NASA Phase I Project Summary
(non-proprietary)

Firm: Creare Incorporated
Contract Number: NNX10CD65P
Project Title: Micromachined Active Magnetic Regenerator for Low Temperature Magnetic Coolers

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Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)

We propose to develop an Active Magnetic Regenerative Refrigeration (AMRR) system that can provide continuous remote cooling at temperatures in the range of 2 K and reject heat at temperatures higher than 15 K. The magnetic cooler directly addresses the cryogenic technologies requested by 2009 Topic S1.07 for cooling scientific instruments and sensors on advanced telescopes and observatories. The AMRR system uses Creare's vibration-free, reversible cryogenic circulator to propel a low-pressure helium flow to facilitate the heat transfer in an AMRR, and thus allows a lightweight AMRR to achieve a large cooling power at high efficiency. Furthermore, the circulator will enable remote distributed cooling, allowing a detector(s) to be located far away from the cooler. The technology for the reversible cryogenic circulator was demonstrated under a prior NASA SBIR project. The innovation proposed here is a highly effective Micromachined Active Magnetic Regenerator (MAMR). The MAMR enables an AMRR to provide low temperature cooling with a high temperature heat sink. The MAMRs use an innovative flow channel configuration and novel micromachining technologies to achieve very high thermal and flow performance

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

The technical objective is to develop a highly effective Micromachined Active Magnetic Regenerator (MAMR) for the AMRR. We performed microfabrication trials to develop a practical machining approach for high aspect ratio microchannels in Gadolinium Gallium Garnet (GGG) disks. We performed a series of experiments to develop processes to produce a thermal insulation layer on a micromachined GGG disk to thermally isolate the GGG disks. We conducted a series of detailed three-dimensional CFD simulations to determine the heat transfer coefficient, pressure drop, and axial conduction in the regenerator. Finally, we used the CFD results to optimize the design of an AMRR system incorporating the MAMR technology.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)

In the Phase I project, we proved the feasibility by demonstrating: (1) a rapid fabrication approach to produce high aspect ratio microchannels in single-crystal GGG disks, (2) a process to fabricate an anisotropic core to reduce axial thermal conduction in the MAMR, (3) high heat transfer coefficients and low pressure drops in the MAMR by detailed CFD simulations, and (4) very high COPs of an AMRR incorporating Creare's MAMR and gas bearing circulator technologies.

Our fabrication trials shows that a practical fabrication approach for microchannels in GGG disks exists and the fabrication cost for an MAMR will be similar to other advance heat exchangers for space cryocooler applications. Our experiments show a robust, effective thermal insulation layer can be attached to the micromachined GGG disk to reduce axial conduction. CFD analyses show that the

thermal and fluid performance in the proposed MAMR is several times higher than stacked mesh screens or a random packed bed. Our design study predicts that the COP of an AMRR incorporating Creare's MAMR and reversible cryogenic circulator technologies will be several times higher than current 4 K mechanical coolers.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)

The proposed AMRR system will enable NASA to carry out future science missions that use cryogenic infrared, gamma ray, and X-ray detectors. Potential missions include the International X-Ray Observatory (IXO) and the Single Aperture Far-Infrared observatory (SAFIR). These detectors need to operate at temperatures in the range of 4 K to below 1 K to reduce the thermal emission of the detectors themselves and to achieve high sensitivity and resolution. The vibration-free, lightweight AMRR can provide efficient cooling for these missions at the required temperature ranges.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)

The military applications for the proposed magnetic cooler include cooling systems on space-based surveillance, missile detection, and missile tracking systems. Scientific applications include cooling systems for material microanalysis using X-ray microcalorimeter spectrometers, cryogenic particle detectors, and biomolecule mass spectrometry using superconducting tunnel junction detectors.

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