QCage.64

User Manual

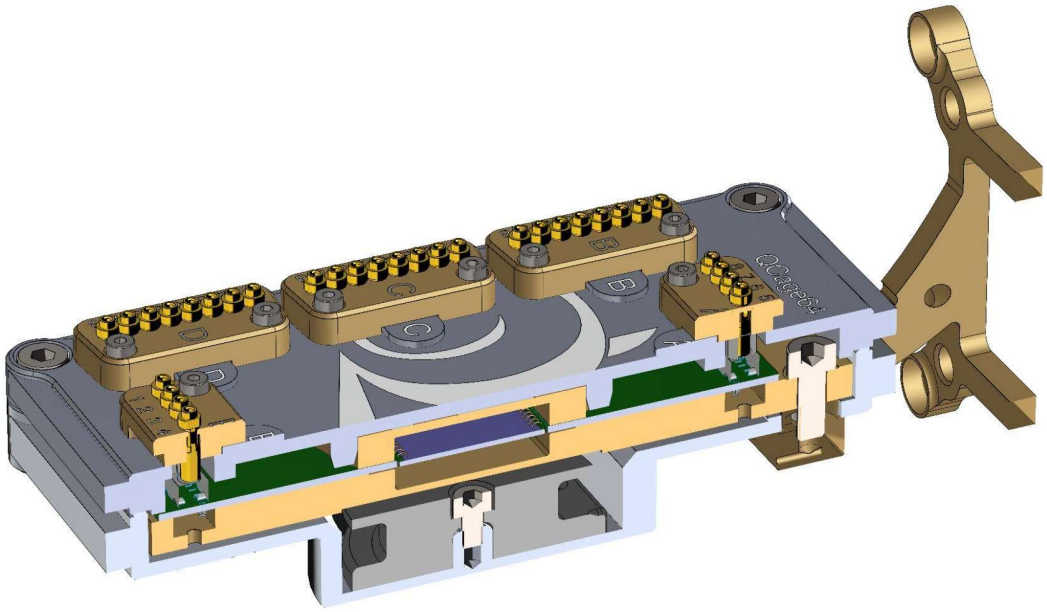

Figure 1 *Cross section of a QCage.64*

Product detail and updated information available at:

https://www.quantum-machines.co/products/qcage/

Made in Denmark - Patent pending

Authors: Søren Andresen, Amalie Paulsen & Oliver Dylander
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Contents

1. OPN Update

Please note that the OPN's (Orderable Part Numbers) for the product parts that appear on quotes and orders were updated throughout 2026. Please use the table below for translating between the new and old OPNs that are referred throughout this manual.

New OPN	Old OPN	Product Name
QCAGE-SHL-64C	Q428	QCage magnetic shielding (64 lines)
QCAGE-64-STD	Q429	QCage.64 standalone
QCAGE-64-PCB	Q430	QCage.64 sample board
QCAGE-64-FRM	Q431	QCage.64 chip holding frame
QCAGE-64-WBF	Q440	QCage.64 wire bonding fixture

2. Safe Handling

The QCage.64 is a delicate piece of equipment, designed to be used in vacuum environments at extremely low temperatures. It is therefore of utmost importance to keep it clean and avoid shocks or impacts that may damage its mechanical integrity.

In particular, avoid bringing strong permanent magnets into proximity of the QCage.64 or any of its parts and accessories, including cables, mounting hardware and magnetic shielding as this may result in residual magnetization.

All parts of the product shall be stored at normal indoor ambient conditions, avoiding exposure to temperatures and humidity levels higher than 45°C and 60% RH (non-condensing). Long-term storage of the sample boards (with or without chips mounted) should be done in a dry passive environment, e.g. dry nitrogen storage or vacuum-sealed bags.

All handling should be done wearing gloves, preferably on a clean covered table top. Care should be taken to avoid scratching or denting by handling with tools. Should there be a need to dispose of the QCage.64, the product and all of its parts shall be returned to Quantum Machines for proper disposal (contact Quantum Machines or QDevil ApS for instructions).

In case the QCage.64 hardware needs to be cleaned, we recommend blowing with dry air. If rinsing is needed, only use isopropanol or deionized water and avoid heating or blowing with hot air for drying.

	Wear gloves to avoid contamination by fingerprints etc.
	Keep dry and away from high temperatures.
	Not for general waste. Return to vendor for disposal.[1]
	Avoid the proximity of strong permanent magnets

	The gold-plated metal parts contain small amounts of beryllium. DO NOT cut or grind the metal parts, to avoid exposure to dust or fumes.[2]

[1] Contact Quantum Machines or QDevil ApS for instructions.

[2] Material safety datasheet for the relevant compound alloys can be obtained by contacting Quantum Machines or QDevil ApS. Translation to local language is the responsibility of the requester.

2.1 Intended use

The intended use of QCage.64 is for packaging and enclosing quantum devices to enable fast, low-loss microwave measurements in a cryogenic environment at temperatures down to a few millikelvin. The target users are physicists, engineers, trained technicians, or supervised university students – in short people who are aware of good and safe practice in advanced quantum laboratories that involves work with vacuum, cryogenics, electrical and microwave testing.

3. Product content

3.1 Standard configuration

The standard configuration for the QCage.64 sample holder system (QCAGE-64-STD) is delivered assembled with a magnetic shielding (QCAGE-SHL-64C) for cold finger mounting. It is supplied as the following individual part numbers:

- QCAGE-64-STD - QCage.64 system, EMC tight cavity with 64 lines
- QCAGE-SHL-64C - QCage magnetic shielding enclosure 64 lines

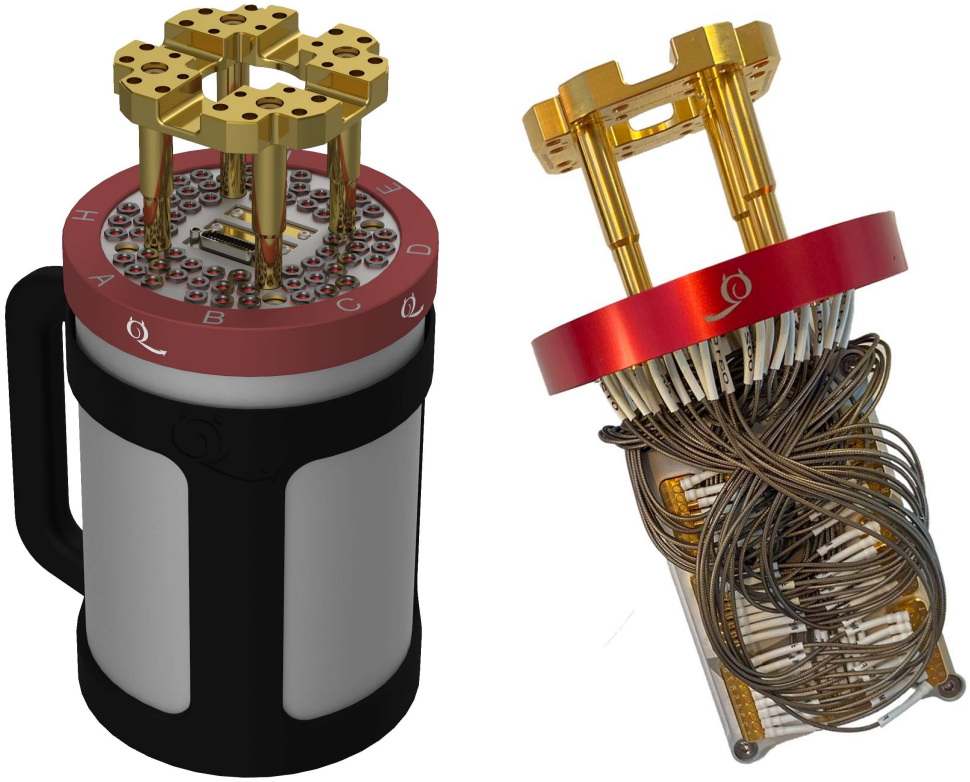


Figure 2 *QCage.64 magnetic shielding (QCAGE-SHL-64C). Left) EM tight cavity w. 64 lines (QCAGE-64-STD) and Right) EM cavity w. 64 cables.*

- QCage.64 system, connector face-plates labelled A, B, C, D, E, F, G, H are included.

