

**Advanced Packaging Drives Quantum Computing Forward:** Quantum computers may provide efficient solutions to certain problems that are intractable to classical computers. They work by processing quantum bits (qubits) which represent 0, 1 or both at the same time, thanks to their ability to be in the quantum state of “superposition.” Qubits are unstable, with short “coherence times” (how long they can stay in a quantum state). Although multiple qubit technologies exist, superconducting qubits that operate at cryogenic temperatures are one of the most mature approaches. They are lithographically scalable and are transitioning from a lab-scale experiment to commercial products. However, advanced cryogenic qubit packaging is critical for further progress, because it enables the integration of higher-density qubit chips, more I/O and smaller interconnect pitches, while maintaining coherence and high-fidelity performance. But while standard cryogenic qubit packaging uses a wire bonding approach to route signals from a commercial printed circuit board interposer onto a custom qubit chip, this unfortunately can cause a significant impedance mismatch and electromagnetic energy leakage. MIT Lincoln Laboratory researchers will describe how they designed and demonstrated a reworkable (i.e., resolderable) heterogeneous integration approach for the chip-to-interposer/substrate attachment process. It makes use of microbumps, not wirebonds, to minimize impedance mismatch and crosstalk, by reducing interconnect length. The fact it is reworkable means that it also enables the selective removal and replacement of damaged, non-functional chips.

The images above show cryogenic qubit packaging environment and assembly requirements.

1. Dilution Refrigerator hosting qubit package.
2. External view of fully assembled package.
3. Exploded view of the microwave package. The qubit chip (not shown in this view) and interposer are fabricated separately and joined together using a microbump approach. The qubit chip is flip-chip bonded with the interposer and the qubit-interposer module are ribbon bonded to the PCB (shown in green) for electrical connectivity. Also shown are mechanical package components (chip pedestal, body, and lid) and compact SMA cable assemblies.
4. package after attaching the flip-chip qubit-interposer (before gasket, lid and connectors are attached) to the PCB. Zoomed-in view of ribbon bonds (1 signal, 2 ground per connection) to interconnect interposer to the PCB.

**(Paper #11.1, “*Reworkable Superconducting Qubit Package for Quantum Computing*,” R. Das et al, MIT Lincoln Laboratory)**