ACTIVE HYDROGEN MASER

VCH-1003M

Operations Manual

411141.032 UG

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1 Introduction

The VREMYA-CH Active Hydrogen Maser VCH-1003M is intended to be used as a source of high stable low noise sine signals at standard frequencies and one pulse per second timing signals. It can operate both as standalone instrument and as a reference of time and frequency measurement systems. Remote control and parameters monitoring through RS-232 interface is provided.

The main maser applications:

– Radioastronomy;

– Radionavigation;

– Time keeping;

– Scientific research.

The unique automatic cavity tuning techniques of cavity frequency switching method provides unsurpassed long-term stability to be reached, typically less than 1×10^{-15} for a day. Properly set cavity tuning system parameters also doesn't degrade short term stability and eliminate frequency shift because of spin-exchange.

This method main advantage is that the maser requires no other stable frequency reference for its cavity to be tuned.

Figure 1 illustrates the maser VCH-1003M outward appearance.

Figure 1 Active Hydrogen Maser VCH-1003M, VCH-1003M Option L and VCH-1003M Option LT

2 Specifications

2.1 Environmental conditions requirements:

– Normal air temperature range is (20±5)ºC;

– Operating temperature range is 10ºC to 35ºC;

– barometric pressure range is from 84 kPa up to 106 kPa (from 630 up to 795 mm Hg);

– Humidity range is 30% to 80% at 25ºC.

2.2 Power requirements:

– mains voltage range is 84V to 264V (47-60Hz);

– DC source or battery voltage range is 22V to 30V.

The maser has one AC input and two separately fused DC inputs on its back. The power required is 150VA max on AC (with automatic crossover to DC) and 100 watts max on 27V DC.

2.3 Output frequencies.

There are two 5 MHz, two 10 MHz, two 100 MHz sine output signals with (1±0.2)V RMS at 50 Ohm load and two 1PPS timing output signals of positive polarity with the following parameters:

– amplitude ≥ 2.5V at 50 Ohm load;

– pulse length is 10μs to 20μs;

– rise time < 3ns;

Synchronization of 1PPS signal is available to a similar signal applied to the sync input "⊕ 1 PPS". The sync error doesn't exceed ±50ns. Sync procedure is described in User Guide 411141.032 UG from the delivery set.

All sine signals have type N connectors and are located on the front panel of the maser. Both 1PPS signal outputs and sync input have type BNC connectors and also belong to the maser front panel.

2.4 Stability, Allan variance is shown in Table 1:

Table 1 Active Hydrogen Maser VCH-1003M stability, time domain

Time domain	Standard	Option L		Option LT
	3 Hz measuring bandwidth	0.5 Hz measuring bandwidth	3 Hz measuring bandwidth	0.5 Hz measuring bandwidth
1s	$\leq 1.5\times10^{-13}$	$\leq 6\times10^{-14}$	$\leq 8\times10^{-14}$	$\leq 8\times10^{-14}$
10s	$\leq 2.5\times10^{-14}$	$\leq 1.3\times10^{-14}$	$\leq 1.4\times10^{-14}$	$\leq 1.4\times10^{-14}$
100s	$\leq 6.0\times10^{-15}$	$\leq 3.6\times10^{-15}$	$\leq 4.0\times10^{-15}$	$\leq 4.0\times10^{-15}$
1000s	$\leq 2.0\times10^{-15}$	$\leq 1.5\times10^{-15}$	$\leq 1.5\times10^{-15}$	$\leq 1.5\times10^{-15}$
1h	$\leq 1.5\times10^{-15}$	$\leq 1.5\times10^{-15}$	$\leq 1.5\times10^{-15}$	$\leq 1.0\times10^{-15}$
1d	$\leq 5.0\times10^{-16}$	$\leq 5.0\times10^{-16}$	$\leq 5.0\times10^{-16}$	$\leq 4.0\times10^{-16}$

Notice: Environmental temperature variation is ±0.1ºC with changing rate less than 0.3ºC/hour. ADEV at 1 day is specified for measurements with removed linear frequency drift.

Long term:$<3.0\times10^{-16}$ per day. Achieved after 1 year of unperturbed, continuous operation.

2.4 Frequency accuracy: $\pm 3\times10^{-13}$.

2.5 Temperature sensitivity: $< 1.5\times10^{-15}$/ºC.

2.6 Magnetic field sensitivity: $\leq 5\times10^{-15}$/Gauss.

2.7 Harmonic distortion in 5 MHz output ≤ -30dB (Standard, Option LT), ≤ -40dB (Option L).

2.8 Non-harmonic distortion ≤ -100dB in the range from 10 Hz to 10 kHz.

2.9 Phase noise specification is shown in Table 2:

Table 2 Phase noise, dBc/Hz

	Standard			Option L			Option LT		
Frequency offset, Hz	5 MHz	10 MHz	100 MHz	5 MHz	10 MHz	100 MHz	5 MHz	10 MHz	100 MHz
1	≤-118	≤-112	≤-92	≤-130	≤-121	≤-100	≤-122	≤-116	≤-96
10	≤-135	≤-129	≤-109	≤-141	≤-135	≤-115	≤-135	≤-129	≤-109
100	≤-149	≤-143	≤-122	≤-151	≤-145	≤-125	≤-149	≤-143	≤-122
1 000	≤-156	≤-149	≤-122	≤-156	≤-150	≤-130	≤-156	≤-149	≤-130
10 000	≤-158	≤-150	≤-152	≤-159	≤-153	≤-153	≤-158	≤-152	≤-152
100 000	≤-158	≤-150	≤-152	≤-159	≤-153	≤-153	≤-158	≤-152	≤-152

2.10 The output maser frequency is adjustable in range to within 1×10^{-10} with the resolution 1×10^{16}. Remote frequency control is also available as described below.

