High-Frequency Cryocooler Is Tiny, Cold and Efficient

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A new cryogenic refrigerator has been demonstrated at the National Institute of Standards and Technology that operates at twice the usual frequency, achieving a long-sought combination of small size, rapid cooling, low temperatures and high efficiency. The cryocoooler could be used to chill instruments for space and military applications, and is a significant step toward even smaller, higher-frequency versions for integrated circuits and microelectromechanical (MEM) systems.

The new cryocooler, described in the current issue of *Applied Physics Letters*, is a "pulse tube" design that uses oscillating helium gas to transport heat, achieving very cold temperatures (-223 degrees C or -370 degrees F) in a matter of minutes without any cold moving parts.

With cold components about 70 by 10 millimeters in size, the device operates at 120 cycles per second (hertz), compared to the usual 60 Hz, which enables use of a much smaller oscillator to generate gas flow, as well as faster cool-down. Because changing the size of one component can negatively affect others, the researchers used a NIST-developed computer model to find the optimal combination of frequency, pressure and component geometry.

The new cryocooler is as efficient as the low-frequency version because it uses a higher average pressure and a finer screen mesh in the regenerator—a stainless steel tube packed with screening that provides a large surface area for transfer of heat between the gas and the steel. This is a key part of the cooling process.

The helium gas is pre-cooled by the screen in the regenerator before entering the pulse tube, where the gas is expanded and chilled. The cold gas reverses its direction and carries heat away from the object to be cooled before it enters the regenerator again and picks up stored heat from the screen. Then it is compressed again for a new cycle. Compared to a prototype NIST mini-cryocooler flown on a space shuttle in 2001, the new version is about the same size but gets much colder.

Pulse tube cryocoolers are more durable than conventional (Stirling) cryocoolers typically used in applications where small size is essential. These applications include cooling infrared sensors in space-based instruments used to measure temperature and composition of the atmosphere and oceans for studies of global warming and weather forecasting, and cooling night-vision sensors for tanks, helicopters, and airplanes. With continued work, the NIST researchers hope to increase operating frequencies to 1,000 Hz, which could enable development of chip-scale cryocoolers. Many difficult technical challenges need to be overcome to attain frequencies that high while maintaining high efficiency, such as the design of regenerators with pores just 10 micrometers in diameters.

Citation: S. Vanapalli, M. Lewis, Z. Gan, and R. Radebaugh. 120 Hz pulse tube cryocooler for fast cooldown to 50 K. *Applied Physics Letters*. 90, 072504 (2007)

Source: NIST