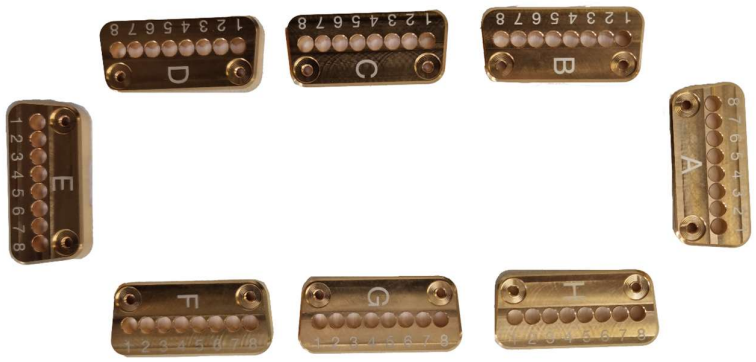


Figure 3 *Connector face-plates labelled A, B, C, D, E, F, G, H.*

For connectivity, different cable assemblies are available, interfacing to either SMP or SMA. Included in the standard configuration for the QCage.64 are eight 20 cm right-angled SMP cables for each of the eight plates.

- Q433-20 - Eight-channel Mini-Coax (right-angled) to SMP (jack) cable assembly, 20 cm

The eight right-angled coaxial cables shall be clicked carefully into the face-plates, fitting the unevenly numbered sockets 1, 3, 5, 7 with male connectors and the evenly numbered sockets 2, 4, 6, 8 with female connectors. Use the Q425 extraction tool to remove the individual connections from the connector face-plates if needed, as shown in the picture below.

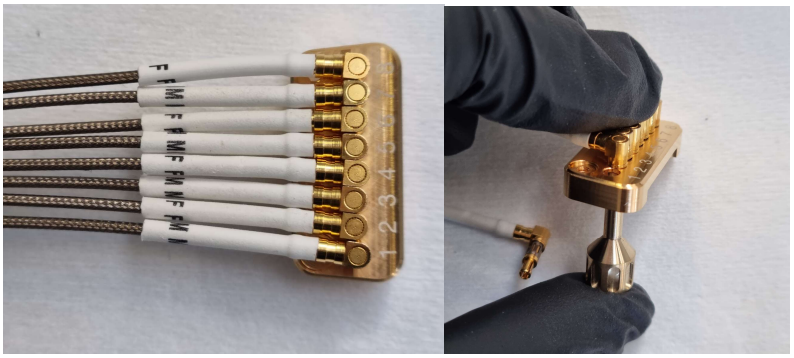


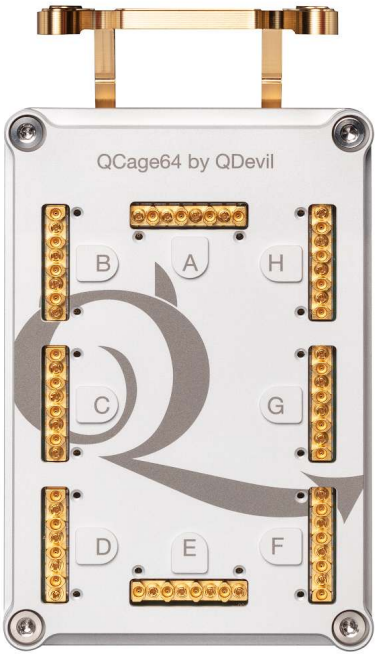
Figure 4 *Left) Eight right-angled coaxial cables clicked into a face-plate. Right) Extraction tool (Q425) used to remove the individual connections from the face-plates.*

For details on how to mount to the fridge, please go to section “Mounting onto cryogenic interfaces” under “Standard configuration - Mounting QCage.64 with magnetic shielding”.

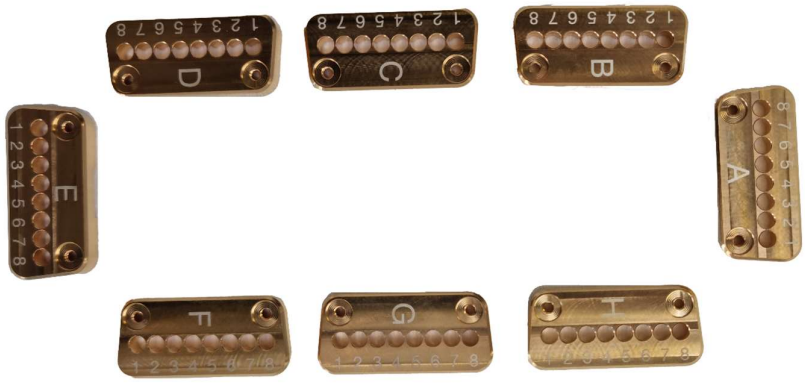
3.2 Standalone configuration

The standalone configuration for the QCage.64 sample holder system (QCAGE-64-STD) is supplied as the following individual part numbers:

- QCAGE-64-STD - QCage.64 system, EMC tight cavity with 64 lines.



- QCage.64 system, plates labelled A, B, C, D, E, F, G, H are included.



For connectivity, different cable assemblies are available, interfacing to either SMP or SMA. In total, eight coaxial cables (either straight or right-angled) shall be clicked carefully into the face-plates, fitting the unevenly numbered sockets 1, 3, 5, 7 with male connectors and the evenly numbered sockets 2, 4, 6, 8 with female connectors. Use the Q425 Extraction Tool for removing the individual connections from the connector face-plates if needed as shown in the picture below.

Figure 7 *Left) Eight straight coaxial cables clicked into a face-plate. Middle) Eight Right-angled coaxial cables clicked into a face-plate. Right) Extraction tool (Q425) used to remove the individual connections from the face-plates.*

Other cable variants are available, e.g. SMP cables (right-angled or straight) in lengths 20 or 30 cm or SMA cables (right-angled) in lengths 30, 40 or 50 cm. Cover plugs to fit in the connector ports that will not be used can be supplied as part no. Q426.

For details on how to mount to the fridge, please go to section “Mounting onto cryogenic interfaces” under “standalone configuration - Mounting QCage.64 without magnetic shielding”.