2.11 Warm-up time from a cold start is approximately 240 hours (10 days).

2.12 The maser dimensions are 550mm wide by 550mm deep by 1010mm high. The overall weight is 105 kg, in transportation crate 190 kg.

2.13 The maser lifetime: 15 years.

3 Delivery Set

Active Hydrogen Maser VCH-1003M delivery set is shown in Table 4

Table 4 Active Hydrogen Maser VCH-1003M delivery set

Item	Designation	Quantity	Notice
1. Active Hydrogen Maser VCH-1003M	411141.032	1	
2. Power cord	Power cord EU IEC C13	1	
3. Interface cable	685670.026-01	1	RS-232C
4. Interface adapter	Converter USB-RS232	1	
5. Interface cable	Cable USB AM-BM	1	
6. Accessory kit:			
6.1. Socket	2PMT14	2	DC power
6.2. Fuse	2 A	2	250V 2A
6.3. Fuse	3.15 A	2	250V 3.15A
6.4. Fuse	5 A	2	250V 5A
6.5. Fuse	1 A	2	250V 1A
6.6. Fuse	2 A	2	250V 2A
7. Operations manual	411141.032 OM	1	
8. User Guide	411141.032 UG	1	
9. Certificate		1	
10. VCH-1003M software	RU.00211-01 90 01	1	USB flash drive Software and documentation
11. Shipping crate	411915.066	1	

4 Brief description of the Maser and its operation

4.1 Active Hydrogen Maser VCH-1003M

Active Hydrogen Maser VCH-1003M structure is shown in Figure 2.

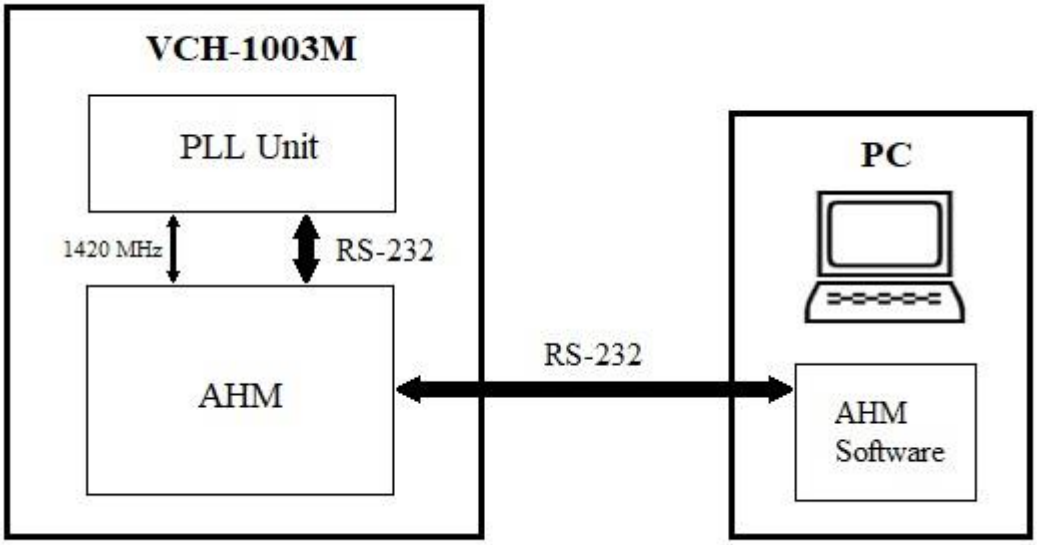


Figure 2 – Structure of the Active Hydrogen Maser VCH-1003M

Designations in Figure 2 are the following:

AHM – Active Hydrogen Maser – Physics Package with surrounding units providing its operation such as a power unit, high voltage ion pumps, multi-level thermal control system, beam intensity stabilizer, source discharge oscillator and processor which enables all mentioned above units to be controlled and monitored via RS-232 connection.

Physics Package produces signal of hydrogen transition frequency 1420 MHz, applied to PLL Unit.

PLL Unit combines two functions. On the one hand it keeps a voltage controlled crystal oscillator (VCO) phase-locked to the maser output. On the other hand it produces signals for cavity tuning. And thus it assures the excellent maser performance.

Local terminal PC contains Active Hydrogen Maser software.

The software installation in detail is described in User Guide 411141.032 UG.

4.2 Physics Package

Figure 3 illustrates Physics Package Layout.

A small metal cylinder filled with intermetal combination of La Ni_5H_x is used as a molecular hydrogen source. When heated it releases the hydrogen flow which goes to the Purifier. This is a thin wall nickel tube of a spiral form. Beam stabilizer transmits the current of about 0.5A through the tube and so regulates the hydrogen flux to the discharge bulb where the source discharge oscillator dissociates them into atoms. Atoms emerge through the multichannel collimator and the magnetic state selector, which directs the beam in right state into the Teflon coated storage bulb.

A microwave cavity causes the atoms to produce the microwave emission. A receiving loop transmits the hydrogen emission power to a low noise receiver. The hydrogen maser output power is about 100 - 200 fW.

Two high voltage ion pumps and the getter provide vacuum inside the whole system.

Magnetic shields reduce the magnetic sensitivity of the maser and multi-level external and internal thermal system decreases temperature sensitivity significantly.

4.3 PLL Unit.

The PLL Unit is intended to keep a VCO 5MHz phase locked to the maser signal. The Multiplier forms from the VCO signal standard outputs 100 MHz and output signal 1500 MHz for the heterodyne receiver.

The PLL Unit circuit is shown in Figure 4.

Low noise receiver transmits the maser signal 1420 MHz to the low frequency 405.7 kHz. This is the operating frequency of the Phase Detector. Another signal comes to the Phase Detector from the Synthesizer which is able to change the output frequency within 1×10^{-10} range with the resolution of 1×10^{-16}. Thus the Phase Detector controls the VCO frequency.

