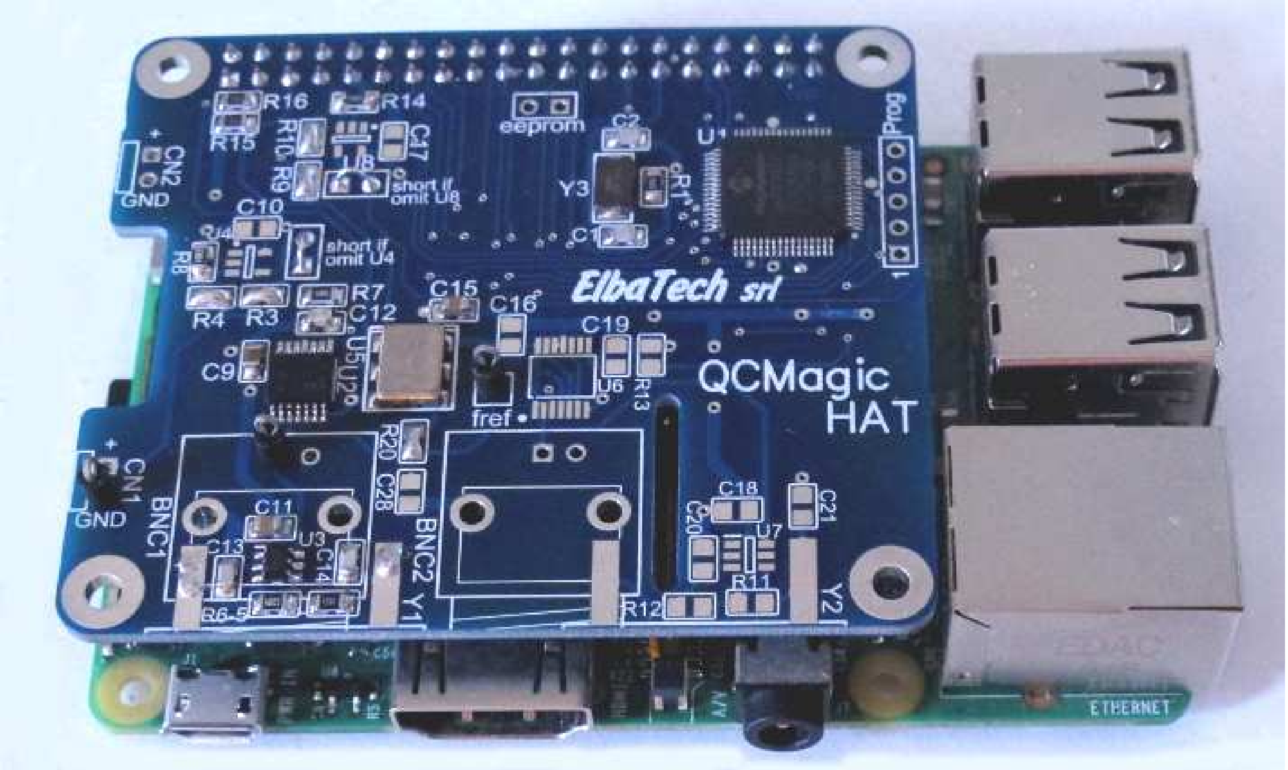
QCMagicHAT

QCMagicHat is a tiny RaspberryPi add-on card featuring a two channel Quartz Crystal Microbalance.



Two independent oscillators and the related measuring electronics live in just 55x65mm. Updated firmware and high-level software make this board plug-and-go. Just connect the board onto your RaspberryPi equipped with our pre-installed OS and software image, switch on the unit and start getting experimental data.
The assembly can also be utilized remotely over the Ethernet, running the GUI software on a client computer.

Features

- Dual channel measurements
- 1-to-10 MHz base crystal frequency
- Fast data acquisition (T_{gate} down to 0.1s)
- High Resolution (better than 0.1Hz)
- Use off-the-shelf AT-cut Quartz Crystals
- Selectable Quartz Holder (HC6/U or HC49U)
- OEM (board only) or in a nice plastic box

QCMagicHat can be equipped with our optional plexiglass Liquid Cell, featuring both static and flow-through operation. This little add-on enables QCM measurements in liquid media (works with HC6/U crystals).