3.3 Accessories for chip handling and wire bonding

In addition to the main product numbers, accessories may be supplied to assist the chip handling and wire bonding:

- QCAGE-64-PCB - QCage.64 sample board, 64 transmission lines
- QCAGE-64-FRM - QCage.64 chip holding frame for sample board

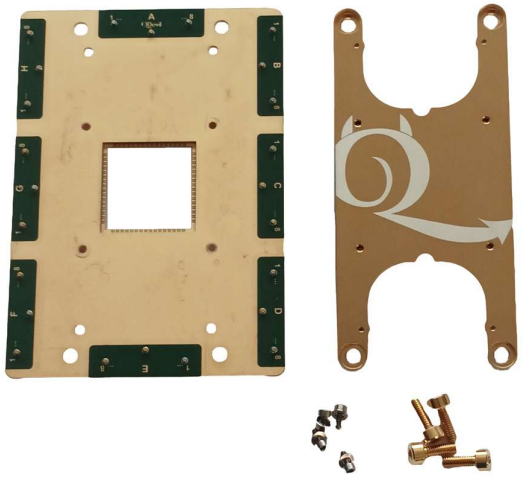


Figure 8 *Left) Sample board (QCAGE-64-PCB). Right) Chip holding frame (QCAGE-64-FRM) with mounting screws.*

- QCAGE-64-WBF - QCage support fixture for wire bonding.

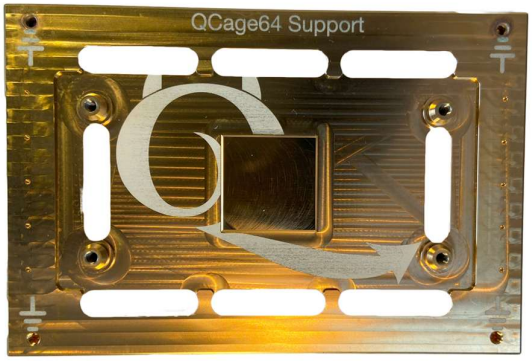


Figure 9 *QCage support fixture.*

Adapter plates for chip sizes smaller than 22 x 22 mm^2 and spacer for thinner or thicker chips can be customized upon request.

4. Interfacing to the sample chip

The QCage.64 sample holder has the sample chip held suspended inside the microwave cavity, supported by four corner pedestals and clamped down by the sample board (QCAGE-64-PCB). The bottom cavity with the corner pedestals is defined in the chip holding frame (QCAGE-64-FRM). It has room for a chip size of 22 × 22 mm^2 and supports die thicknesses of 525 μm ± 50 μm. The tolerance in chip size is 0.5 mm as chips larger than 22.5 mm will not fit in the cavity and chips smaller than 21.5 mm will risk dropping below the pedestals. After bolting down the sample board (QCAGE-64-PCB) and establishing connection by wire bonding, the chip carrying assembly is loaded into the QCage.64 main assembly (QCAGE-64-STD) which completes the microwave cavity formed by the bottom and top cavity parts as shown below. For further details on how to load the sample chip and guidelines for wire bonding, please refer to section *"Loading the sample chip"*.

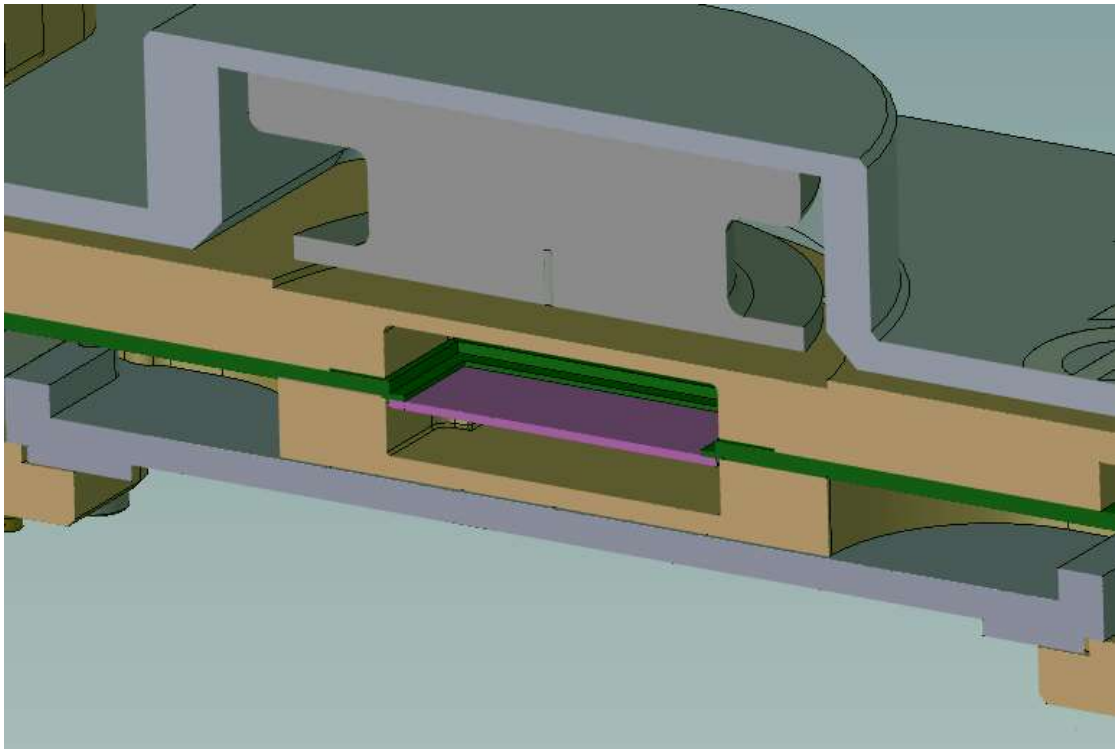


Figure 10 *Microwave cavity with sample chip suspended on four corner pedestals, clamped down along the edges by the sample board (QCAGE-64-PCB) with connections established by wire bonding.*

It is highly recommended never to use glue or other compounds to mount the sample chip in the QCage.64 sample holder, as it may cause microwave losses and decoherence. Great efforts have been made to optimize the cavity to provide the best microwave surroundings with minimal losses and decoherence, both by separating the normal metal boundaries and selecting some of the lowest loss dielectrics for the sample board. Any additional microwave loss and decoherence mechanisms introduced in the cavity are likely to degrade the performance of the quantum circuits operated in the QCage.64.

4.1 Interface layout

The dimensions of the cavity and sample board interfacing to the sample chip are:

- Cavity space for fitting the chip = 22.5 × 22.5 mm^2
- Sample board step-down to bond pads = 22.0 × 22.0 mm^2
- Bond pad extension = 20.2 × 20.2 mm^2
- Sample board opening = 20.0 × 20.0 mm^2
- Transmission line separation = 1.1 mm

