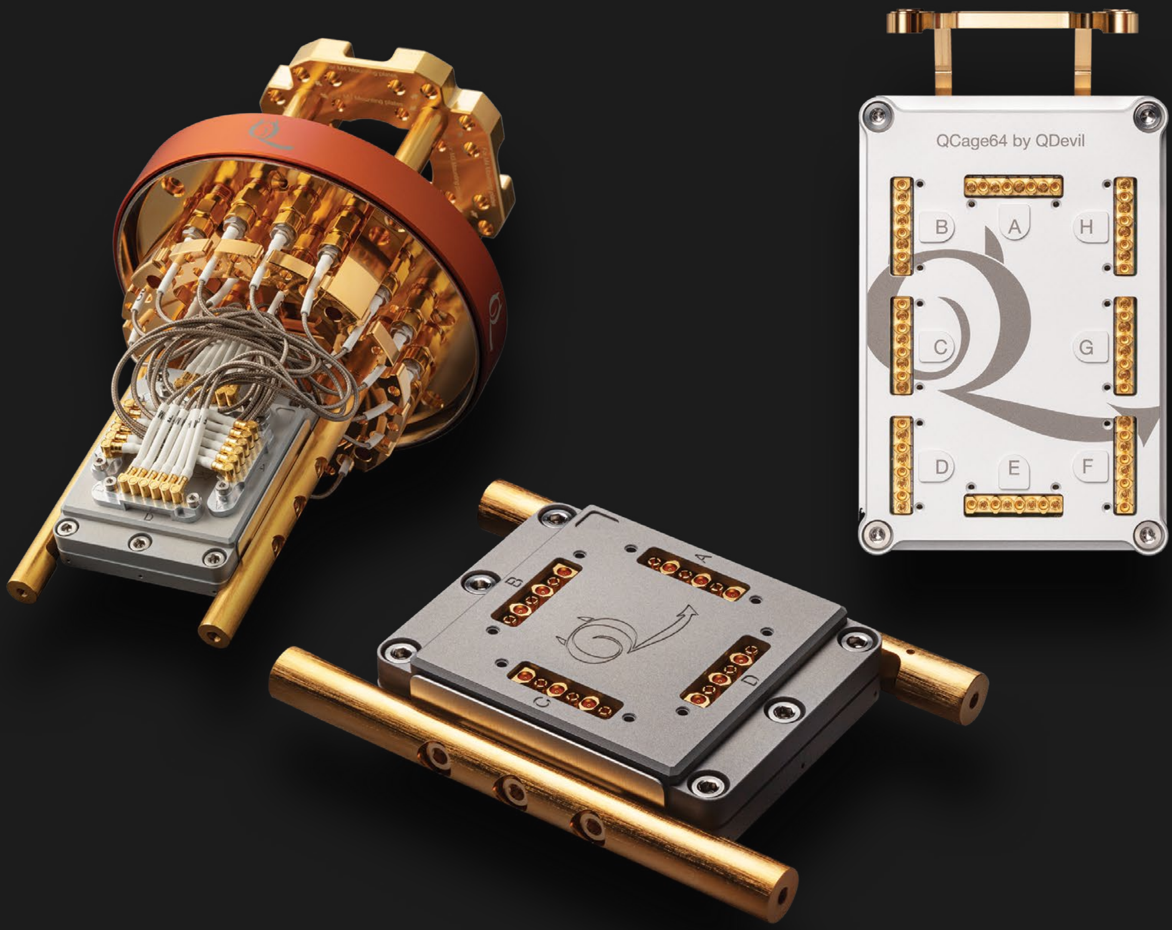
QUANTUM MACHINES



QCage

Industry Leading Chip Carrier
for Coherent Superconducting Quantum Systems

quantum-machines.co

Highlights

Cutting-Edge Sample Holder
Eliminating common issues like decohering microwave losses and quasiparticle poisoning, enabling record-breaking coherence performance.

EMC-Tight Enclosure
A precision-machined aluminum casing blocks infrared and microwave interference, ensuring high-fidelity operation.

Thermal Stability
Beryllium copper bolts and optimized cavity design guarantee effective thermalization and structural rigidity under cryogenic conditions.

Complete Installation Kit
All required mounting hardware is included, enabling straightforward deployment into dilution refrigerators with minimal adjustments.

