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Laboratoire commun de métrologie

Thermometry - Doctoral Thesis Subject

Conservatoire National des Arts et Métiers
Laboratoire Commun de Métrologie (LNE-Cnam)

DOCTORAL THESIS SUBJECT

Specialty: Metrology

Thermometry from 0.9mK to 8mK by Continuous Nuclear Demagnetization Refrigeration: Realization of the Provisional Low Temperature Scale of 2000 and Metrological Validation

Context and Positioning

The Provisional Low Temperature Scale of 2000 (PLTS-2000) is the international temperature reference between 0.9mK and 1K, based on the melting curve of helium-3. The doctoral work of C. Tauzin (2025) enabled the realization of this scale at LNE-Cnam and its comparison with the MFFT, revealing excellent agreement. However, these studies were limited to 8mK, the minimum temperature of the dilution refrigerator used. Extension down to 0.9mK requires an additional cooling technique, made possible by the CNDR (Continuous Nuclear Demagnetization Refrigerator) developed within the CRYONEXT project.

Scientific Objectives

This thesis aims to extend the realization of PLTS-2000 in the 0.9mK – 8mK range by exploiting continuous nuclear refrigeration. The central originality lies in the continuous nature of the CNDR: unlike single-shot systems, it maintains a stable temperature around 1mK, paving the way for long-duration measurement campaigns that are essential for reducing statistical uncertainty and observing the superfluid transitions of helium-3 (phases A and B), key reference points of PLTS-2000 in this range. Three axes are planned: (1) realization and validation of PLTS-2000 below 8mK by melting pressure measurement and identification of superfluid transitions; (2) comparison with the MFFT and the CSNT (Current Sensing Noise Thermometer), two primary or quasi-primary thermometers based on thermal noise measurement, enabling a cross-comparison with thermodynamic temperature; (3) metrological validation of the CNDR: minimum temperature, stability, cooling power, perturbations related to magnetic cycles, all traceable to PLTS-2000.

Novelty and Contribution

The availability of a continuous cold source below 8mK represents a paradigm shift. Measurements in this range have until now relied on single-cycle systems, limiting the duration of temperature plateaus and the achievable precision. The CNDR removes this constraint by providing extended thermal stability. This thesis will realize, for the first time in France, PLTS-2000 across its full range and will establish a metrological characterization protocol for CNDRs, an essential tool in view of their industrialization. The platform will also benefit the characterization of quantum components (qubits, KIDs, TES, SNSPD) at sub-10mK temperatures, in synergy with the MetriQs-France programme.

Environment and Supervision

The thesis will be carried out at LNE-Cnam (Temperature team), in collaboration with Institut Néel (CNRS). The doctoral candidate will have access to a dedicated dilution refrigerator, the MCT, the MFFT, the CSNT, and measurement chains traceable to national standards. The CNDR will be provided by Institut Néel (CNRS) within the framework of CRYONEXT (Project P6-B). Funding is secured.

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