Theoretical Foundation

The QCMagicHat belongs to the Quartz Crystal Microbalance-based (QCM) instruments.

QCM consists of a thin quartz disk with electrodes plated on it: it is a shear mode device in which the acoustic wave propagates in a direction perpendicular to the crystal surface.

The minimum impedance occurs when the thickness of the crystal is a multiple of a half wavelength of the acoustic wave; the resonant oscillation is achieved by including the crystal into an oscillation circuit where the electric and mechanical oscillations are near to the fundamental frequency of the crystal.

The fundamental frequency depends on the thickness of wafer, its chemical structure, its shape and its mass; oscillation frequency is influenced by thickness, density and shear modulus of the quartz and physical properties of the adjacent medium like density and viscosity of air or liquid.

As shown by Sauerbrey in 1959, changes in resonant frequency are simply related to the mass accumulated on the crystal by the following equation:

$$\Delta f = -\, f_0^2 \Big/ A\sqrt{(\mu_q \rho_q)}\,\Delta m$$

where:

Δm is the mass variation adsorbed on the surface [g], Δf is the frequency change [Hz], A is the electrode crystal area [cm^2], ρ_q is the density of the quartz [2.648 g/cm^3], μ_q *is* the shear modulus of the quartz [for an AT-cut crystal is equal to 2.947×10^{11} $g \cdot cm^{-1} \cdot s^{-2}$], f_0 is the basic oscillator frequency of the quartz [Hz].

The equation is derived by treating the deposited mass as though it was an extension of the thickness of the underlying quartz.

Because the film is treated as an extension of thickness, Sauerbrey’s equation only applies to systems in which the following three conditions are met:

- the deposited mass is rigid
- the deposited mass is evenly distributed
- the frequency change $\Delta f / f < 0.02$.

The Sauerbrey equation was developed for oscillation in air and only applies to rigid masses attached to the crystal. It has been shown that quartz crystal microbalance measurements can be performed also in liquid, in which case a viscosity related decrease in the resonant frequency will be observed.

When a quartz crystal oscillates in contact with a liquid, a shear motion on the surface generates motion in the liquid near the interface. The oscillating surface generates plane-laminar flow in the liquid, which causes a decrease in the frequency, depending on the liquid density and viscosity:

$$\Delta f = - f_0^{3/2} \left(\rho\eta / \pi\mu_q \rho_q \right)^{1/2}$$

where ρ is the density and η is the viscosity of the liquid (Kanazawa and Gordon 1985).