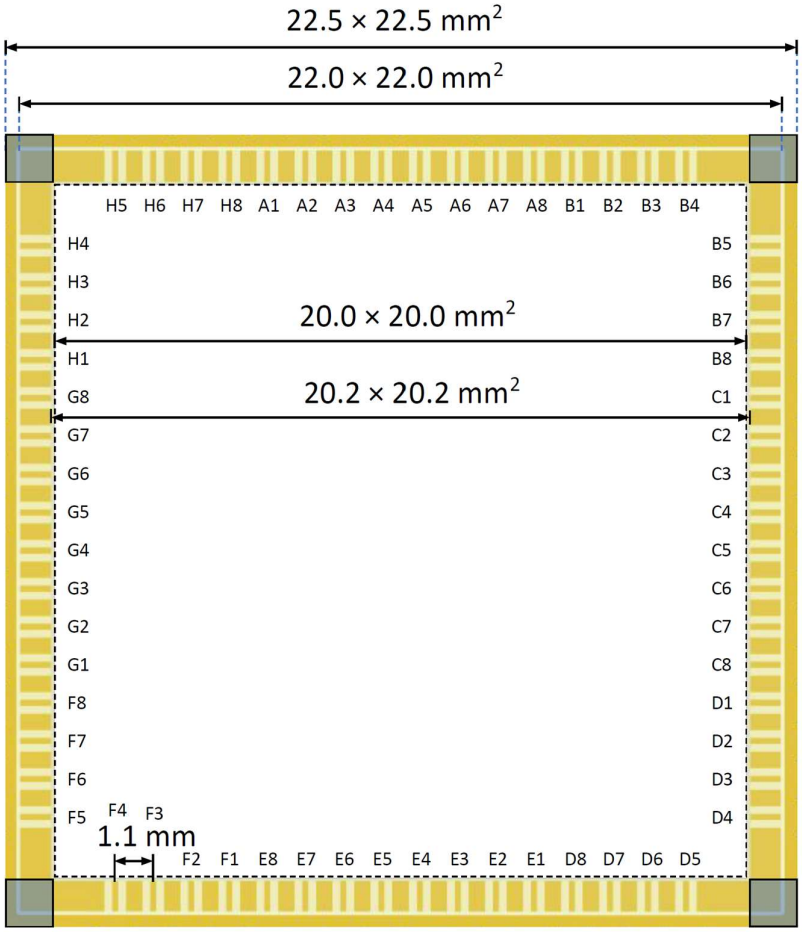


Figure 11 *Dimensions of cavity and sample board layout (false color)*

The transmission lines have a central linewidth of 0.17 mm with 0.23 mm gap to the ground plane on each side. In this 20.0 × 20.0 mm^2 step-down region with the bonding pads, the thickness of the sample board is reduced to 0.3 mm. Outside this exposed region, the sample board has a step-up of 0.75 mm.

5. Disassembling the QCage.64

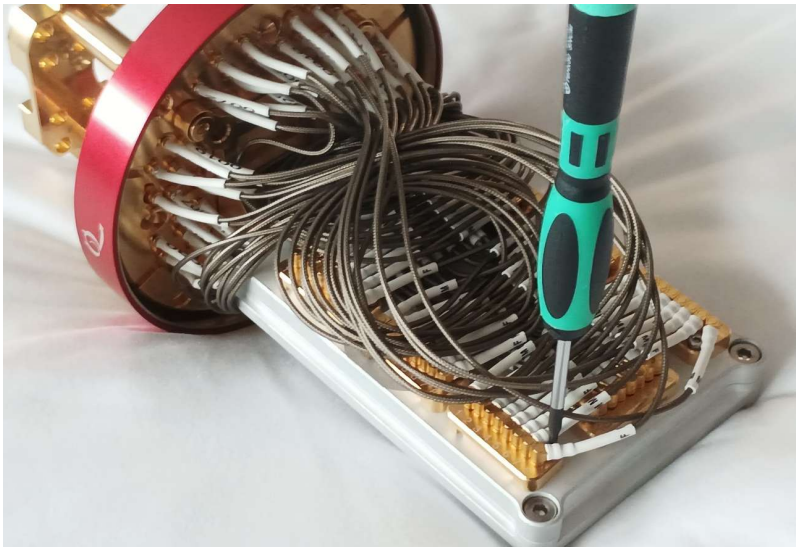
5.1 Standard configuration

The QCage.64 with magnetic shielding comes assembled. The following steps show the workflow for disassembling, inserting the chip and assembling again.

- Unscrew the red bottom finger screw. Remove the mu-metal can and make sure the spring seal engages (slight force can be needed for sliding).

- Unscrew the four 45° slanted screws. Separate the top from the bottom to access the QCage.64.

- Remove the eight-way coaxial cables by unscrewing the face-plates labeled A, B, C, D, E, F, G, H.

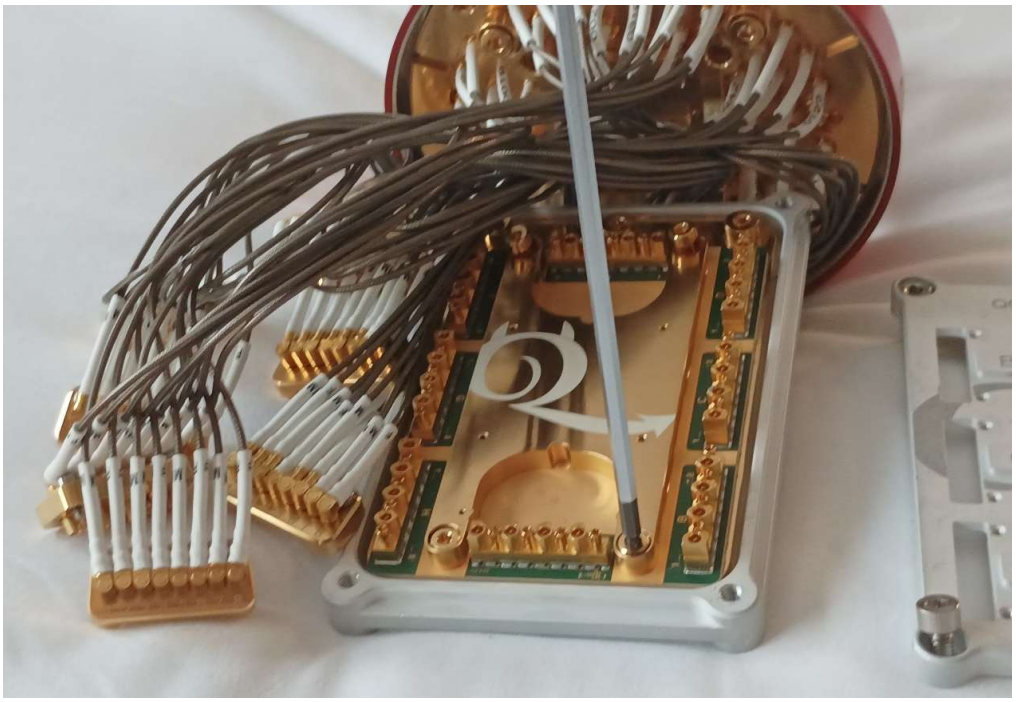


- Use a screwdriver or similar tool to carefully lift the connector face-plates and thereby disengage the connectors.

- Continue until they are all removed.

- Next remove the aluminum top cover with the QDevil logo by unscrewing the bolts at each corner of the assembly.

- Remove the four screws that hold the sample board (QCAGE-64-PCB) and lift it out of the QCage.64.



- The sample board (QCAGE-64-PCB) is now ready for chip-loading.

Figure 19 *Left) The EMC tight cavity. Middle) The aluminum top cover. Right) The sample board.*

6. Loading the sample chip

The sample chip is first loaded into the cavity of the chip holding frame and then clamped down by bolting the sample board on top. After that, connections are established by wire bonding while thermalization and grounding are ensured by direct contact between the chip and sample board.

6.1 Placing sample chip in cavity

- Place the chip holding frame (QCAGE-64-FRM) onto the support fixture (QCAGE-64-WBF).

