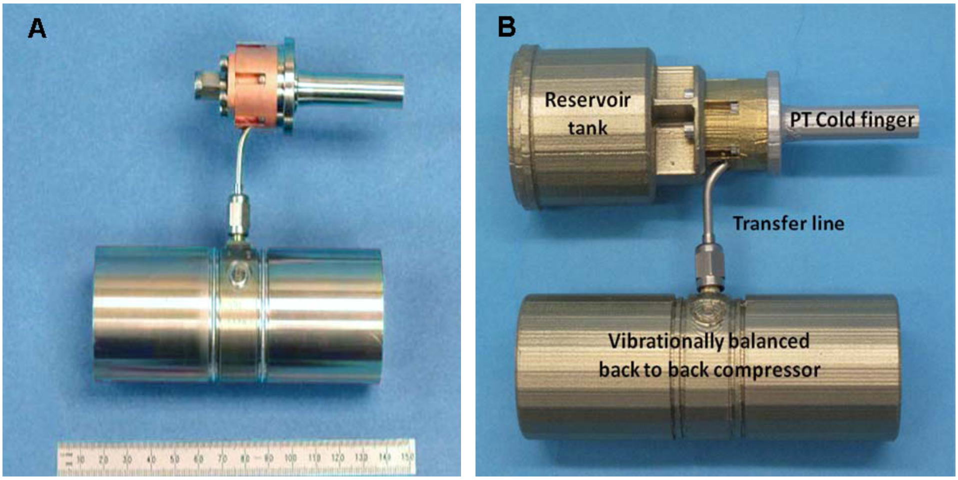

Figure 2. Flight design PT microcooler and its flight configuration with attached reservoir tank

cold head connected via a transfer line to a vibrationally balanced back to back linear compressor. The micro compressor is scaled from the flight proven high efficiency cooler (HEC) compressor and contains non-wearing pistons suspended on flexure bearings. Designed for > 10 year operation with no performance change, the 900 gram mechanical cooler can cool sensors and optics to temperatures <50K while rejecting heat to radiators over a wide range of reject temperatures. The very small, low vibration, high frequency cooler is designed to be readily integrated into space payloads. The coaxial cold head can also be integrated with custom focal planes into an integrated detector cooler assembly (IDCA) similar to those used with the shorter lived tactical coolers. A model of the space micro pulse tube cooler is shown in Figure 2B with its integrated inertance line and reservoir tank.

The engineering model space micro pulse tube cooler (micro) that was tested incorporated a coaxial pulse tube cold head welded into the dewar and connected via a transfer line to a vibrationally balanced back to back linear compressor. A description of the design and performance of the earlier prototype versions of the micro cooler was reported previously.[2, 3] The micro compressor is scaled from the flight proven high efficiency cooler (HEC) compressor and contains non-wearing pistons suspended on flexure bearings. The HEC compressor has been scaled both to larger and, in this case, to smaller sizes over a two order of magnitude capacity range.[4, 5] As shown in Figure 2B the flight micro cooler has been implemented with an all welded compressor and in the flight configuration shown has an estimated mass of 900 g. The cold finger is designed to interface with infrared focal planes either through a thermal strap, as is typical of space cryocoolers, or as in this case, into an integrated detector cooler assembly (IDCA), as is typical of tactical cryocoolers. The integrated reservoir tank and inertance line assembly shown in Figure 2B is designed to be integrated with the cold head, or alternatively, to be located elsewhere if required by instrument packaging constraints. The transfer line can also be lengthened or re-oriented as required by payload packaging constraints.

The following section presents thermal characterization test data for the microcooler integrated into the IDCA over a range of input powers and heat rejection temperatures.

TESTS

Figure 3 is a photo of the IDCA and microcooler in its test configuration. The tested cooler is identical to the flight configuration shown in Figure 2B except that the reservoir tank end cap is sealed with a bolted flange rather than being welded. The cold finger is welded into the IDCA, and the IDCA is hermetically sealed. Shown in the photo are the hardware test setup including the compressor, transfer line, IDCA and pulse tube reservoir, as well as the conductive reject surfaces to which they are mounted. Prior to delivery to NGAS, the hermetic integrity of the system was verified, and the parasitic heat leak with the focal plane turned off was measured using the liquid nitrogen boil-off method; the heat load was found to be ~400 mW. Since the typical focal plane dissipation (including this InSb focal plane) is much less than 100mW, the cooling power at 80 K is 2.5x the total load. Thus, a cooler no-load temperature <50K is quite feasible, and it appears that this IDCA subsystem may also be useable for some LWIR systems if the reject temperature is lowered.

The tests were conducted in a thermal vacuum chamber with varying input power and reject temperature. Figure 4 shows a cool down curve, with the input power to the compressor and focal plane temperature plotted versus time for a 300 K reject temperature. Since the IDCA does not contain a heater attached to either the cold tip or to the focal plane, it is not feasible to measure the cooling power of the cooler versus temperature, i.e. measure the load lines directly. In Figure 5 we show measurements of the minimum focal plane temperature vs. compressor input power for three reject temperatures at the cold head reject surface ranging from 300 K to 285 K.