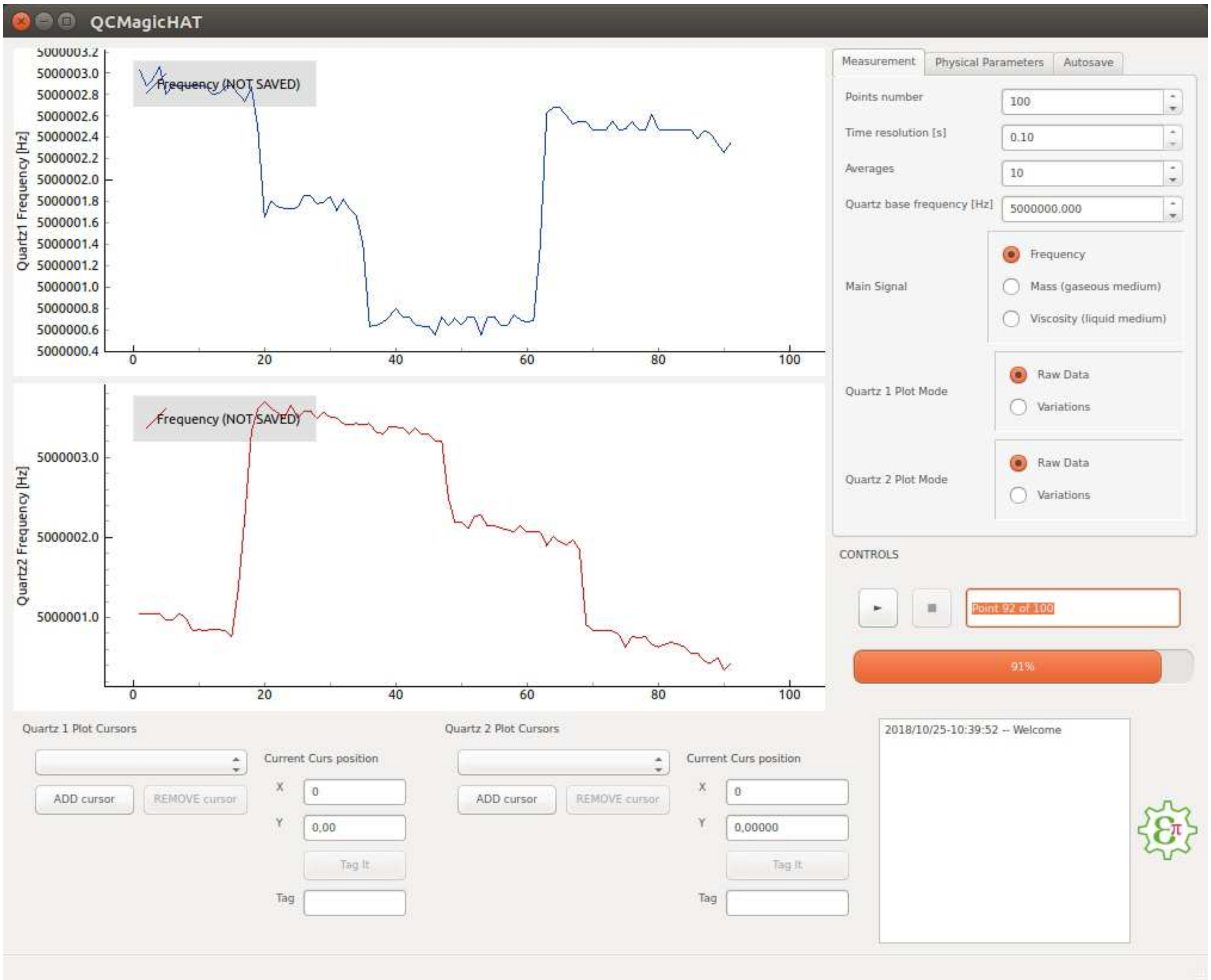
If the liquid is flowing, major problems are: viscous damping of oscillations, medium temperature fluctuations and non-specific adsorption.
In this case an empirical equation applies:

$$\Delta f = - (a\rho^{1/2} + b\eta^{1/2} - c)$$

where:
a,b and c are constants; ρ is the density and η is the viscosity of the solution.

GUI software

Our GUI is organized in tab windows, allowing the user to drive acquisition, manage the acquired data according to the previous formulas, related to the experiment type (in air, in liquid – static or dynamic) and finally save the acquired data.
The main tab is shown below:



Points number: 100

Time resolution [s]: 0.10

Averages: 10

Quartz base frequency [Hz]: 5000000.000

Main Signal: ● Frequency ○ Mass (gaseous medium) ○ Viscosity (liquid medium)

Quartz 1 Plot Mode: ● Raw Data ○ Variations

Quartz 2 Plot Mode: ● Raw Data ○ Variations

Point 92 of 100

91%

Quartz 1 Plot Cursors – X: 0, Y: 0,00, Tag:

Quartz 2 Plot Cursors – X: 0, Y: 0,00000, Tag:

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The GUI has two stripcharts to plot the frequency vs. time of the quartz at the “Quartz 1” and “Quartz 2” connectors (the upper plot refers to Quartz 1 and the lower to Quartz 2).

