

# Development of the 4 K G-M assisted J-T cooler with off-the-shelf mini compressor

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A 4 K J-T cooler is developed to provide sufficient cooling capacity for SNSPD (superconducting nanowire single photon detector) or other quantum information devices. The system is designed for a nominal cooling capacity of 10 mW at 4 K and is conceived to retain sufficient operating flexibility so to properly tune the operating condition. To that extent the design facilitates additional compressor capacity respect to nominal value. The cooling system consists of a compressor, a series of three recuperative heat exchangers and a commercial G-M cryocooler to pre-cool the compressed helium gas before the J-T expansion valve, the J-T valve and an evaporator. For the compressor, a series of small commercial units originally made for R-134a working fluid and a commercial oil removal system are utilized. It is tested with helium gas instead of R-134a. Compression ratio above 9 and with power consumption lower than 100 W can be achieved. In addition, the commercial oil removal system is utilized to prevent oil from reaching the J-T circuit. The three recuperators are adopted in the J-T system to exploit the cooling capacity of the returning cold gases, reducing the load on the compressor. The optimized recuperators are specifically designed in consideration of the load map of the two-stage cryocooler according to the principle of entropy generation minimization. Especially, the coldest heat exchanger is designed to have minimal volume and mass to maximize the available space for the user scientific package and to reduce cooling time after startup. Furthermore, the performance of the J-T cooler with a novel heat exchanger design is assessed and compared with that of more conventional solutions.

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