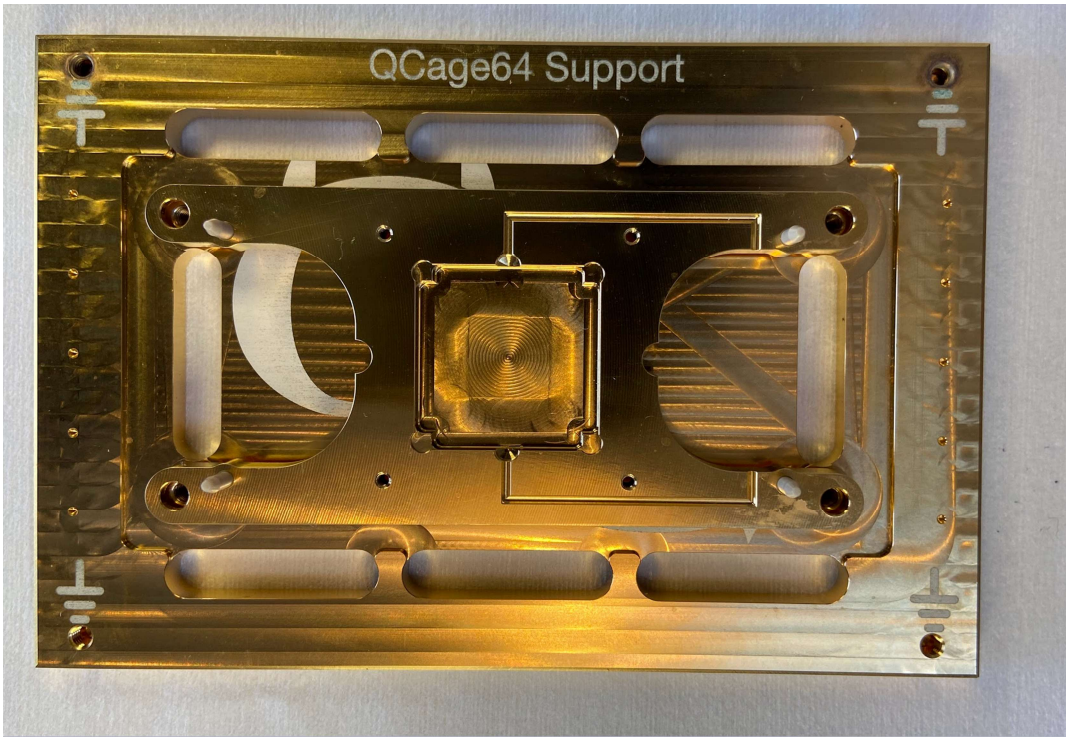


Figure 20 *Chip holding frame (QCAGE-64-FRM) on top of the support fixture (QCAGE-64-WBF).*

- Carefully place the chip in the cavity using tweezer tips

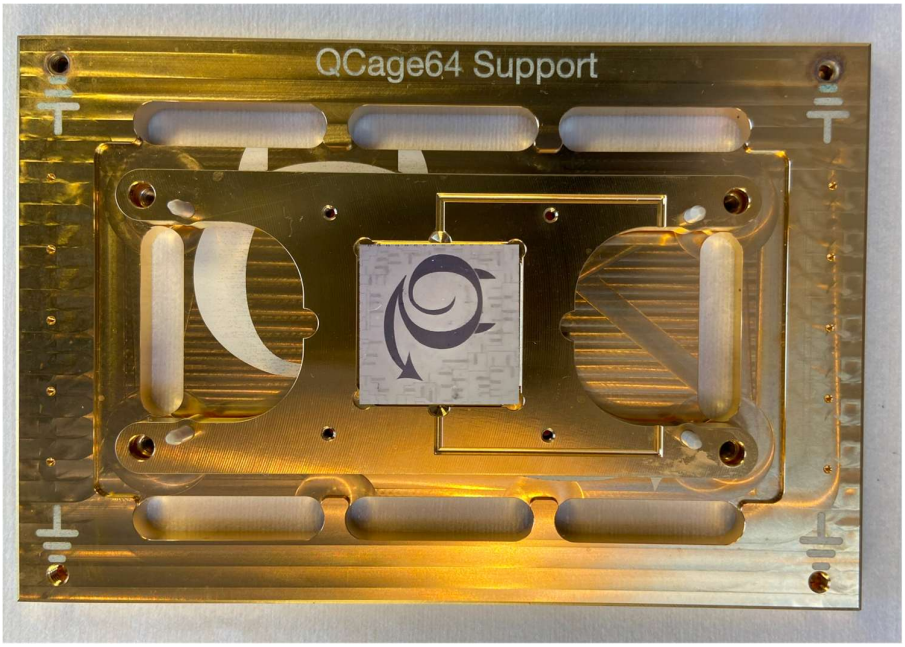


Figure 21 *Chip holding frame (QCAGE-64-FRM) placed onto support fixture (QCAGE-64-WBF) with chip placed in cavity.*

As described before, the chip cavity is designed to hold a chip size of 22 × 22 mm^2 (± 0.5 mm) supported by the four corner pedestals. Regarding chip thickness, the pedestal height is designed to support 525 μm ± 50 μm. Adaptors are available to support different chip sizes and thicknesses.

6.2 Clamping sample board down

- Place the sample board (QCAGE-64-PCB) on top with the four guide pins aligned.
- Tighten down the sample board by the four M1.6 × 4 mm screws to a maximum hand torque of 0.12 Nm – use of washers is optional.
- After clamping down the sample board, the whole chip package may be secured onto the support fixture by the four M3 × 10 mm screws.

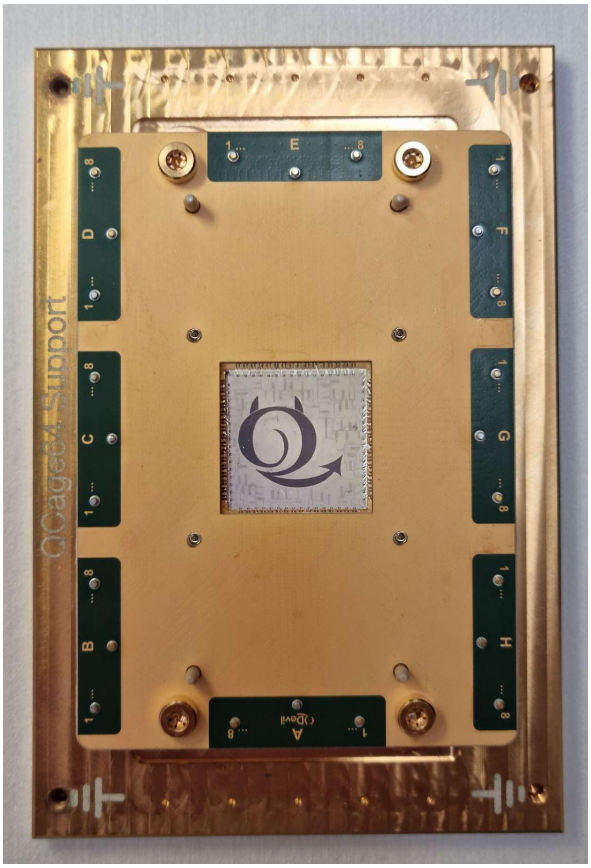


Figure 22 *Sample board (QCAGE-64-PCB) clamped down on top of chip holding frame (QCAGE-64-FRM) with chip loaded in the cavity.*

6.3 Wire bonding guidelines

Depending on the wire bonder model, holes may need to be drilled in the support fixture (QCAGE-64-WBF) to fit the mounting holes on the wire bonder. Alternatively, clamping clips may be used to keep the support fixture in place in some wire bonders. In all cases, ensure the support fixture is securely mounted in the wire bonder.

