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Knowledge through Measurement

Progress towards single pressure refractive index gas thermometry of helium-4 from 5 K to 25 K

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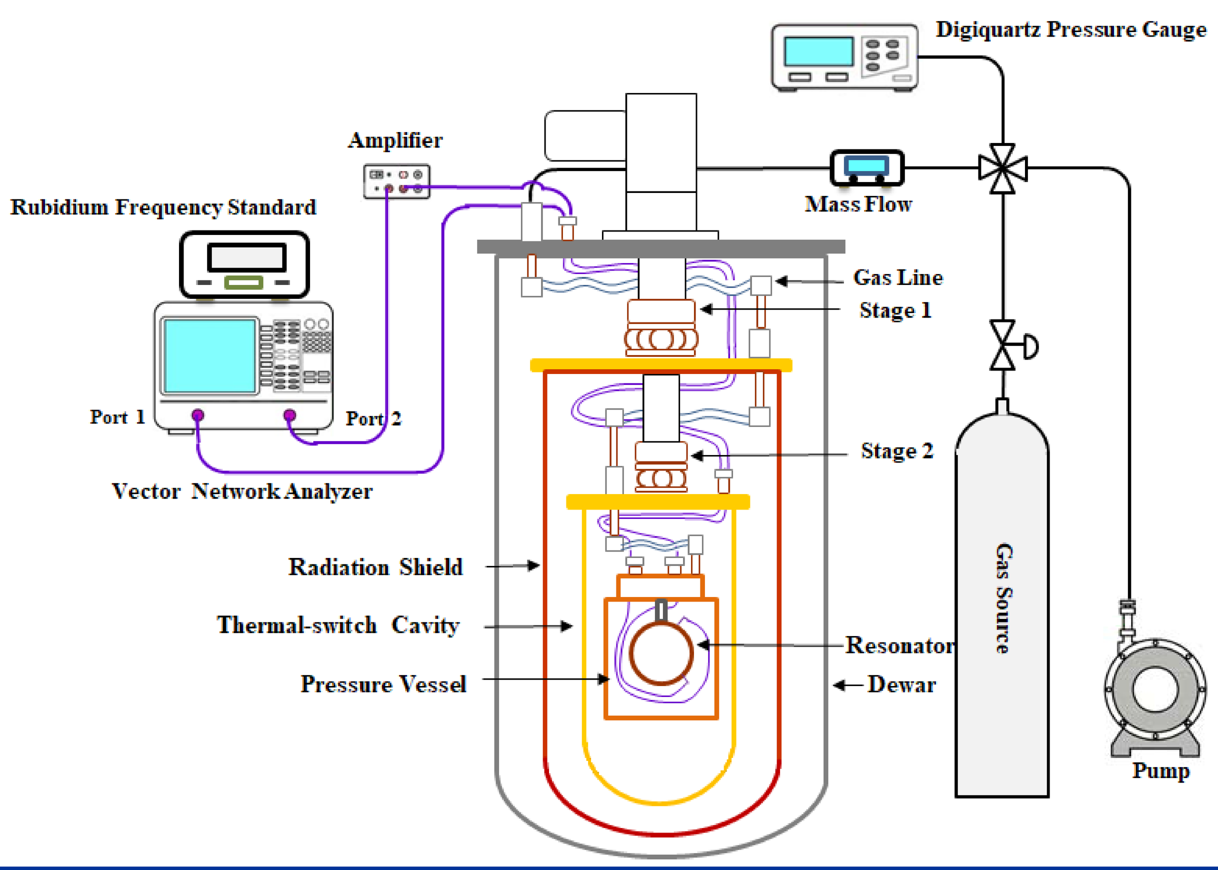
1. INTRODUCTION

