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C3Po1E-02: Design of a Three-Stage Continuous Adiabatic Demagnetization Refrigerator for Ultra-Low Temperature Applications

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The demand for extremely low temperatures in quantum computing and quantum devices has led to significant interest in advanced refrigeration methods. Among these methods, the continuous adiabatic demagnetization refrigerator (cADR) presents a promising alternative that does not rely on the increasingly scarce He3. While traditional dilution refrigerators (DR) are effective in reaching low temperatures, they require He3, leading to complexities in design and operation due to their large size and intricate components.
In contrast, the adiabatic demagnetization refrigerator (ADR) operates using the magnetic enthalpy of a solid, allowing for a more compact design. However, a significant challenge remains in maintaining low temperatures, as the ADR's operation inherently involves temperature fluctuations. To address this issue, the multi-stage configuration of the cADR has been proposed, which enhances temperature stability during operation.
This research focuses on the design of a three-stage cADR system utilizing Gadolinium Gallium Garnet (GGG) and Chrome Potassium Alum (CPA) as the magnetic materials. The first stage will employ a commercially available pulse tube cryocooler to achieve cooling down to 4 K. Heat switches will be strategically placed between each stage and the final cold end to control thermal transfer during operation, ensuring efficient temperature regulation.
The selection of appropriate paramagnetic materials is critical for optimizing the cADR's performance. GGG, with its high magnetic susceptibility and thermal conductivity, is well-suited for the initial cooling stage. CPA, on the other hand, offers advantageous thermal properties for subsequent stages. By implementing this multi-stage design, our cADR aims to maintain a steady temperature around 60 mK, which is essential for various applications in quantum technology.
The results of this study will contribute to the development of cADR systems capable of achieving and sustaining ultra-low temperatures without the reliance on He3. Our findings will pave the way for the construction of a 60 mK cADR, ultimately facilitating advancements in quantum computing and other low-temperature applications.

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