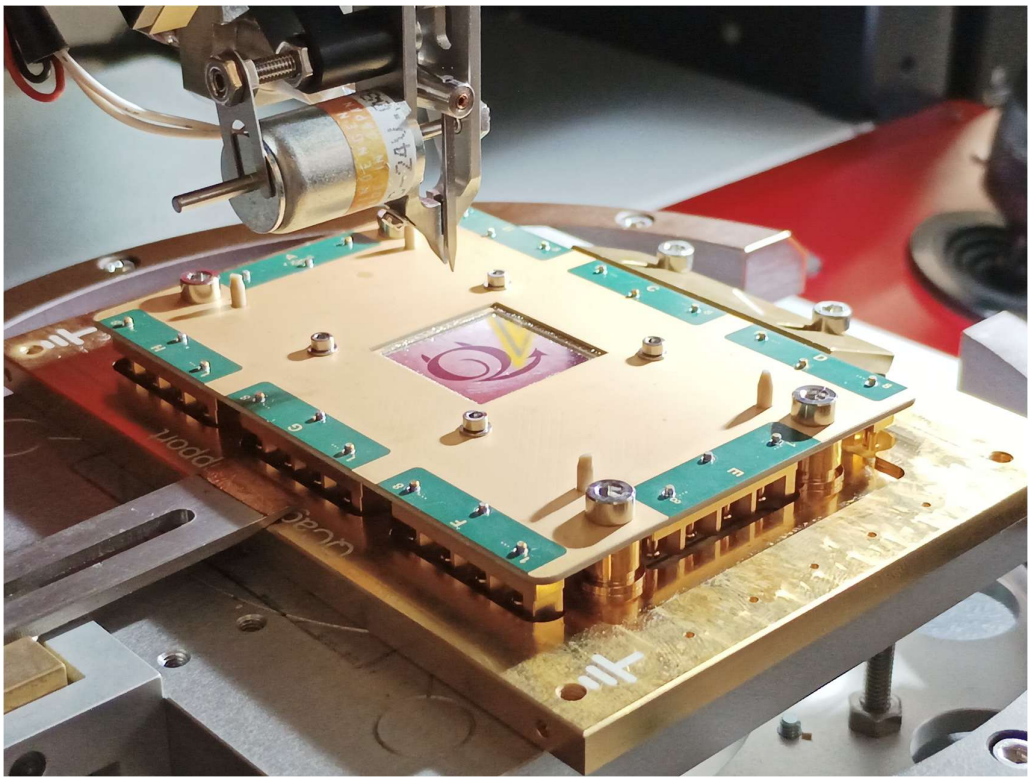


Figure 23 *Utilizing the support fixture (QCAGE-64-WBF) with the chip holding frame (QCAGE-64-FRM) and the sample board (QCAGE-64-PCB) containing a chip. Mounted in an aluminum wedge wire bonder.*

The chip holding frame and support fixture has been designed and verified to provide a solid anchoring of the ultrasonic agitation from the wire bonding wedge. As a result, we have found that the optimal bonding parameters are achieved with only slightly higher ultrasonic power and bond force than what works for conventional chip carriers. The exact optimal settings will depend on the particular wire bonder model and wedge head that is used.

7. Transferring into the main assembly

After establishing the connections by wire bonding, the chip holding package is ready to be transferred to the main QCage.64 assembly. This can be done either on the lab bench (as shown below) or with the assembly already mounted onto the fridge.

- Place the sample board (QCAGE-64-PCB) into the QCage.64 by flipping the sample board with the chip.

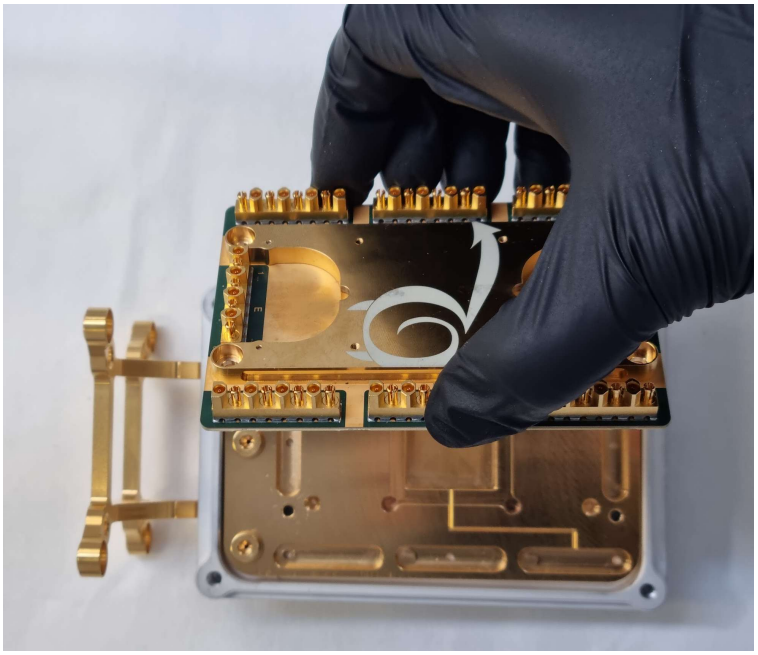


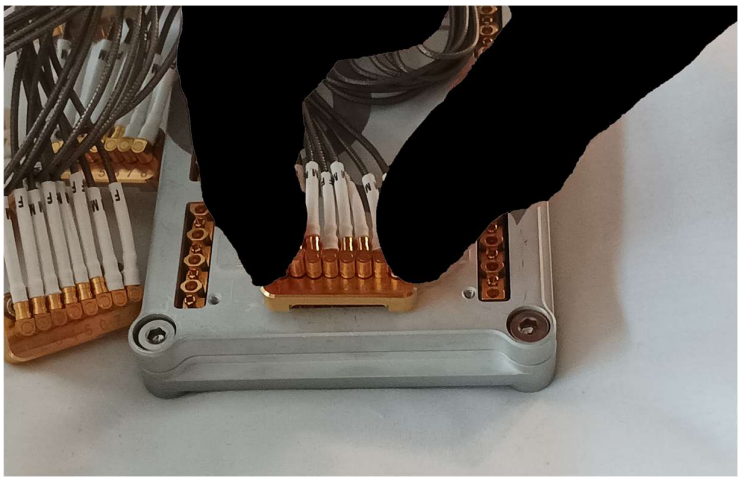
Figure 24 *Placing the sample board* (QCAGE-64-PCB) *into the QCage.64* (QCAGE-64-STD).

- Tighten the four M3 screws (gold plated) to a torque of 0.6 – 0.8 Nm.

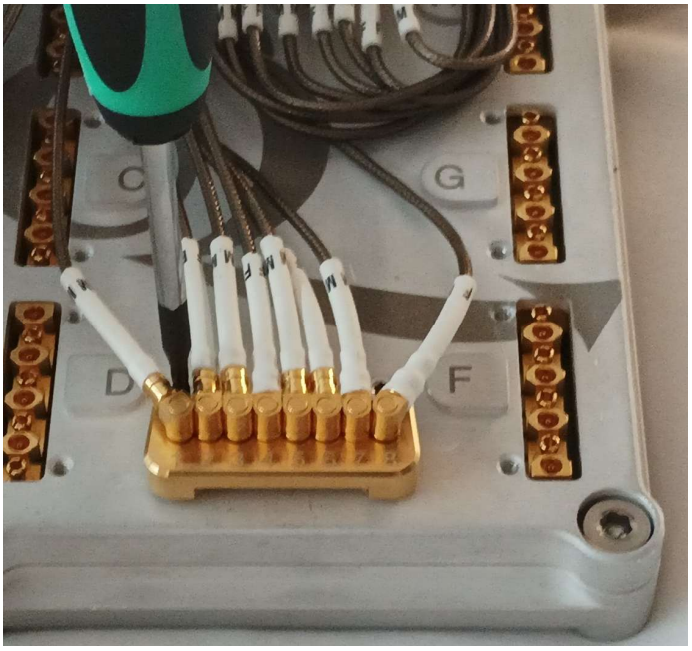
- Mount the aluminum top cover with the four screws – tighten to 0.2 Nm.