A Frequency divider produces 1PPS timing signals. A Sync input enables output signals to be synchronized to an external 1PPS signal.

Processor provides the possibility of monitoring different PLL Unit parameters and controls the standard output frequencies via RS-232 port. For more detail information see User Guide 411141.032 UG.

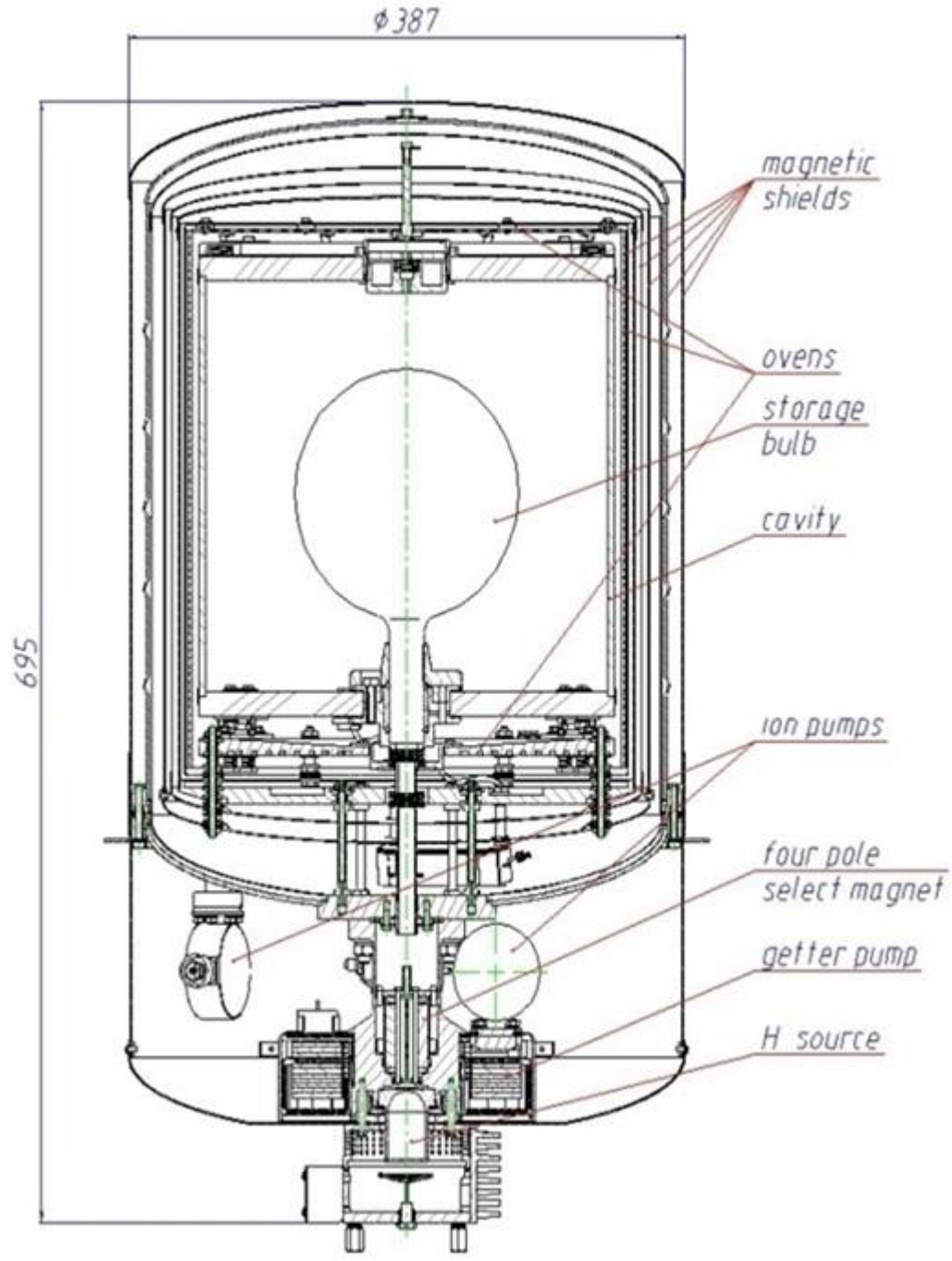


Figure 3 Physics Package Layout

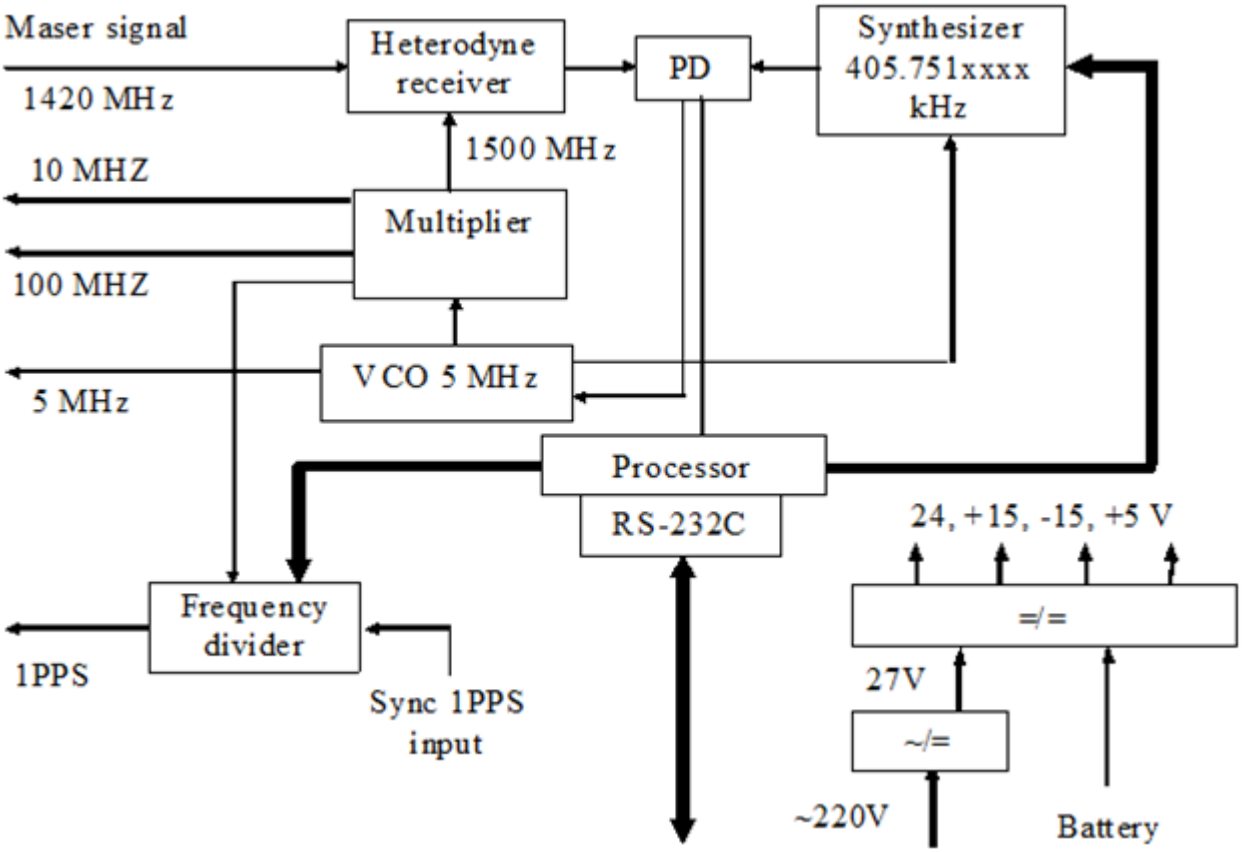


Figure 4 PLL Unit circuit

4.4 Cavity auto-tuning.

This auto-tuning system uses cavity frequency switching method in its operation.

Figure 5 illustrates its circuit.

A Modulator changes data of modulating digital-to-analog converter DAC2 register with modulation frequency and its voltage applied to a modulating varactor switches the cavity frequency.

An Amplitude detector and a low pass filter derive a mistuning signal, which amplitude depends on cavity mistuning, from the maser signal and transmit it to a synchronous detector. This detector changes DAC1 register and its voltage applied to a tuning varactor shifts the cavity frequency to the hydrogen emission line frequency.