TIPC-CAS in China and LNE-Cnam in France have jointly developed a novel single pressure refractive index gas thermometry (SPRIGT), which is expected to be an alternative for the other primary thermometry due to its competitive accuracy of 0.25 mK and increased measurement speed at temperatures from 5 K-25 K[1]. In SPRIGT, microwave resonances are used to determine the refractive index of a working gas in a quasi-spherical resonator at a single pressure, and thereafter a temperature can be obtained by comparing the refractive index between a reference temperature (e.g. fixed point of neon) and the one to be determined. To realize a accuracy of 0.25 mK for the measurement of thermodynamic temperature in SPRIGT, high accuracy temperature regulation (0.2 mK), pressure regulation ($4x10^{-6}$) and microwave measurement ($2x10^{-9}$) are required. Up to now, we have made progress better than the above requirements on the three key techniques, which will be presented in this paper.

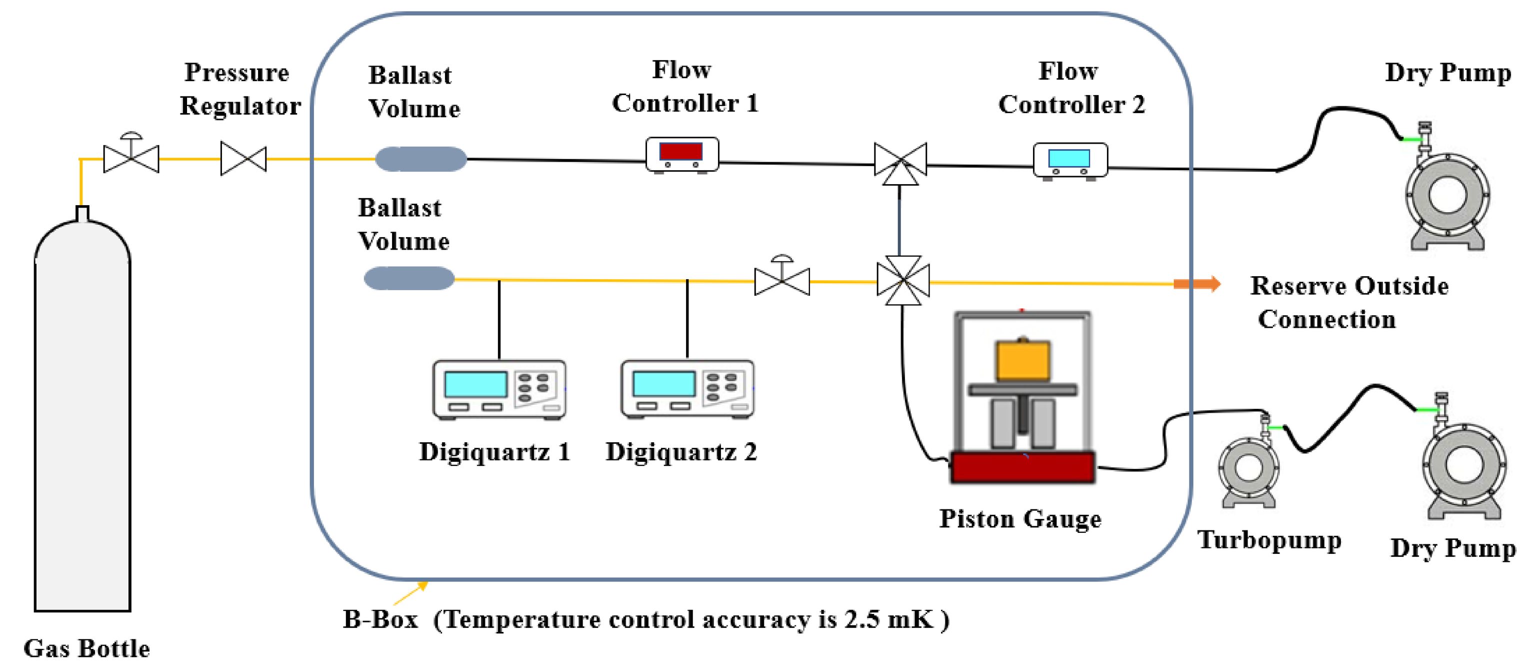
2. SPRIGT APPARATUS

The SPRIGT apparatus is mainly composed of three sub-systems, namely cryostat system, pressure system and microwave system. The core of the system is a quasi-spherical resonator, which was machined with precision diamond turning and closed successfully at room temperature using a microwave method [2]. In the final set-up, the quasi-spherical resonator will be housed in a cryostat cooled using a two-stage pulse-tube. The resonator will either be evacuated to determine its dimensions by microwave resonance, or else filled with flowing gas to determine the refractive index of the latter. The gas pressure will be measured by an absolute-pressure piston gauge and maintained constant by a servo-loop. To date, the microwave resonator has been housed in the cryostat and investigated its characteristics at low temperatures. In parallel, the performance of pressure system at room temperature has also been evaluated.

