Faster and more sensitive electronics thanks to compact cooling

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Electronics work better under cold conditions (-150 C): with less thermal noise, detectors are more sensitive and low-noise amplifiers reduce noise further. Furthermore, the speed and reliability are increased. Dutch-sponsored researcher Srinivas Vanapalli has investigated the possibilities for the extreme cooling of electronic components at a chip level.

Besides research into extremely small structures, Vanapalli has constructed a proof-of-principle cooler, which despite the smaller dimensions, cools more effectively than conventional coolers and has therefore aroused commercial interest. Vanapalli carried out his successful research at the University of Twente, partly in cooperation with the National Institute of Standard and Technology in Boulders, US.

He focused on miniaturising regenerative coolers. These are coolers that make use of the oscillating compression and expansion of a working gas. Two factors proved to be critical in the miniaturisation of these coolers: the cycle frequency had to be increased as well as the average pressure of the gas in the system. Both are necessary to ensure that the miniaturised system has sufficient cooling capacity.

Vanapalli constructed a cooler with a frequency of 120 Hz. This cooler was approximately three times smaller than conventional (50 Hz) coolers, yet nevertheless had a higher cooling output and cooled down the smaller dimensions much faster. The cooler was realised in close cooperation with the National Institute of Standard and Technology in Boulder, US. Thales Cryogenics in Eindhoven has expressed a serious interest in this development, which is directly applicable to their products.

Vanapalli carried out a significant part of his research on even smaller and consequently even higher frequency coolers. This mainly concerned the balance between heat exchange and pressure drop in the micro-channels of the cooler. A good heat exchange requires many small gas channels but then the pressure loss is unacceptably high. Consequently a compromise must be sought. Test structures were etched in silicon with a typical width of 20 um and a height of 200 um. Theoretical models were found to accurately describe the pressure losses caused by this type of structures.

An important step towards a high-frequency microcooler is Vanapalli's research on a 1 kHz compressor that works on the basis of a metal membrane moved by a piezo stack.

Regenerative coolers

Regenerative coolers compress a working gas, usually helium, cyclically. In a regenerator, incoming hot gas transfers heat to the matrix of the regenerator, where the heat is stored for a half cycle in the heat capacity of the matrix. In the second half of the cycle the returning cold gas flowing in the opposite direction through the same channel, picks up heat from the matrix and returns the matrix to its original temperature before the cycle is repeated. At equilibrium, one end of the regenerator is at room temperature while the other end is at the cold temperature.

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