The user can set:

- the acquisition’s number of points
- the time resolution (at which rate the data will be acquired and plotted),
- a number of points to compute the average (useful to get an immediate feeling about data trend)
- the base frequency of the quartzes in use

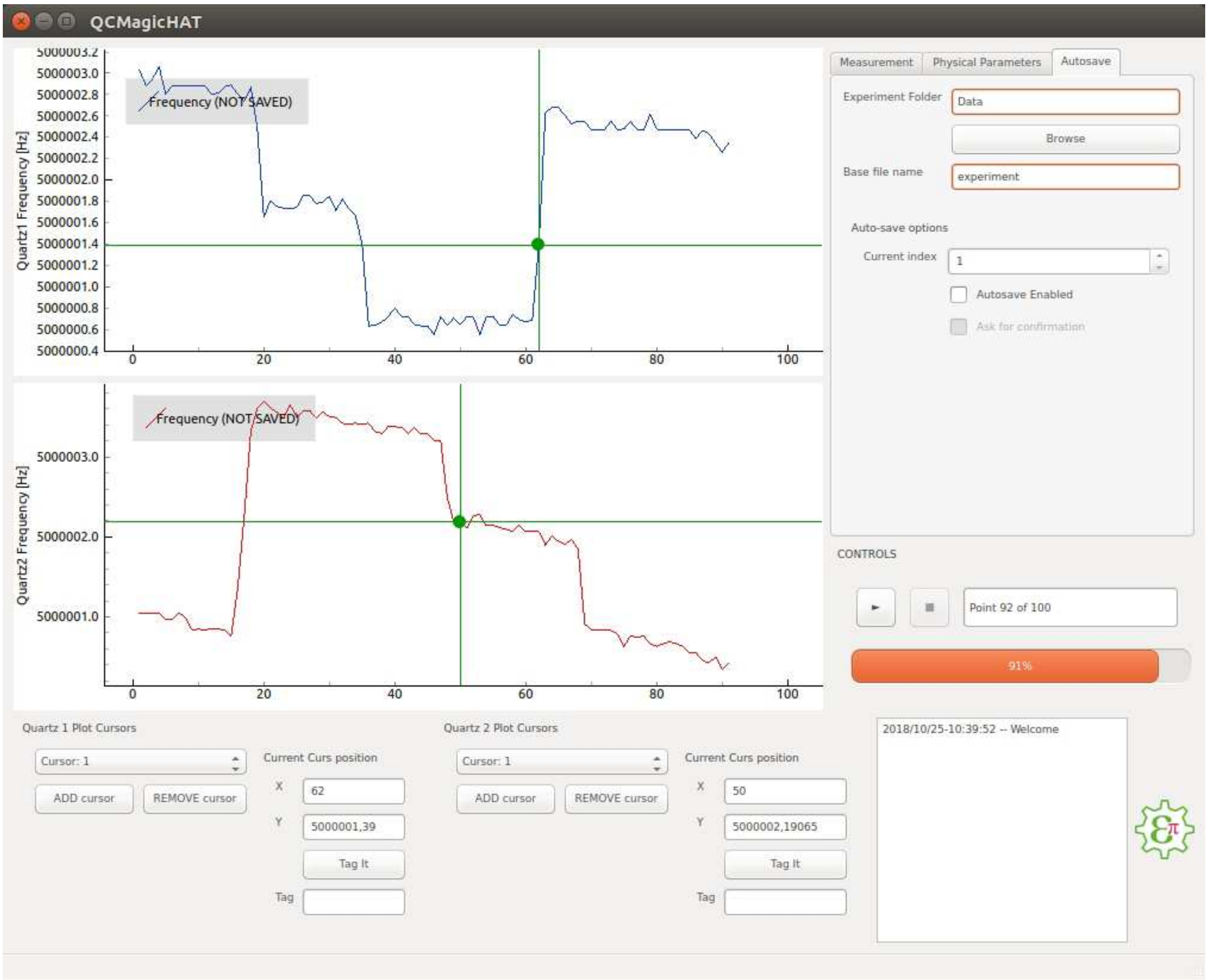
The user can even choose what to plot on the y-axis: frequency, mass or density. The GUI can plot raw data, i.e. frequency vs. time, or variations (with respect to first acquired data), for both channels.

When all these parameters are set, the acquisitions can start by clicking the arrow button.

The acquisition can be stopped at anytime clicking on the square button.

The lower right corner contains an info box with messages related to the system’s status.

When the acquisition is stopped or ended, the user can analyze the acquired data adding cursors to each plot, finding the cursors coordinates and tagging these acquisition points on the plot.