Cavity tuning system parameters are adjusted at factory and are not to be changed by a customer (see below). Only tuning DAC readings are important during the operation.

Synthesizer code _____

DAC20 code _____

DAC16 min _____

DAC16 mid _____

DAC16 max _____

Phase shift _____

Duty factor _____

Average _____

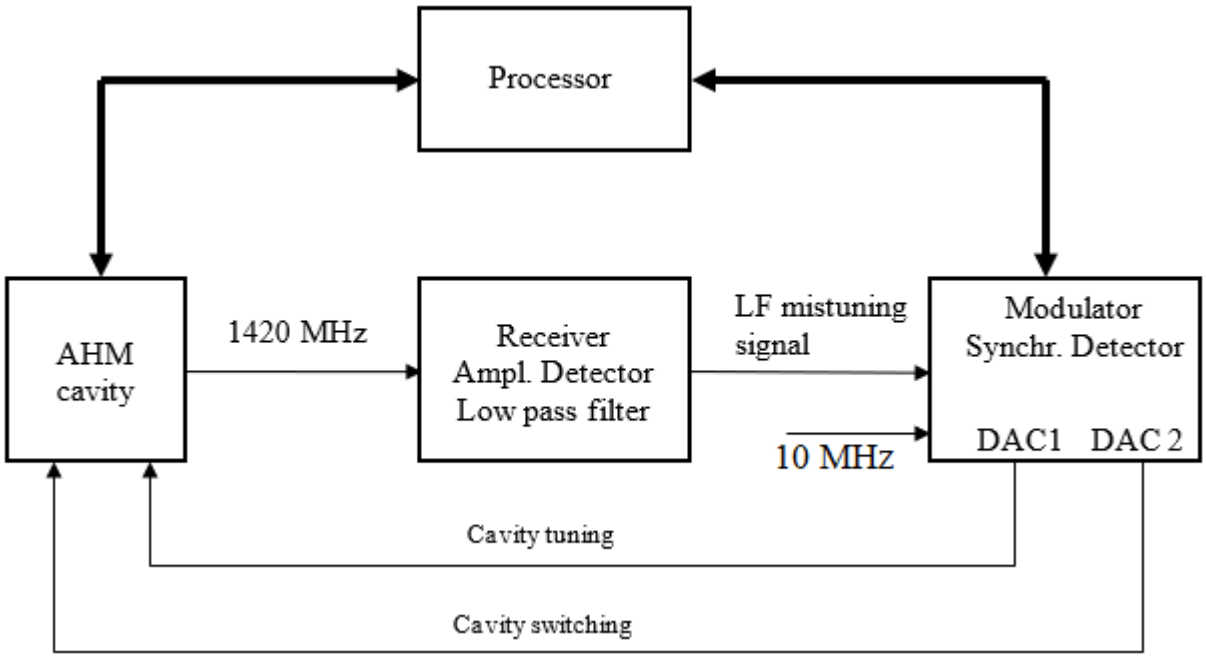


Figure 5 Cavity tuning system

5 Transportation and storage

5.1 The maser should be kept in vertical position during the transportation. It's necessary to avoid heavy shocks and vibration, turning it over, ingress of moisture and dust. Environmental conditions are:

– Air temperature from +5ºC up to +40ºC;

– Humidity up to 90% (non-condensing) at temperature +30ºC;

5.2 Storage conditions are:

– Air temperature from +5ºC up to +40ºC;

– Humidity up to 80% (non-condensing) at temperature +25ºC;

The maser should be switched on monthly to start ion pumps for at least 30 minutes to avoid the vacuum loss inside the Physics Package. In 30 minute or 1 hour period high voltage current shouldn't exceed 100μA.

