Efficient Strategies Towards Low-loss Damping of Intrinsic Temperature Oscillations in 4 K Pulse Tube Coolers

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Abstract - Among all regenerative cooling systems, Pulse Tube Coolers (PTC) distinguish themselves by the absence of cold moving parts, which results in low vibration and long live operation of the cold head. However, PTCs, as well as Gifford-McMahon coolers, exhibit a periodic variation of the cold flange temperature resulting from the periodic compression/expansion of the process gases (helium). This temperature oscillation can disrupt the distortion free cooling of detectors and superconducting voltage standards by use of PTCs. One successful method to reduce these oscillations during cooling of such voltage standards is the implementation of a thin stainless steel plate between the cold flange and the sample platform. Because of the low thermal diffusivity of stainless steel, the temperature oscillation can be efficiently damped. However, because of the low thermal conductivity of stainless steel this method leads to a temperature gradient over the stainless steel plate, which depends on the necessary cooling power at the sample platform. Therefore, this approach is only applicable up to cooling powers of approx. 100 mW at 4 K.

Here we present a damping concept which is also suitable for higher cooling powers. Instead of a metal plate, the setup consists of a small pot made of copper (volume approx. 0.2 liters) installed between the sample stage and the cold flange of a two stage 4 K PTC. By use of precooling heat exchangers at the two cooling stages, a small amount of helium from an outer tank (volume approx. 4 liters) can be liquefied into the copper pot within a few minutes. The high specific heat of the liquid helium together with the heat transfer through two-phase flow (“thermosyphon”) allow the damping of the temperature oscillations without notable loss of cooling power in the temperature range from 2.2 K to 5.0 K. An amount of only 35 cm^3 of liquid helium in the pot allows the damping of the temperature oscillation down to a residual peak-to-peak variation of 15 mK near 4.2 K with 0.7 W heat load at the sample platform. This new temperature damping unit is a closed cycle system and maintenance free.

Keywords – Cryocooler, pulse tube cooler, temperature oscillation, damping temperature oscillation, closed cycle system

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