Experiment Folder: Data

Base file name: experiment

Current index: 1

☐ Autosave Enabled

☐ Ask for confirmation

Point 92 of 100

91%

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Quartz 1 Plot Cursors: Cursor: 1

X: 62

Y: 5000001,39

Tag:

Quartz 2 Plot Cursors: Cursor: 1

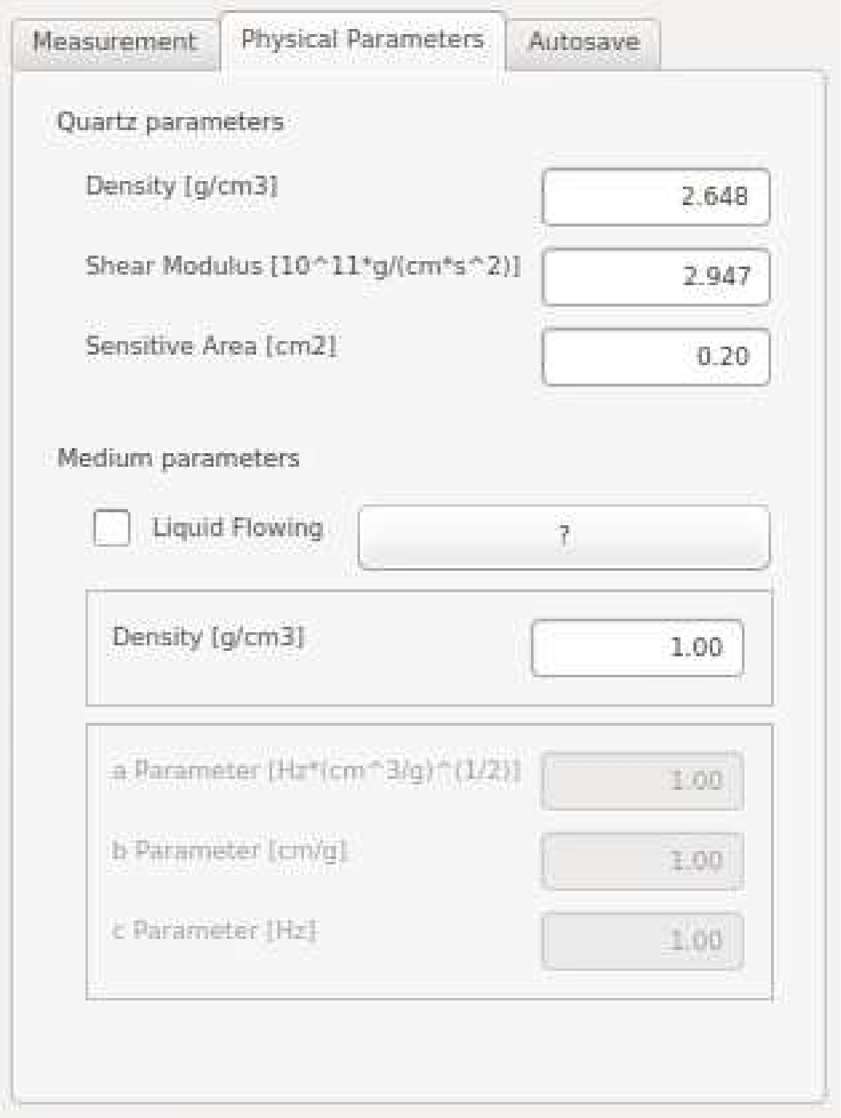
X: 50

Y: 5000002,19065

Tag:

When the acquisitions is stopped or ended, the user can save in a .txt file the acquired data, before starting a new acquisition.

