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Integrated, autonomous solutions for thermal management in high energy physics and space applications

Thermal management represents a major challenge in both high energy physics (HEP) and space missions. Whether it is to dissipate the heat generated by readout chips and other electronic components or to extend the service life of silicon sensors susceptible to radiation damage, cooling has become one of the main design concerns in both fields. Furthermore, the harsh environmental conditions encountered in both outer space and HEP experiments impose severe constraints, as the cooling solutions must operate under vacuum and absorb significant radiation doses.

Continuous advances in micro-engineering have opened the door to the development of smaller and more efficient cooling devices capable of handling increasing power densities with a minimum mass penalty. In this respect, previous work carried out at CERN has focused on the use of micro-channels etched in single crystal silicon (ScSi) wafers to circulate a cooling fluid. However, whilst this technology represents an appealing solution for thermal management in detector modules, it poses a number of challenges, particularly for high fluid pressures and long structures. Among these, the brittle nature of ScSi, the lack of suitable interconnections and the difficulties for the integration, packaging and qualification of such devices hinder their application in areas where reliability is paramount.

While some of these issues have been partially resolved, further advances are required to widen the areas of application and simplify the implementation of this technology. In this respect, the Detector Technologies group at CERN is starting a collaborative effort to develop a novel solution in which the sensor and the cooling circuit would be integrated in a single device. This collaboration would build on and benefit from an existing partnership with the École Polytechnique Fédérale de Lausanne (EPFL) and the Swiss Space Center (SSC), the objective of which is the production of silicon micro heat pipes.

From a heat-management standpoint the new device would be completely autonomous, operating in standalone mode without any external connection. To that end both a condenser and an evaporator would be included in the micro-fluidic circuit, which would act as a miniaturised loop heat pipe. Once demonstrated, this technology could be employed in a wide range of fields other than HEP experiments and space missions, including medical applications, transport industry, high-power computing and consumer electronics.

Summary

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