Cryostat and Microwave Coupling System

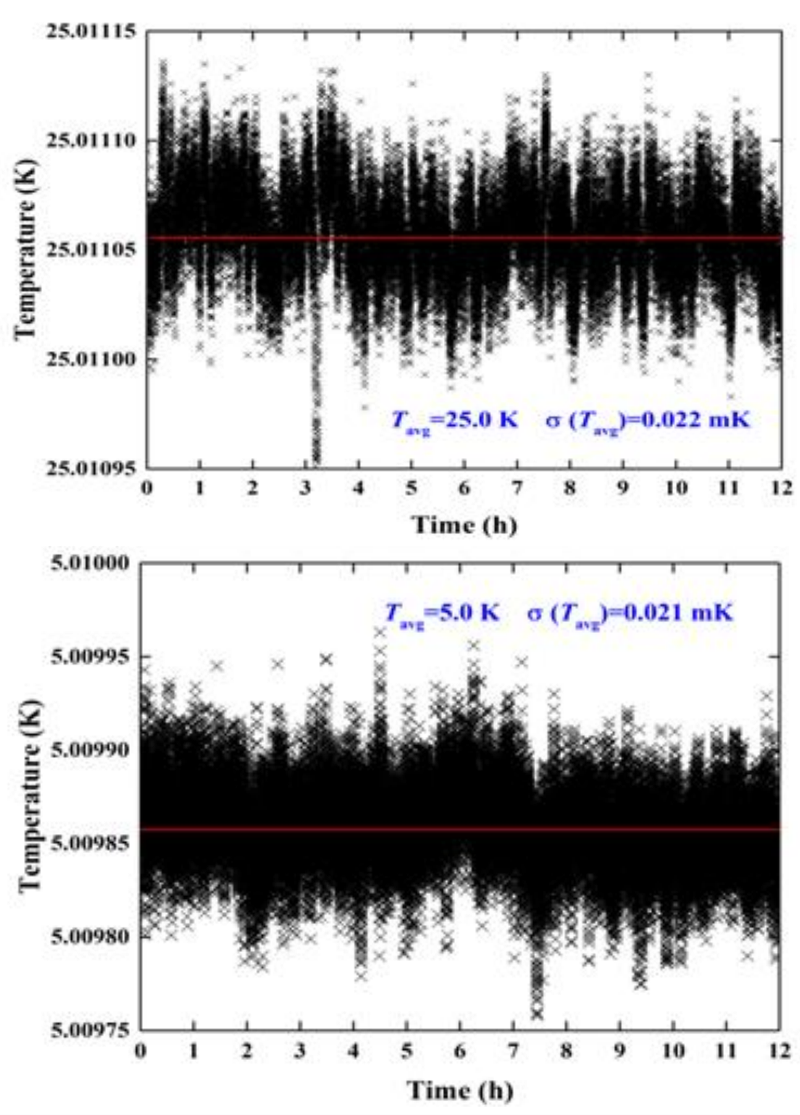


Pressure System



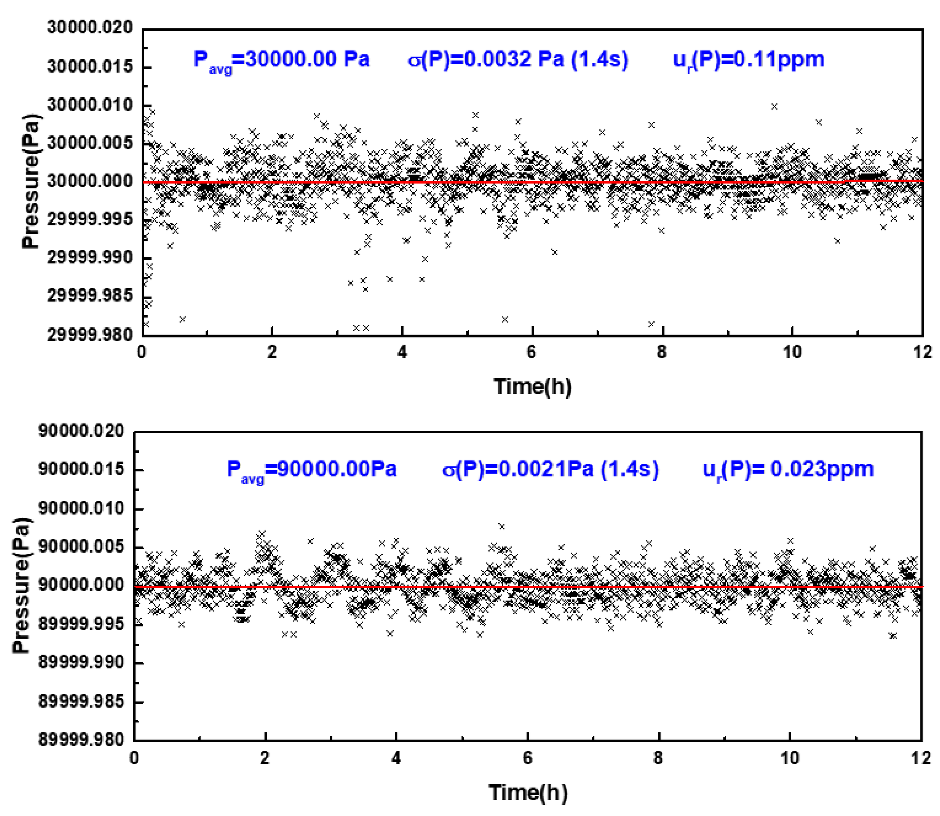
3.1. CRYOSTAT SYSTEM

Ultra-high temperature stability at temperature range of 5-25 K has been realized in the SPRIGT with the smallest instability about **0.021 mK** with an integration time of 0.8 s[3]. (**goal 0.2 mK**)