7.1 Connecting the multi-way coaxial cables

- Mount the connector flanges by pressing the connectors together with two fingers. Use a firm grip to press the connector backshells together from the sides in order to align the eight connectors in parallel. Pair the letter on each plate with letters on the Aluminum top cover. Be careful not to break the connector engagement springs.



- Tighten the screws with light torque.



7.2 Shielding the QCage.64 using QCage magnetic shielding

- Slide the QCage.64 into the magnetic shielding. Be very careful not to damage the cables while sliding into the aluminum can. Tighten the four 45° slanted screws to a torque of 0.2 – 0.4 Nm.

- Slide on the mu-metal can and ensure that the spring seal engages. You may need to apply slight force for the last few millimeters of engagement. Afterward, secure the red finger screw.

8. Utilizing the auxiliary magnet coil

The QCage.64 sample holder system comes with an auxiliary magnet coil mounted inside the aluminum EMC shielding:

***Figure 31** Left) Superconducting magnet coil mounted. Right) DC current supplied via filtered feed-throughs inside the superconducting shield*

The magnet coil has 500 windings of superconducting wire corresponding to a field strength of approximately 0.10 Gauss/mA perpendicular to the sample plane. It is placed inside the aluminum superconducting shield, which will repel the external magnetic fields by the Meissner effect. The resulting magnetic field strength will remain under the critical field of the aluminum shield for supply currents ranging to over 100 mA, ensuring full integrity of the superconducting shield.

The homogeneity of the magnetic field is affected by the Meissner effect of the aluminum shield, which repels the field lines from the magnet coil. Below is shown a magnetic field simulation from COMSOL Multiphysics, showing a homogeneity of about ±30% for the perpendicular field across the

22.0 × 22.0 mm^2 active chip region. Furthermore, it suggests that the nominal field strength is reduced to about 0.04 Gauss/mA by the deflection of the field lines by the Meissner effect.

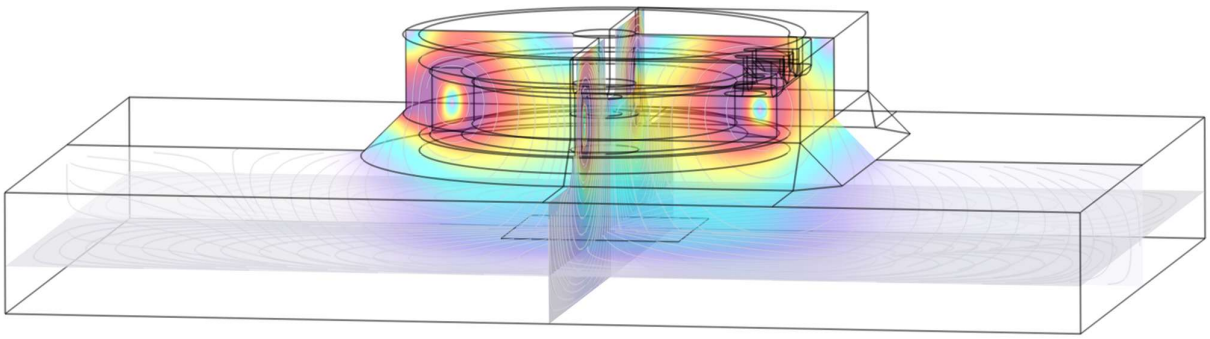


Figure 32 *COMSOL Multiphysics simulation of the magnetic field inside the superconducting shield.*

8.1 Magnet coil specifications

Field strength	0.040 Gauss/mA
Homogeneity	±30%
Current limit	100 mA

It should be noted that the supply current may be further limited by heating in any normal metal wiring that may be used outside the QCage.64 package. We recommend that heating effects are carefully monitored when passing currents in excess of 10 – 20 mA.

9. Mounting onto cryogenic interfaces

9.1 Standard configuration - Mounting QCage.64 with magnetic shielding

All the dimensions seen below are in mm unless stated otherwise. The dimensions of the QCage.64 with magnetic shielding are H:228.7 mm x D:113.4 mm as seen below.

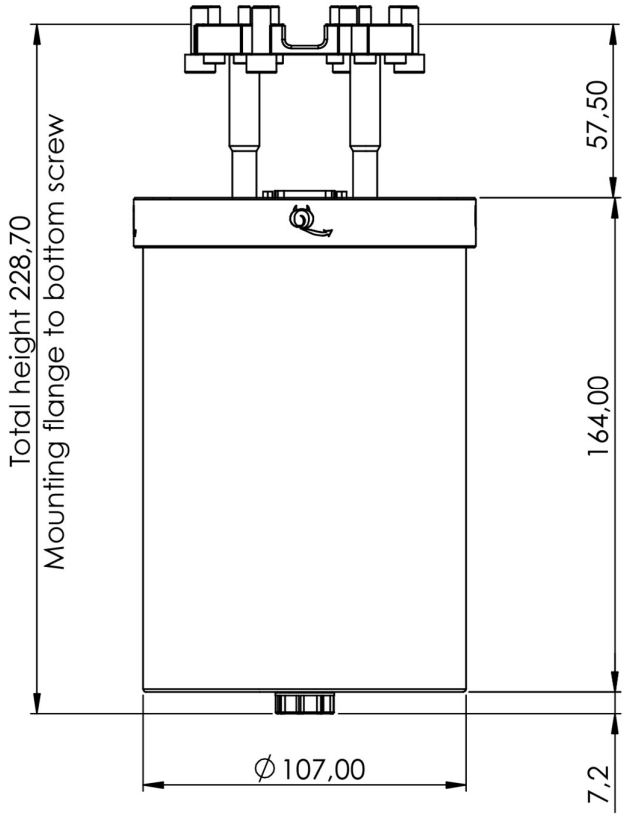


Figure 33 *Side view of QCage.64 standard configuration CAD drawing.*

All dimensions are given in mm.

The top flange plate is prepared with holes for mounting onto the most common mixing chamber plates. These are 8 x M3 holes and 16 x M4 holes intended for mounting onto the common 20 x 20 mm^2 square pattern of either M3 or M4 holes. As an alternative to the square hole pattern, the Ø75 mm outer circle of

8 x M6 holes provides for mounting directly to e.g. the central KF40 port on BlueFors LD refrigerators. The spacing and placement of M3, M4 and M6 holes are shown in the figure below.