6 Installation

6.1 Shipping crate unpacking

The maser unpacking has the following consequence (see Figure 6):

– Unscrew four nuts M16 from the top cover;

– Unscrew four bolts M12 from the top cover;

– Remove top cover carefully;

– Heel the crate slightly and unscrew four bolts M12 at the bottom;

– Unscrew eight cap screws from the front wall;

– Screw two ring-bolt at the opposite corners of the maser and using the pulley block lift the maser out of the crate gently and carefully;

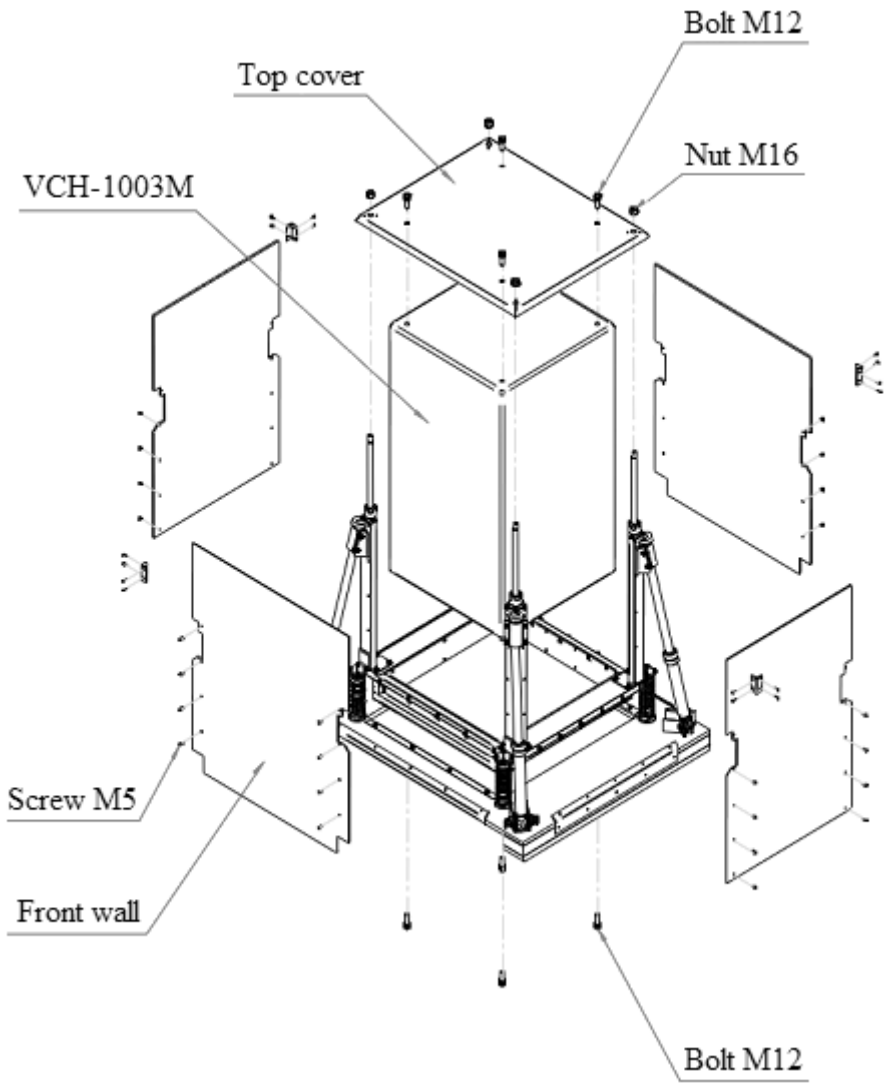


Figure 6 Shipping crate Layout

6.2 Starting up the maser

To achieve the best performance the maser should be located at the area with minimal temperature deviation. The maser meets its specification only if environmental temperature changes within ±0.1ºC range at the rate slower than 0.3ºC/hour.

Please read the following information carefully before continuing.

Table 5 and Figure 7 describe indicators, connectors and switches on the maser front panel.

Table 5 Indicators, connectors and switches on the maser front panel

Items in figure 7	Designation	Description
1	POWER	LED indicator. It illuminates green when PLL Unit operates on AC power
2	BATTERY	LED indicator. It illuminates green when DC source is connected to the maser but PLL Unit still operates on AC power and blinks with a period of about 1s when PLL Unit operates on DC power.
3	CAVITY TUNING	LED indicator. It illuminates green when the maser operates in cavity tuning mode
4	PLL	LED indicator. It illuminates green when VCO is locked.
5	POWER	LED indicator. It illuminates green when the maser operates on AC power
6	POWER	Power switch.
7	BATTERY 1, 2	LED indicators. They illuminate green when DC source is connected to the maser DC input 1 or 2 correspondingly but the maser still operates on AC power and blink with a period of about 1s when the maser operates on DC power.
8	1 PPS	Sync input BNC-type
9	1 PPS 1,2	1 PPS outputs BNC-type
10	5 MHz 1,2	5 MHz sine signal outputs N-type
11	10 MHz 1,2	10 MHz sine signal outputs N-type
12	100 MHz 1,2	100 MHz sine signal outputs N-type