In order to estimate the parasitic heat load in this dewar, Figure 6 plots the minimum temperature on a load line plot measured with its predecessor engineering model that included the same thermodynamic cold head design. From this plot we can infer that, if the cold heads have identical performance, the actual parasitic heat load is ~ 300 mW.

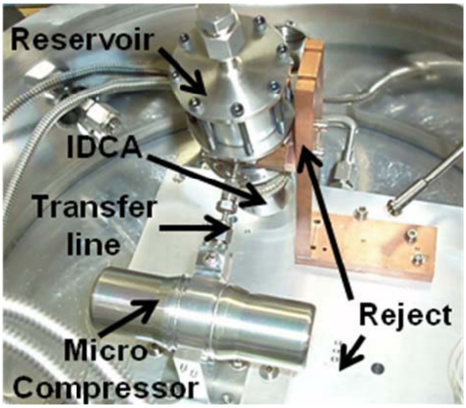

Figure 3. IDCA Test Setup

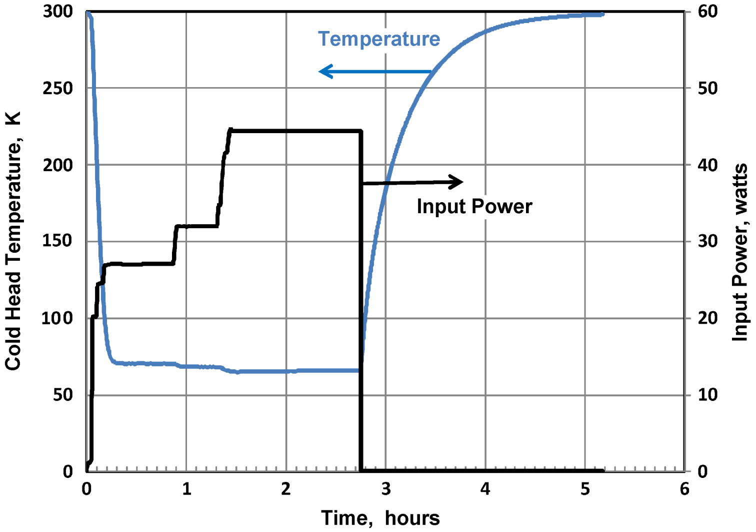

Figure 4. Test measurement including cooldown

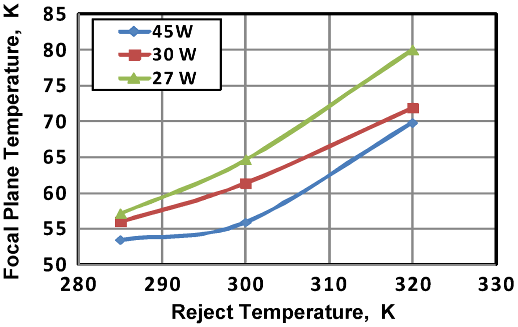

Figure 5. Minimum focal plane temperature vs. compressor input power for three reject temperatures

CONCLUSION

The microcooler and IDCA have been characterized for thermal performance in order to determine the range of application of the system for use with various focal planes. Because of its cooling capability and the typical dissipation of focal planes at less than 100 mW, this system appears capable of cooling focal planes to temperatures less than 50 K , i.e. temperatures characteristic of LWIR focal planes. The small envelope with its low mass and very long life makes it attractive as a subsystem that is easy to integrate and test for many small payloads.

In the future we intend to flight qualify the system and extend its range of application by increasing the efficiency of the cold head.

ACKNOWLEDGEMENTS

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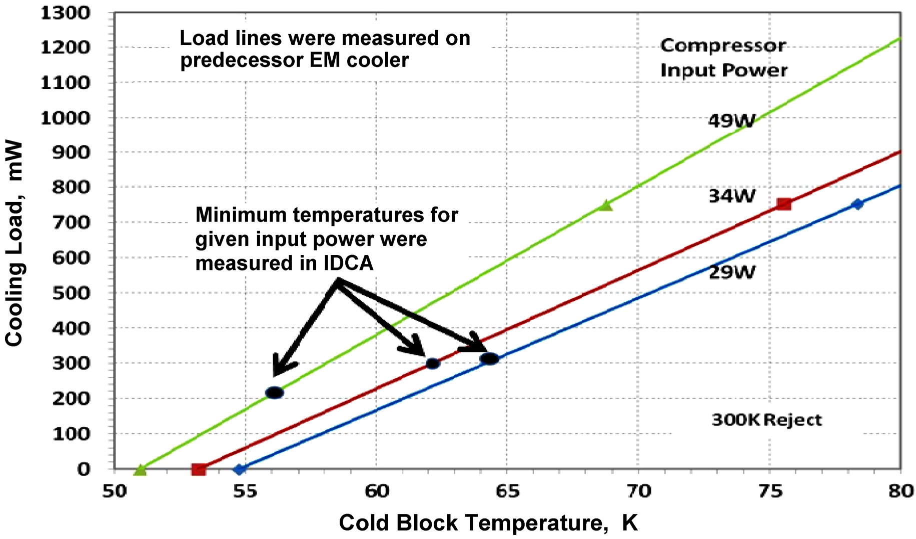

Figure 6 . Estimated parasitic heat load is approximately 300 mW.

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