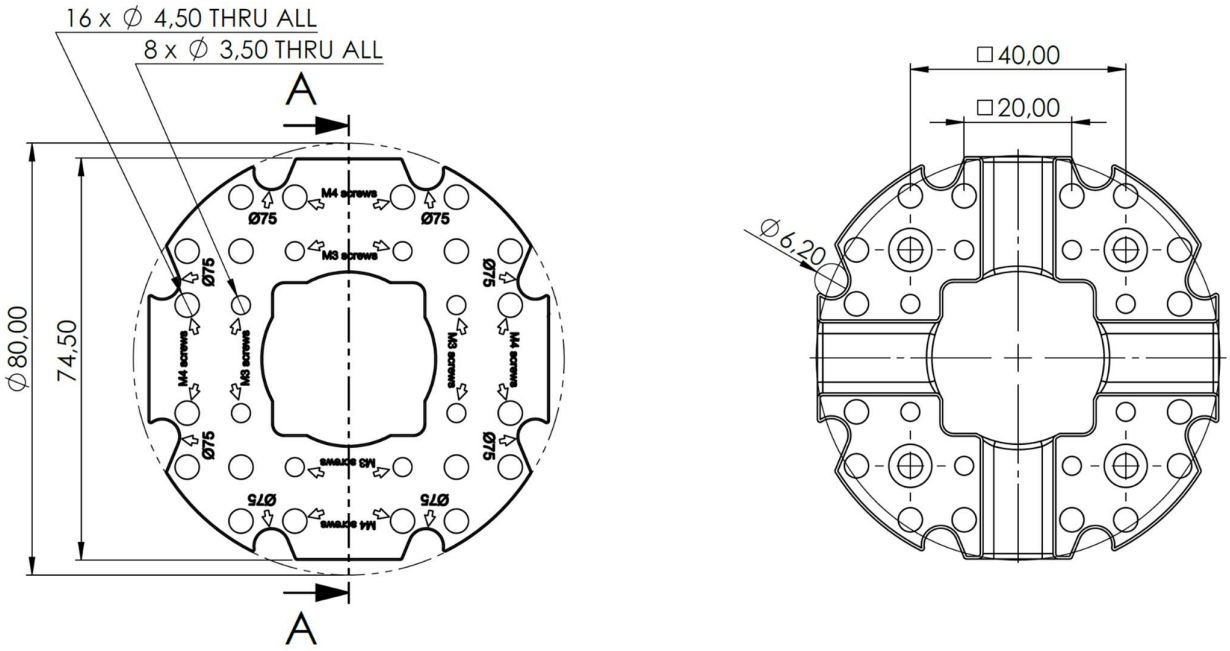


Figure 34 *CAD drawing of the top flange of the QCage.64 standard configuration (incl. magnetic shielding). All dimensions are given in mm.*

Please note that the black plastic handle should be **removed before cool-down**.

9.2 Standalone configuration - Mounting QCage.64 without magnetic shielding

All the dimensions seen below are in mm unless stated otherwise.

The dimensions of the QCage.64 without magnetic shielding are H: 137 mm x L: 78 mm x W: 62.35 mm as seen in the picture below.

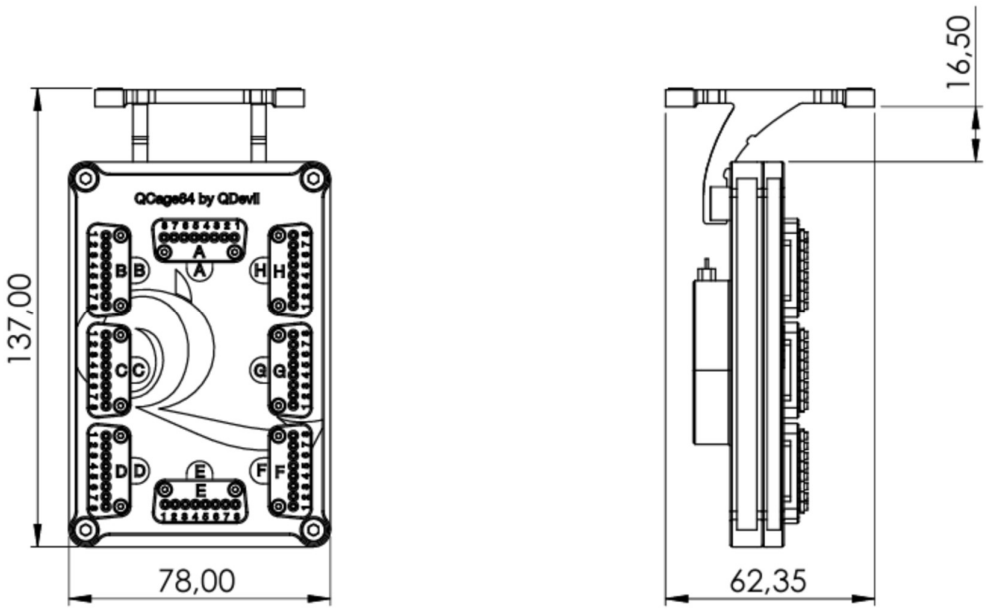


Figure 35 *CAD drawing of the standalone configuration. All measures are given in mm. Left) Front view. Right) Side view.*

For custom installations, there should be a corresponding clearance space that also allows for routing of the 64 coaxial cables coming from the connector ports. The top bracket has four mounting holes allowing QCage.64 to be mounted onto a flat surface with M4 screws. The placing and spacing of the holes are seen in the picture below.

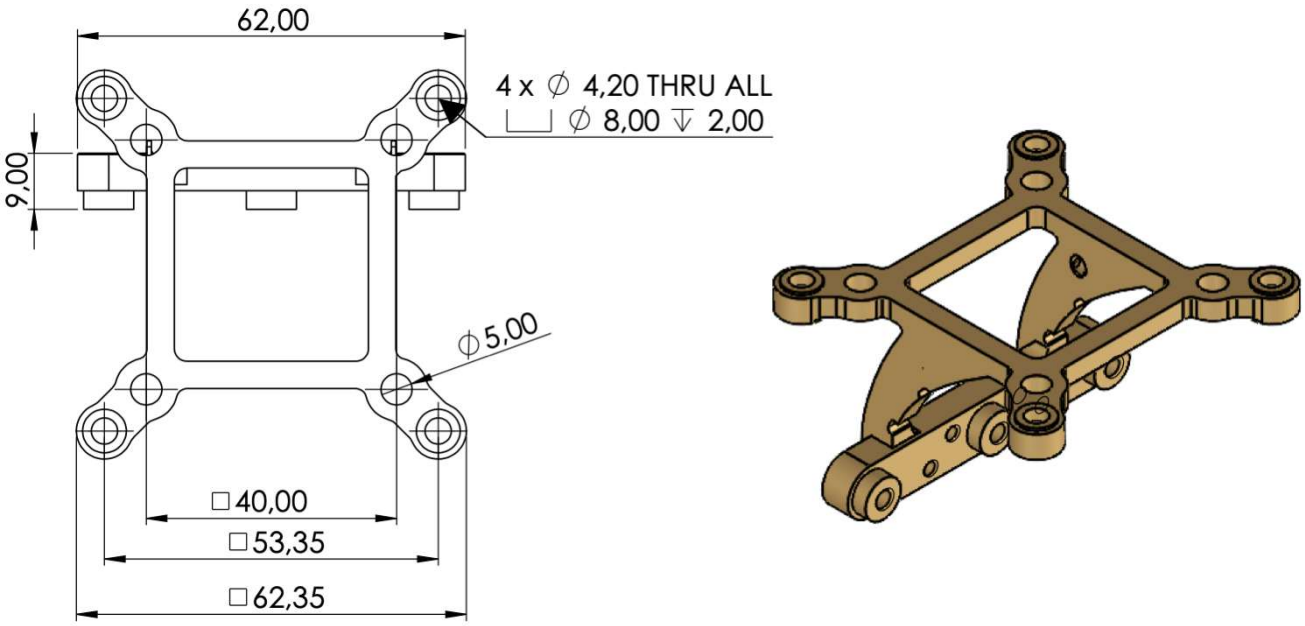


Figure 36 *Left) Schematic of the QCage holder. Dimensions in mm and identical in horizontal and vertical direction. Right) Side view of the QCage holder.*

10. Troubleshooting

If you have any problem getting our Products to work and you cannot find the answer in this manual, or if anything is broken, please do not hesitate to contact:

QM TechnologiesApS

Lautrupvang 2,

2750 Ballerup

Denmark

https://www.quantum-machines.co/

e-mail: support@quantum-machines.co

Phone: +45 3699 2145

We will do our best to Help You Succeed!