The “Physical Parameters” tab window is related to the relationship between frequency and the corresponding mass/viscosity variations in time, accordingly to the formulas shown in the “Theoretical foundations” section:



Quartz parameters

Density [g/cm3]: 2.648
Shear Modulus [10^11*g/(cm*s^2)]: 2.947
Sensitive Area [cm2]: 0.20

Medium parameters

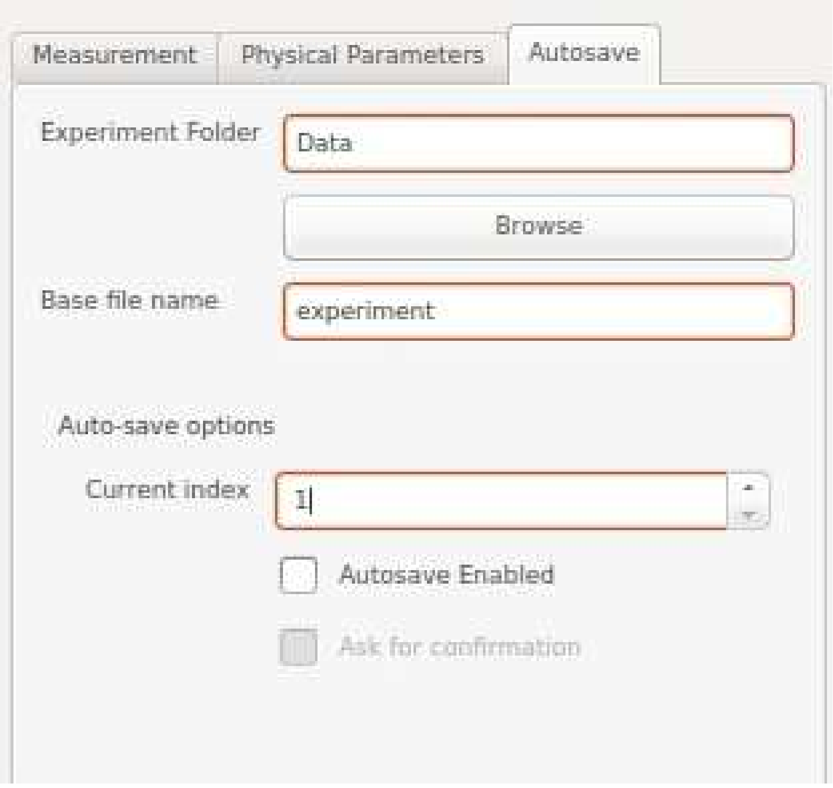
☐ Liquid Flowing

Density [g/cm3]: 1.00

a Parameter (Hz*(cm^3/g)^(1/2)): 1.00
b Parameter [cm/g]: 1.00
c Parameter [Hz]: 1.00

By default, each parameter has values related to an AT-cut quartz crystal. If the instrument is used with liquids, the user must input the medium’s density. If the liquid medium flows, the user must input also the a,b, and c parameters, as described above.

The tab “Autosave” is related to the autosaving of acquired data:



Experiment Folder: Data

Base file name: experiment

Auto-save options

Current index: 1

☐ Autosave Enabled

☐ Ask for confirmation

The user, in addition to manually save each single acquisition plot, can automatically save all the acquisition sessions simply indicating the working folder, a base file name and the initial count number. The program will take care of incrementing and adding a numerical suffix when saving data.

For example if the input is as follows:

- Experiments folder: /data
- Experiments name: myexperiment
- Current index: 1
- “Autosave Enabled” checked

Then the software will save each acquisition as /data/myexperiment1.txt, /data/myexperiment2.txt, /data/myexperiment3.txt, etc.

Flow/static QCMagicHat chamber

QCMagicHat can be equipped with our plexiglass Liquid Cell, featuring both static and flow-through operations, designed for HC6/U crystals, namely for quartzes featuring blank diameter of about 0.550” and electrode diameter of about 0.295”.

It is composed by two parts:

The base part has the quartz fitting place and two (in-out) flow connectors. The top part shows a conical hole for static liquid measurements.

If it is used as a flow-through chamber, it is a microvolume chamber, confined to the sealing. Our O-ring diameter is 6mm and thickness is 2mm, hence the total cell volume is 110 μl.

If it is used as a static chamber, the volume is that of the conical hole with one base diameter of 6mm (O-ring diameter) and the second of 21 mm. Being the height of 23mm, the maximum volume is 35 ml.

The O-ring material is silicone in order to avoid chemical interferences with the most typical liquid media.

The connectors are in polypropylene showing a very good chemical inertness of the material.

To use the chamber, put the crystal in its proper place, install the second part of the chamber and close gently with the knobs in order to ensure the proper fitting.