Suspended Chip Architecture
The sample chip is fully suspended within a cryogenic cavity, supported by four corner pedestals, and securely clamped with a signal-carrying printed circuit board (PCB). This minimizes losses and box-mode coupling in a well-confined electromagnetic environment.

Reliable Connectivity
PCB transmission lines connect to the chip via wire bonding, while microwave grounding is established directly at the chip/PCB interface for minimal noise and maximum signal integrity.

Broad Compatibility
SMA and SMP connector interfaces ensure reliable signal transmission across a range of experimental setups.

Benefits

Superconducting Qubit Operations
Achieves Q-factors of at least 200 million and millisecond coherence times, setting a new benchmark for qubit performance.

Versatile Applications
Achieves Q-factors of at least 200 million and Supports single-qubit characterization, resonator studies, and multi-qubit processor development.

Simplified Workflows
Streamlines the entire process, from bonding to cryogenic integration, enabling faster and more reliable experimentation. .

Applications

Record-Setting Coherence
High-fidelity characterization and operation of superconducting qubits in cryogenic environments.

Microwave Circuit Measurements
Reliable performance for advanced studies of transmission lines, resonators, and other critical microwave components.

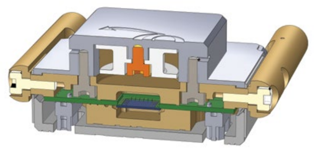
Hybrid Quantum-Classical Systems
Fully compatible with hybrid control platforms, enabling the execution of complex quantum-classical experiments.

Large-Scale Quantum Processors
Robust infrastructure for up to 10 superconducting qubits (QCage.24) or 30 superconducting qubits (QCage.64) with frequencies tailored to experimental needs.

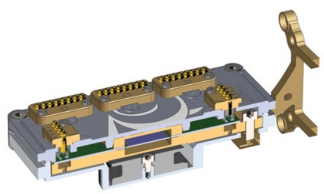
Resonator Characterization
Precision measurements of superconducting resonators, achieving unparalleled Q-factors and coherence.

Two Configurations | Options

QCage.24
- For up to 10 superconducting qubits
- Up to 18 GHz



QCage.64
- For large-scale processors, up to 30 superconducting qubits
- Up to 8 GHz

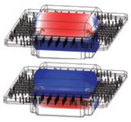


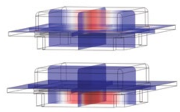
Cross-sectional view of the QCage assembly showing sample chip (blue) suspended between the top and bottom cavity parts, clamped down by the PCB (green), and connected by wire bonds. Thermalization is ensured by bolting the cavity parts together and onto the mounting rods with beryllium-copper screws.

Specifications

Electrical field simulations[1]

QCage.24	QCage.64
Top cavity resonance = 20.0 GHz Bottom cavity resonance = 18.8 Ghz	Top cavity resonance = 10.4 GHz Bottom cavity resonance = 8.95 GHz





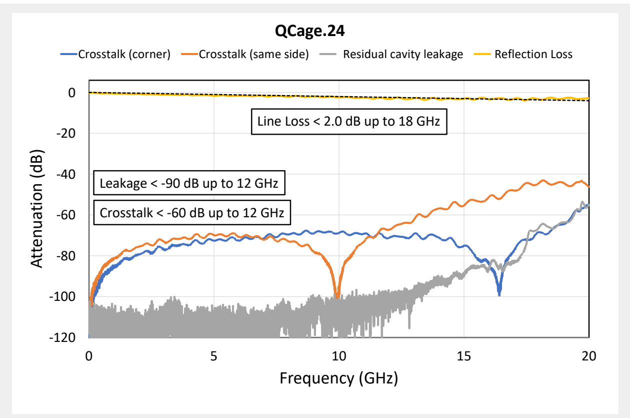
Features	QCage.24	QCage.64
Chip fixing	Clamped down by PCB to corner pedestal without using glue or other lossy substances	
Connectivity PCB	Low loss stackup, 24 embedded coplanar lines (6 from each side)	Low loss stackup, 64 embedded coplanar lines (16 from each side)
Connector interface	Four 6-way Mini-Coax ports for connectivity to at least 20 GHz	Eight 8-way Mini-Coax ports signal connectivity to at least 20 GHz
Thermalizing microwave cavity	Gold-plated beryllium copper brackets on both sides of the chip and PCB provides thermalization and microwave confinement	
Shielding enclosure	Light-tight superconducting aluminum casing for best possible microwave rejection	
Flux biasing magnet	Superconducting coil for global flux biasing	
	up to 2.6 Gauss, ± 20% homogeneity	up to 4.0 Gauss, ± 30% homogeneity

