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ADVANCING CRYOGENIC SYSTEMS FOR THE NEXT GENERATION OF ASTROPHYSICS DISCOVERIES

Abstract

Future astrophysics discoveries can only be enabled with the most advanced technologies in order to permit more sensitive, accurate and effective detection. Cryogenic systems, consisting of cryocoolers and cryostats, serve to reduce thermal noise on focal plane assemblies in space telescopes. This allows for the cool down of detectors and superconducting devices, and present many other applications for a wide range of technologies within the realm of space science studies. In this research, developments in creating more efficient, compact, and reliable Stirling pulse tube cryocoolers are detailed. Stirling pulse tube cryocoolers (SPTCs) are pulse tube cryocoolers that utilise a warm end displacer in order to improve performance and efficiency compared to pulse tubes with inertance tubes. Previous studies have demonstrated a good performance through the use of an actively driven displacer at the SPTC warm end, however, an active displacer driven by a motor requires a second phase from the power electronics. This increases the complexity of the design due to the extra motor and electrical feedthrough. Hence, a passively driven displacer is an attractive design option, given that no moving parts at the cold end is beneficial for astrophysics detectors where vibration requirements are especially stringent.

This study presents the design, experimental testing, and validation of a passively driven displacer integrated within a coaxial Stirling pulse tube cryocooler cooling between 40-80 K. Thereafter, a system integration with a cryostat is explored for reaching temperatures within the sub-Kelvin range. An insight into the mass flow, pressure pulse and phase angles is presented, providing an understanding into the passive displacer activity for work recovery in a coaxial Stirling pulse tube cryocooler. The pressure and harmonic driving forces of the displacer are analysed and validated with the theoretically modelled operation of the passive displacer. Further studies are conducted on flexure bearing technology that permits continuous operation of the SPTC for long lifetime space missions.

With an input power of 97 W, the passive displacer SPTC experimentally achieved a cooling power of 3 W and a Carnot efficiency of 9.5% at 80 K. This study further compares its performance to the active displacer using simulated and experimental performance. This is a notable development in cryogenic technology in terms of cooling power and efficiency, for a system that reduces vibration and presents itself as a novel and attractive technology for future long lifetime astrophysics detector systems.