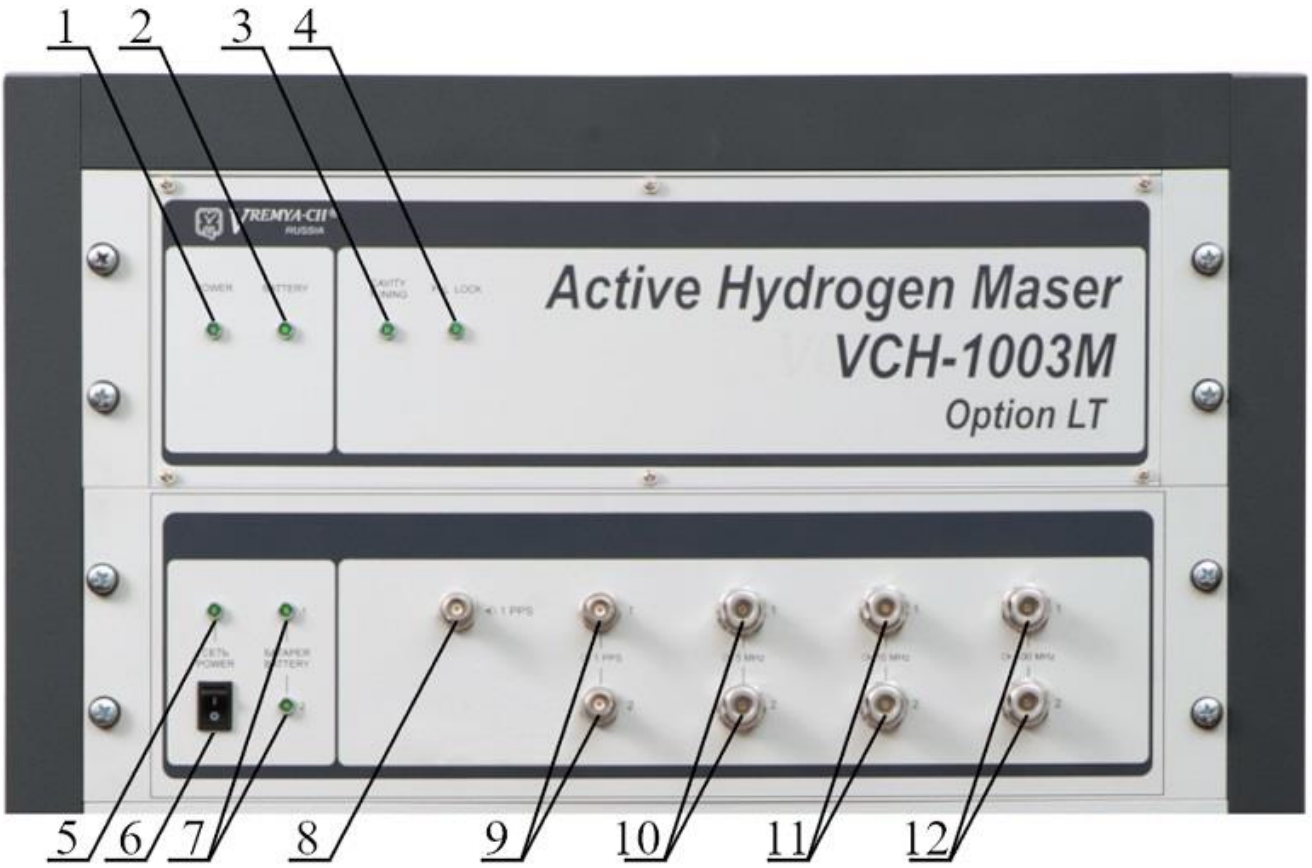
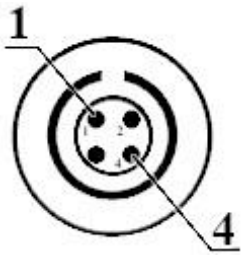


Figure 7 Indicators, connectors and switches on the maser front panel

Table 6 and Figure 8 describe connectors and switches on the maser rear panel.

Table 6 Connectors and switches on the maser rear panel

Items in Figure 8	Designation	Description
1	RS-232C	Interface connector RS-232C
2	OVEN USB	Oven connector USB
3	22…30 V F 5AL, F 5AL	DC power connectors' fuses 250V 5A
4	PHYSICS PACKAGE F 2 AL 250V, F 2 AL 250V	DC power fuses of Physics package 250V 2A
5	PLL UNIT F 3,15 AL 250V, F 3,15 AL 250V	AC power fuses of PLL Unit 250V 3.15A.
6	BATTERY 1, 2	DC power sources 1 and 2 connectors Use connector from delivery set (Table 4 Position 6.1)  Pin 1 – Battery plus Pin 4 – Battery minus
7	⏚	Ground terminal connector
8	~220 V 50 Hz 160 VA	AC power connector

