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A high-turnaround cryogenic platform for a 4 Kelvin production testing

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The rapid expansion of cryogenic technologies, such as quantum computing, necessitates robust, scalable, and high-throughput cryogenic testing infrastructure. As these systems transition from prototypes to commercial products, a significant bottleneck emerges in the need for efficient, production-level testing of numerous components at low temperatures. While many cryogenic systems are designed for research and development at the milli-Kelvin scale, the development of automated, high-density testing platforms operating at 4 Kelvin is crucial. Such platforms are essential for accelerating production testing, enabling large-scale manufacturing, and reducing the overall cost of these technologies.

This work presents a custom-built testing platform using a Gifford-McMahon (GM) cooler, specifically designed to meet the demands of rapid production testing of our cryogenic products at 4 K. The system's key innovation is a high-density radio frequency (RF) and direct current (DC) wiring solution, enabling the simultaneous testing of numerous devices in a single thermal cycle. High throughput is further enhanced by a cost-effective resistive heating solution for rapid system warm-up.

The core of our platform is a custom-designed radio frequency (RF) wiring tree. To maximize signal density, a high-density epoxy-beaded sub-miniature push-on micro (SMPM) connector feedthrough, with up to 61 individual RF lines per single flange, is integrated into a custom vacuum flange. This compact arrangement is thermally and mechanically robust, ensuring vacuum integrity and a large number of mating cycles.

The signal chain utilizes semi-rigid stainless steel coaxial cables to minimize thermal load to the 4 K stage. At the 4 K plate, a custom fanout box provides a standardized SubMiniature version A (SMA) interface for connecting to devices under test. This fanout box features a standardized array of SMA connectors, providing a convenient, robust and well-established interface for connecting to the devices under test and external measurement equipment. This design allows for rapid test setup reconfiguration, which is critical for a high-throughput environment. The high-density feedthrough demonstrates excellent performance, with an insertion loss below 0.32 dB and a return loss less than 20 dB for frequencies up to 15 GHz at room temperature. We have also characterized the full RF chain at 4 K to ensure signal fidelity. This RF chain, paired with a cryogenic calibration kit can enable the precise characterization of crucial microwave properties such as S-parameters, at 4 K.

In addition to the RF capabilities, our system includes a parallel tree for DC signal delivery. These DC lines, essential for powering and controlling devices, are thermally managed through an appropriate feedthrough printed circuit board (PCB) at each temperature stage of the GM cooler. This multi-stage layout allows for efficient thermal anchoring of the DC lines at each intermediate temperature, ensuring that the final heat load to the 4 K stage is minimized. For the DC connections, we have Molex PicoBlade connectors, for a compact and reliable high-density solution. Woven loom 42 SWG manganin serves as wiring, offering low thermal load and minimal thermal coefficient of resistance. The design also allows direct solderability of manganin onto the PCB for minimal contact resistances, a crucial feature for the warm-up heaters.

This dual-purpose wiring architecture, with dedicated, optimized paths for both RF and DC signals, creates a comprehensive and efficient testing environment. In conclusion, our custom-built GM cooler system with its high-density, multi-channel wiring tree represents a step forward in cryogenic production testing at 4K. It underscores its value in bridging the gap between small-scale cryogenic research and the demands of industrial-scale manufacturing, and emphasizes cryogenic quality and performance characterization of components, particularly in the quantum computation industry.

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Authors: Mr KOJ, Andre; Mr NILSSON, Markus; Dr BHASKAR, Priyamvada (Scalinq); Dr REHAMMAR, Robert; Mr SAEED, Zaid

Presenter: Dr BHASKAR, Priyamvada (Scalinq)

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