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Closed cycle dilution refrigerator 3He-4He for space application

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The studies of the cosmic microwave background (CMB) face significant technical constraints. To obtain accurate maps, the instrument must be capable of measuring fluctuations on the order of microkelvin over long observation periods (greater than two years). The Planck mission was a success, but with performance of 0.1 µW at 100 mK, its lifetime was limited by the maximum amount of helium that could be loaded onboard the satellite. Indeed, the ^{3}He dilution refrigerator in superfluid ^{4}He operated as an open-cycle dilution refrigerator (OCDR) venting into space. Future space missions require more cooling power, lower temperatures, and extended lifetimes. Consequently, unlike Planck, it is necessary to close the dilution cycle using a isotope separator.

On one hand, based on historical work carried out at the Néel Institute on the OCDR, we have developed a demonstrator model (TRL4) of a closed-cycle dilution refrigerator (CCDR). This setup performs 2 µW at 50 mK with the challenge that all the physical processes involved in the demonstrator are against the gravitational field (unlike conventional dilution refrigerators, which use gravity to both distill and dilute 3He). On the other hand, recently, a transfer of know-how from the CNRS/Institut Néel to the CEA/DSBT has been set up to carry out the next developments of the CCDR in order to increase its technological maturity to TRL6 (e.g., mechanical environment).

We will present the latest CCDR developments obtained at the Institut Néel and the CEA/DSBT.

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Author: Dr VESSAIRE, Jérémy (Univ. Grenoble Alpes, CNRS, Institut Néel, 38000 Grenoble, France)

Co-authors: LUCHIER, Nicolas (Univ. Grenoble Alpes, CEA, IRIG-DSBT, 38000 Grenoble, France); Mr SIBEUD, Pierre-Fréderic (Univ. Grenoble Alpes, CNRS, Institut Néel, 38000 Grenoble, France); Mr DERREVEAU, Quentin (Univ. Grenoble Alpes, CEA, IRIG-DSBT, 38000 Grenoble, France); Mr DORNE, Raphaël (Univ. Grenoble Alpes, CEA, IRIG-DSBT, 38000 Grenoble, France); MARTIN, Sylvain (Univ. Grenoble Alpes, CEA, IRIG-DSBT, 38000 Grenoble, France)

Presenter: Dr VESSAIRE, Jérémy (Univ. Grenoble Alpes, CNRS, Institut Néel, 38000 Grenoble, France)

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