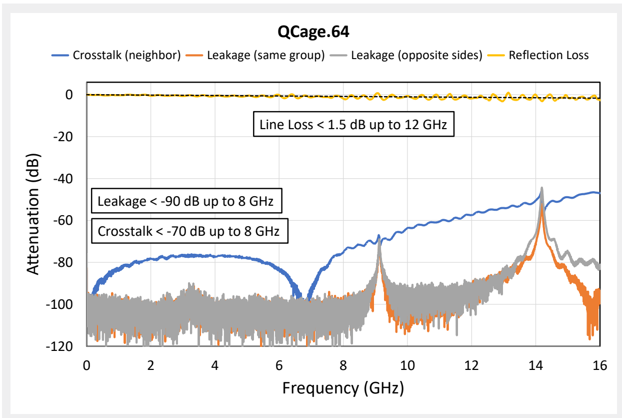
Specifications	QCage.24	QCage.64
Standard chip size	10.0 × 10.0 mm2 (± 0.5 mm) with 8.0 × 8.0 mm2 active circuit area	22.0 × 22.0 mm2 (± 0.5 mm) with 20.0 × 20.0 mm2 active circuit area
Standard die thickness	525 µm (± 50 µm)	525 µm (± 50 µm)
Front-side cavity	10.5 × 10.5 × 2.5 mm3	22.5 × 22.5 × 3.3 mm3
Rear-side cavity	10.5 × 10.5 × 3.0 mm3	22.5 × 22.5 × 3.5 mm3
Lowest box-mode resonance	18.8 GHz (rear-side) 20.0 GHz (front-side)	8.95 GHz (rear-side) 10.4 GHz (front-side)
Insertion loss to bonding pads	- 1.5 dB to 8 GHz - 2.0 dB to 18 GHz	- 1.5 dB to 12 GHz
Reflection loss from cable end	-25 dB to 8 GHz -15 dB to 18 GHz	-15 dB to 12 GHz
Neighbor line crosstalk	-60 dB to 12 GHz -40 dB to 18 GHz	-70 to 8 GHz
Leakage across cavity	-90 dB to 12 GHz -60 dB to 18 GHz	-90 dB to 8 GHz
Highest Q factors for superconducting resonators	200 million[2]	Currently being measured
Longest coherence times for transmon qubits	220 µsec[3]	Currently being measured

1 - Electrical field simulations have been carried out with COMSOL Multiphysics to ensure near-perfect line transmission. The simulations also confirm extremely low crosstalk, cavity leakage transmission, and line loss induced by PCB dielectric losses and connectivity mismatch.

2 - Unpublished results from A. P. M. Place, Houck lab Princeton University.

3 - Published by K. D. Crowley et. al. in Phys. Rev. X Vol. 13, 041005 (2023).





S-parameter characterization showing line loss inferred from the open-end reflection, crosstalk between neighboring channels, and residual leakage measured across the cavity.

About Quantum Machines

Quantum Machines (QM) is driving the future of quantum computing through Hybrid Control, seamlessly integrating quantum and classical computing. Conventional controllers struggle with disjointed operations, creating friction that limits scalability. The Pulse Processing Unit (PPU), at the core of QM's innovation, is a special processor for quantum control, designed to eliminate this barrier by bringing classical computing closer to qubits, reducing latency and enabling real-time execution of quantum error correction, and other advanced algorithms. The hybrid development platform further streamlines development, empowering quantum computer builders to create efficient quantum-classical programs. OPX1000, QM's flagship controller, embodies this hybrid approach. It is a modular, high-density control platform with a cutting-edge quantum-led analog front end. OPX1000 is tailored for large-scale quantum computers, offering unparalleled performance, scalability, and ready HPC integration, including an ultra-fast interface to GPU/CPU accelerators for boosting quantum control. With hundreds of deployments worldwide, Quantum Machines' solutions are trusted by quantum computer builders, research labs, and HPC centers. For more information, visit **quantum-machines.co**.

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