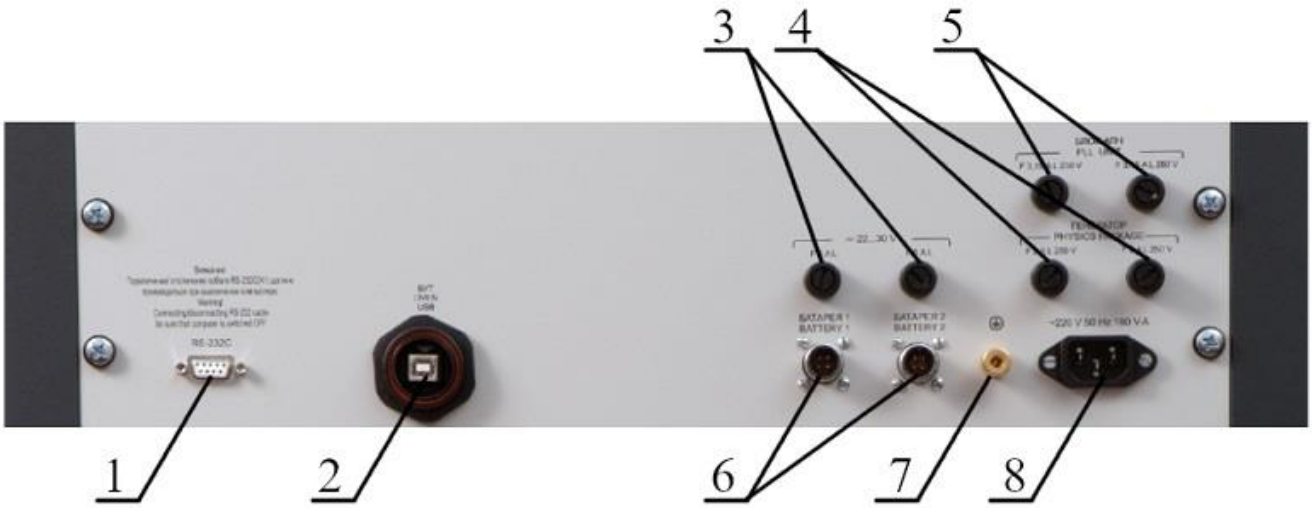


Figure 8 Connectors and switches on the maser rear panel

Before switching on the maser connect RS-232 interface cable 685670.026-01 via interface adapter UC232R-10 to the computer USB port to avoid any interface damage. Then install the software on the computer according to the description in User Guide 411141.032 UG and then start up the maser. Switch on the “POWER”. Launch Server and Manager software and implement all procedures as it is described in User Guide 411141.032 UG.

To avoid any maser operation disturbances due to AC power failures the continuous connection of DC power 24V sources is recommended.

7 Marking and identification

Trade mark of the manufacturer (1) and model of the maser (2) are located on the front panel (see Figure 9).

Serial number and production date are labeled on the back panel (1) (see figure 10).

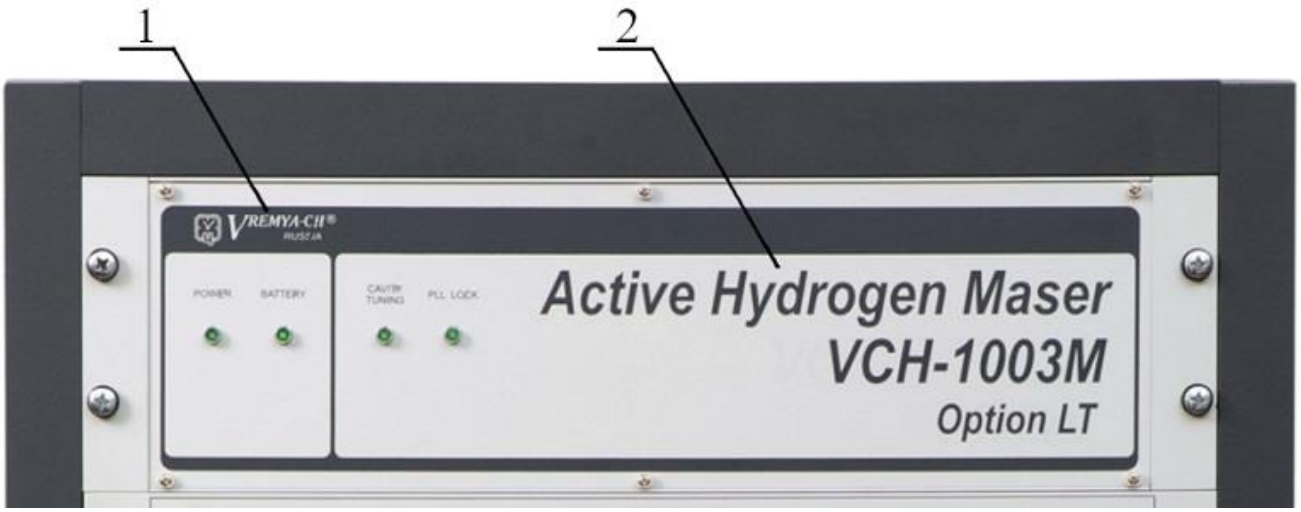
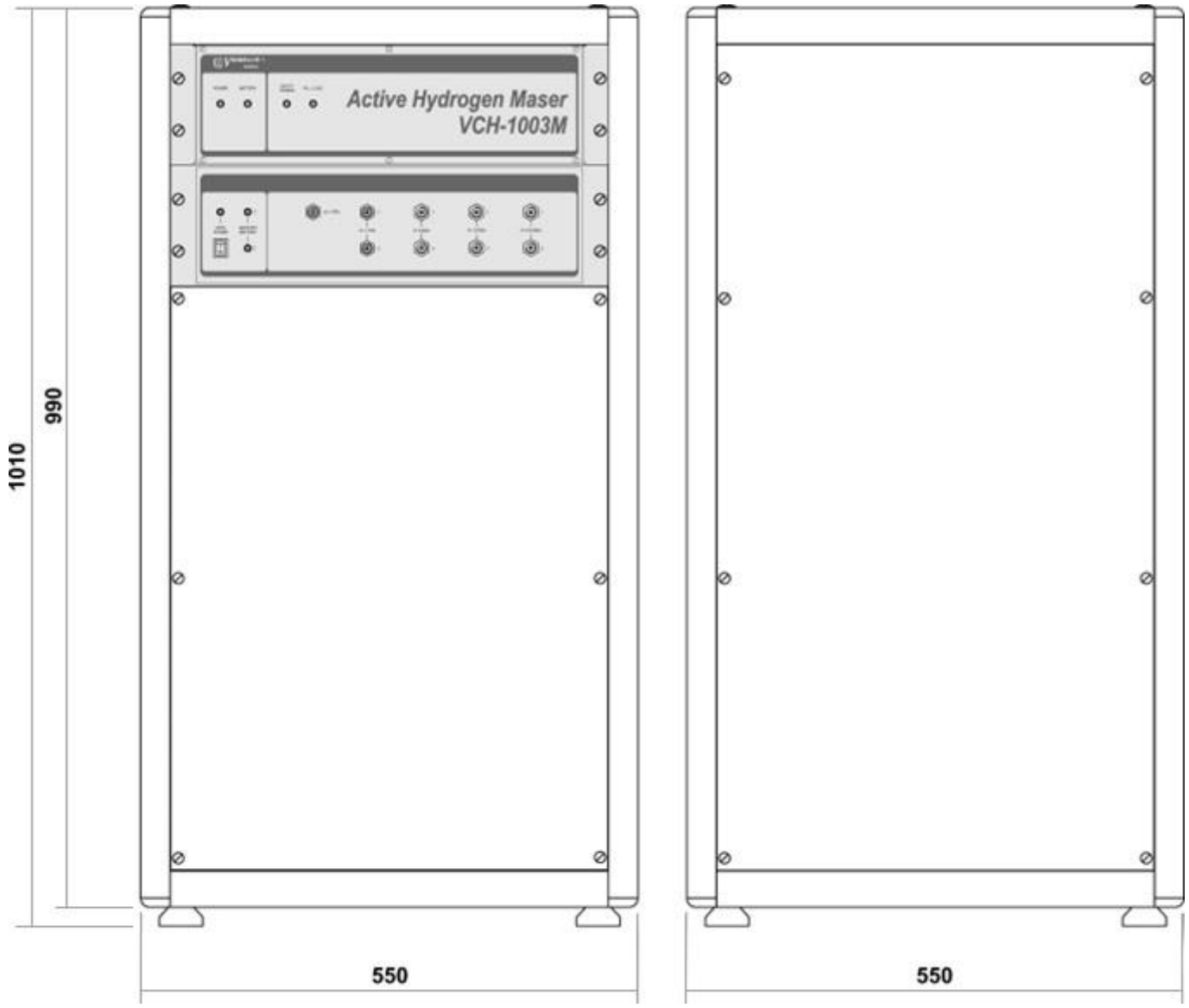


