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C2Or3A-01: Rapid cooldown of cryostats using dynamic acoustic impedance matching in pulse tube refrigerators

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The terminating network of low-frequency pulse tube refrigerators consists of a reservoir and main orifice valve. Taken together, these components represent an acoustic impedance that determines how much acoustic power is delivered from the compressor to the refrigerator. The volume of the reservoir, flow resistance of the valve, and frequency of the acoustic oscillations are today chosen by manufacturers to maximize the cooling power available at the cold heat exchanger when it is at its base operating temperature, often near 4 K. At such low temperatures, conditions within the regenerator(s) of the refrigerator make the optimal impedance of the terminating network relatively high. However, during cooldown the optimal impedance of the terminating network is much lower, and a pulse tube refrigerator with static network impedance is unable to accept much of the power available from the compressor because the impedance matching between compressor and refrigerator is poor. By adjusting the network impedance of a two-stage commercial pulse tube refrigerator, we demonstrate that the cooling power available at temperatures higher than the base temperature can be substantially increased. For example, at 295 K we have increased the cooling power of the first and second stages from 197 W to 342 W and from 63 W to 116 W (respectively). Although the greatest increases to cooling power occur near ambient temperature, acoustic impedance matching still provides large relative increases to cooling power at temperatures just slightly above the base temperature. Cryostats may be rapidly cooled by dynamically adjusting the network impedance at all temperatures during cooldown. For 4 K cryostats, improvements to cooldown speed using acoustic impedance matching are further enhanced by thermally connecting the first and second-stage heat exchangers of the pulse tube refrigerator before the base temperature is reached.

Authors: Dr SNODGRASS, Ryan (National Institute of Standards and Technology, Boulder, CO USA; University of Colorado Boulder, Boulder, CO USA); Dr KOTSUBO, Vincent (National Institute of Standards and Technology, Boulder, CO USA; University of Colorado Boulder, Boulder, CO USA); Dr BACKHAUS, Scott (National Institute of Standards and Technology, Boulder, CO USA; University of Colorado Boulder, Boulder, CO USA); Dr ULLOM, Joel (National Institute of Standards and Technology, Boulder, CO USA; University of Colorado Boulder, Boulder, CO USA)

Presenter: Dr SNODGRASS, Ryan (National Institute of Standards and Technology, Boulder, CO USA; University of Colorado Boulder, Boulder, CO USA)

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