| Proposal Code : PDF-FusionTech-0004 | |
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| **Title** | Development of Stirling cryocooler for the cryopump |
| **Abstract** | Institute for Plasma Research (IPR) has already developed cryopumps that work at liquid nitrogen (~ 80 K) and liquid helium (~ 4–5 K) temperatures. These include development of sorption pumps for fusion and space applications. Sorption pumps were supplied to top Indian scientific organizations like ISRO (SAC) for their thermo-vac chambers. Also, developed pump was tested in SST-1 machine during the baking cycle of the vacuum vessel and PFCs. For the future needs of cryopumps, a high capacity stirling cryocooler needs to be developed for efficient, closed loop operation of this cryogenic system.<br><br>Stirling Pulse-tube refrigerators are developed and tested in IPR but Stirling cryocooler use a moving part called a displacer, which results in improved heat transfer and efficient cooling cycle. The system will also include a moving magnet linear compressor, which allows for efficient performance, adjustable cooling power, and reduced vibration which makes it suitable for application of cryopumps.<br><br>The project will be carried out in two phases. The first phase will focus on designing of the stirling cryocooler. The second phase will focus on testing and optimization of the developed cryocooler.<br><br>**Phase 1**: Design of the Stirling Cryocooler (77 K)<br><br>• Study and literature survey of the stirling cryocooler and creation of a design methodology.<br>• Design of key components like the displacer (active), regenerator, and heat exchangers |

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| | considering thermal and engineering point of view.<br>• Use computational Fluid simulations (like CFD) to study flow behaviour in different components during operation cycle of the cryocooler.<br>• Design of the moving magnet linear compressor to accurately ensure the gas flow control and operating frequency.<br>• Design of an electronic control system to operate the compressor and displacer together.<br><br>**Phase 2:** Developing, Testing, Improving and Scaling the Stirling Cryocooler System<br><br>• Build and test a working model (prototype) of the Stirling cryocooler with all its parts combined.<br>• Testing and improve its performance by adjusting parameters like cooling power, operating frequency, stroke length, and timing for better efficiency (COP).<br>• Operation of the cryocooler in a vacuum environment (cold heat exchanger).<br>• Scaling of the striling cryocooler for higher capacities (77 K @ 100 W). |
| **Research Focus Areas** | The work will begin with literature survey of stirling cryocooler and understanding both ideal and real cycle behavior. Then, the key parts like the displacer, regenerator, and heat exchangers will be designed and modeled. A moving magnet linear compressor will be developed, including its electrical and thermal behavior. Computer simulations will be used to check the system's flow, temperature, and movement. All components will be fabricated using Indian manufacturers. After that, the system will be assembled and tested under vacuum to |

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| | check its cooling performance, efficiency, pressure changes, and vibrations. A power supply and control system will be developed to manage frequency and sensor data. Finally, a high capacity stirling cryocooler will be designed and developed for the cryopump application.<br><br>**Expected Outcomes:**<br><br>• A fully developed high-performance stirling cryocooler made in India, with advanced control features.<br>• Successful use of this cryocooler for closed-loop cryopump working around 77 K.<br>• A strong base for developing future cryocoolers that can reach even lower temperatures.<br>• Reduced need for imported systems and a boost to India's capability in cryogenic technology. |
| **Qualifications** | PhD in Mechanical Engineering |
| **Desired Experience** | Expertise in thermal design and engineering. Knowledge of vacuum and cryogenics technology is desirable. Preference will be given to candidates with prior experience in designing, analyzing, and testing of cryogenic systems. |
| **Other remarks** | Design of stirling cryocooler can be done using numerical methods and optimization of the design can be done using REGEN and CFD simulations. But the fabrication within the close tolerances of compressor and expander is critical for better operations of cryocooler. Also, making of regenerative heat exchanger is difficult because of procurement and material availability. Instruments like high frequency pressure transducer and LVDT needs to be procured for the better investigations for the development. |