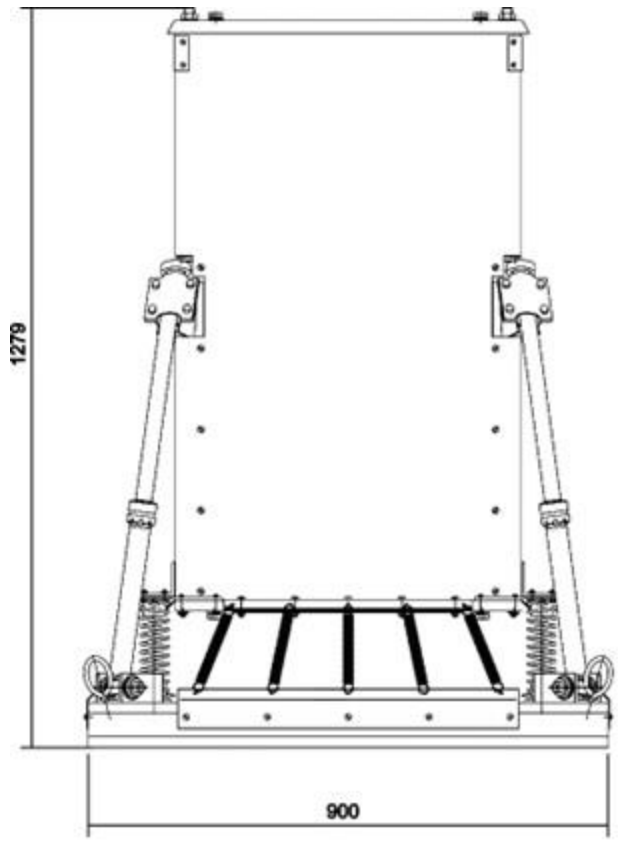
Figure 9 Trademark of the manufacturer (1) and model of the maser (2)

Figure 10 Serial number and production date label

Appendix A

Dimensions of the maser and shipping crate

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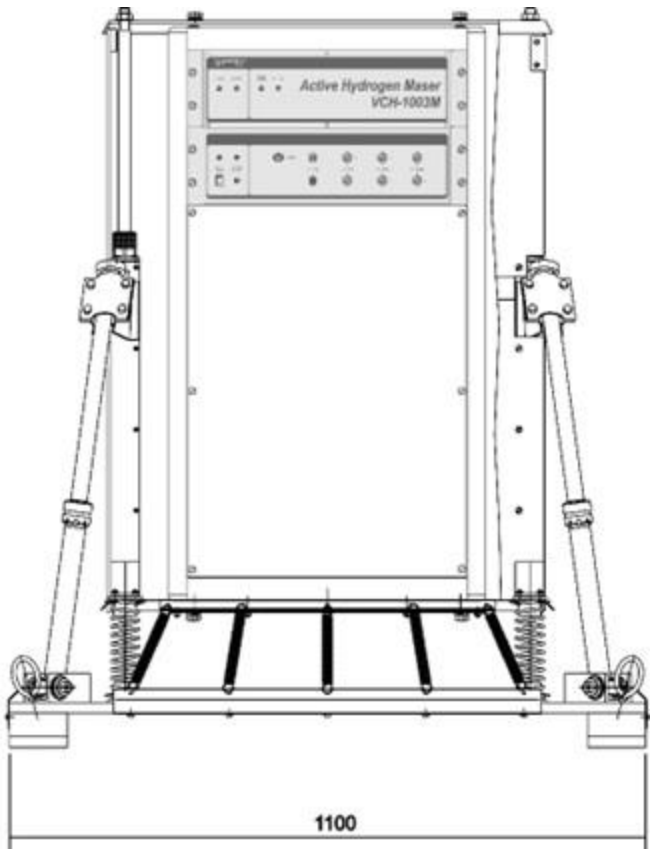
900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