Recent development status of compact 2K GM cryocoolers

M Y Xu and Q Bao

Technology Research Center, Sumitomo Heavy Industries, Ltd.,
2-1-1, Yato-cho, Nishitokyo-city, Tokyo 188-8585, Japan

E-mail: mingyao.xu@shi-g.com

Superconducting single photon detectors play an important role in a variety of areas of quantum information science and technology thanks to their low noise counts and high detection efficiency. One of main obstacle in practical application of them is to develop more compact systems. In this paper, we present current status of our effort in this direction.

As a reliable cooling solution providing cryogenic temperatures under 80 K, Gifford-McMahon(GM) cryocoolers have been widely used for the past 30 years in various applications. In the 1990s, rare earth material with high heat capacity in the 4 K region was introduced into GM cryocoolers, which in turn made it possible for GM cryocoolers to achieve temperatures around 4 K. The market for GM cryocoolers in MRI cooling applications was opened by this significant advancement and still remains one of its most active applications today.

Recently, the rapid development of superconducting electronic devices indicates a new, large, substantial market for cryocoolers because most of them need to be cooled to cryogenic temperatures. Since, in most cases, noise level decreases with temperature, a temperature even lower than 4 K is desired for these devices or sensors. Also, in contrast to large scale applications, such as MRIs or superconducting motors, a much more compact size is desired to eventually achieve a reasonably-sized measurement system. With the hope of filling this spot in the current market, a compact 2K Gifford-McMahon (GM) cryocooler has been developed by Sumitomo Heavy Industries, Ltd. (SHI) since 2012 [1]. The objective is to reduce the total height of the expander by 33% relative to the existing 0.1W 4K GM cryocooler, RDK-101. In addition, considering the targeted cooling application, we set the design temperature targets of the first and the second stages under 1 W and 20 mW of heat load at 60 K and 2.3 K respectively. As a result, the cylinder length was reduced by 99 mm and the total height of the expander was reduced by 147 mm compared with a commercially-available 0.1W 4K GM cryocooler. With no load on the second stage, a temperature of about 2.1 K was achieved. With 1 W and 20 mW heat load, the temperature was 57.4 K at the first stage and 2.23 K at the second stage with an input power of about 1.1 kW. The detailed experimental results are discussed in this poster.

Figure 1. Photos of a compact and an existing RDK-101 GM expander.

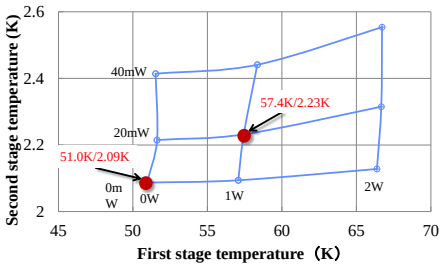

Figure 2. Typical cooling load-map of a compact GM cryocooler

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[1] Bao Q, Tsuchiya A, Xu M, and Li R 2015 *Proc. 25th Int. Cryogenic Engineering Conf. and Int. Cryogenic Materials Conf. in 2014 (Twente, The Netherlands), Physics Procedia* vol 67 (Amsterdam: Elsevier) p 428