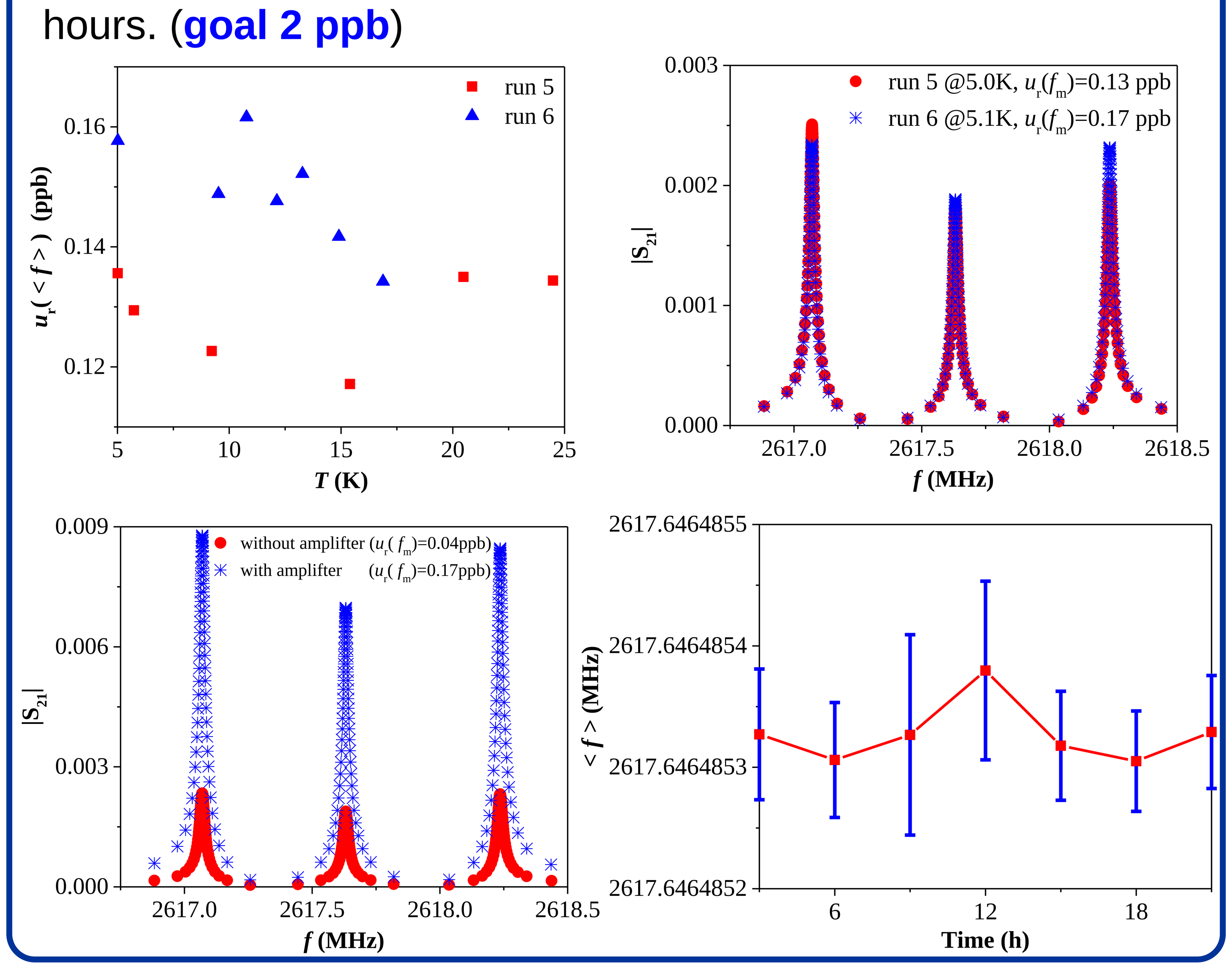
3.2. PRESSURE REGULATION

The pressure was controlled and measured by the piston gauge with the help of a flowing gas system at temperature T = 298 K. High pressure stability of 0.0021 Pa at 30 kPa and 0.0032 Pa at 90 kPa, corresponding a relative uncertainty of **0.11 ppm** (10^{-6}) and **0.023 ppm**, have been realized with an integration time of 1.4 s by maintaining the piston at a constant height. (**goal 4 ppm**)



3.3. MICROWAVE MEASUREMENT

The lowest relative uncertainty of frequency of TM11 **0.04 ppb** (10^{-9}) with the amplifier was achieved in a single measurement. In a long term measurement, high stability (**0.01 ppb**) and low uncertainty (**0.03 ppb**) of resonant frequency of TM11 mode without amplifier has been realized with a time interval of 3 hours. (**goal 2 ppb**)



4. CONCLUSION

High stability in temperature regulation (0.021 mK) and microwave measurement (0.01 ppb) at temperatures below 25 K, and pressure regulation (< 0.11 ppm) at room temperature 298 K have been achieved in the SPRIGT of China. All these progress will promote the realization of the SPRIGT with a expected uncertainty of 0.25 mK for the measurement of thermodynamic temperature at temperatures between 5 K and 25 K.

ACKNOWLEDGEMENT

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