THE RF CAVITY FOR THE SESAME FACILITY

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Abstract

SESAME is a 2.5 GeV Synchrotron Light Source under commissioning in Allan (Jordan). It will be the first international research centre in the Middle East. It is a cooperative venture with support provided by several international organizations and scientific laboratories. Elettra-Sincrotrone Trieste (Italy) is among them.

In the framework of the collaboration agreement among SESAME (Jordan), INFN (Italy) and Elettra-Sincrotrone Trieste, four 500 MHz normal conducting (NC) copper cavities have been built and commissioned at Elettra and then successfully installed in the SESAME storage ring. The cavities' properties, their fabrication process, their characterization at low and high RF power is presented here.

CAVITY DESCRIPTION

The Elettra-type cavity is a single cell, NC copper resonating accelerating structure. It is made of two shells brazed along the equatorial circumference forming a bell shape cavity as shown in Fig. 1. Its inner profile has an elliptical design to avoid parallel surfaces so that the resonant cell is free from multipacting phenomena.

Besides their implementation in the Elettra storage ring, these cavities have been installed in UVX, LNSN (Brazil); ANKA, KIT (Germany); SLS, PSI (Switzerland) and Indus-2, RRCAT (India). These cavities have now been built and commissioned for the SESAME storage ring.

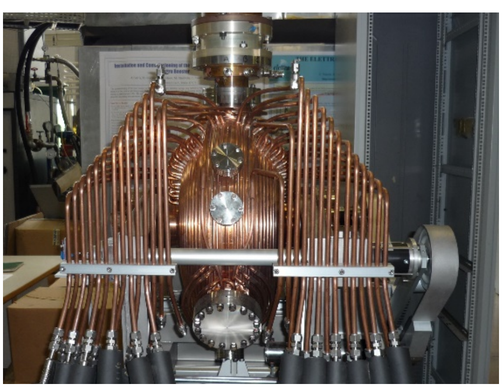

Figure 1: 500 MHz Elettra-type cavity.

The cavity is equipped with three larger equatorial brackets terminated with CF 100 flanges to install the Input Power Coupler (IPC), the ultrahigh vacuum (UHV) ion pump and the High Order Mode Frequency Shift (HOMFS) plunger.

Moreover, three smaller equatorial brackets are designed to host two picks up to sample the RF cavity signal and one cathode vacuum gauge for the pressure monitoring, all three having CF 40 flanges.

The fundamental mode frequency tuning is obtained by lengthening or squeezing symmetrically the cavity axial length. Two RF shielded bellows must be therefore installed upstream and downstream the cavity beam axis to compensate the axial length variation due to the tuning system.

The radiofrequency power (RF) is fed to the cavity via a coaxial type IPC [1]. The appropriate transition to cope with the 6 1/8" EIA 50 Ω standard coaxial line is delivered to match one IPC ending, while the other IPC end dips into the cavity UHV. The vacuum to air transition is realized with the insulating alumina ceramic window having purity greater than 97.5%. The IPC coupling to the cavity is obtained via an inductive loop and can be adjusted by rotating the whole IPC that is the loop orientation, thanks to a swivel flange. This operation shall be done before the UHV sealing.

The HOMFS plunger position is statically set to avoid the interaction between the beam and the cavity high order mode (HOM) frequencies [2].

Cavity fundamental mode parameters are listed in Table 1. The accelerating mode frequency can be statically adjusted in the ± 1 MHz range. The RF pick up insertion loss can be set by means of swivel flanges, always before the UHV sealing.

Table 1: SESAME RF Cavity Parameters

Parameter	Value
RF Frequency	499.6 MHz
Accelerating Voltage	670 kV
Copper losses	68 kW
IPC coupling coefficient	1.0 to 2.4
Pick up insertion loss	-40 dB to -74 dB
Tuning range (±1.8 mm axial stroke)	±200 kHz
L0 frequency shift versus reference temperature	9 kHz/ºC
L0 frequency shift versus plunger position (40 mm stroke)	≥ 900 kHz

Cavity Cooling Rack

The cavity cooling is provided by two separate cooling circuits: the first is dedicated to the cavity resonant body, the second is meant for the brackets, the IPC and the HOMFS. The first cooling circuit of the cavity is connected to a dedicated cooling rack for a precise temperature setting of the cavity during the operation with beam. An additional by-pass cooling pipe and ball valve installed between the two cooling circuits can modify the water cooling path providing an easy way to perform the cavity bake out with hot water.

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The cooling rack is a free-standing device with two cooling circuits that interacts through a heater exchanger. The first circuit whose flow is regulated by a three-way valve shall be connected with the SESAME primary water circuit. In the second circuit a pump keeps the water circulating to cool down the cavity. A process controller (Siemens SIPART DR24) manages automatically the thermal process. The controller is provided with the firmware and software to check and control the thermal process.

CAVITY FABRICATION

The cavity fabrication process has been developed by Strumenti Scientifici CINEL together with the Elettra team. In 2011, the cavity mechanical design has been further optimized to safely improve the cooling of the three CF 100 equatorial brackets. A cooling jacket now ensures the proper cooling of the IPC bracket avoiding any cooling pipes bending, see Fig. 2 and a single wider cooling ring is used for the last two brackets having these less demanding cooling rate need.

Figure 2: Detail of the new cooling jacket design.

Before starting any working; a chemical composition analysis of the raw material' samples is performed to check their quality. The cavity used material is oxygen free high purity copper OFHC 99.9% for the cavity body and AISI 319LN and AISI 319L stainless steel for the flanges and the brackets. The outer cooling pipes are standard copper.

The rough cavity shells are first cold shaped from copper plates on a mold, then the accurate machining of the inner surface is realized and the first brazing of the beam port pipes are performed.

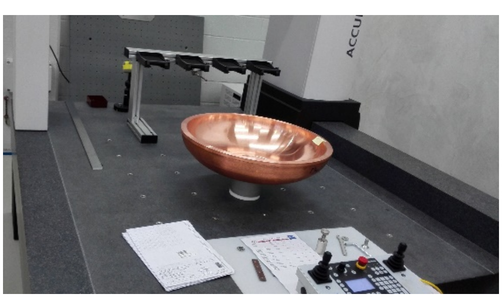

Figure 3: Cavity' shell during the CMM test.

Inner surface roughness and 3D profile check is performed at this stage. The inner surface arithmetic mean roughness is Ra ≤ 0.2 µm measured with Perthometer M2 from Mahr. The inner profile tolerances, the parallel and perpendicular factor between the plane and the flange, the roundness and concentricity are below 0.05 mm, measured with a calibrated Accura 2 CMM instrument from Zeiss as shown in Fig. 3.

Then the grooves to host the cooling pipes on the external surface and the brazing joint are machined. The cavity cooling system preparation starts as well as the machining and brazing of the equatorial brackets.

Several brazing steps are sequentially performed to join the two shells and add the equatorial pipe, see Fig. 4.

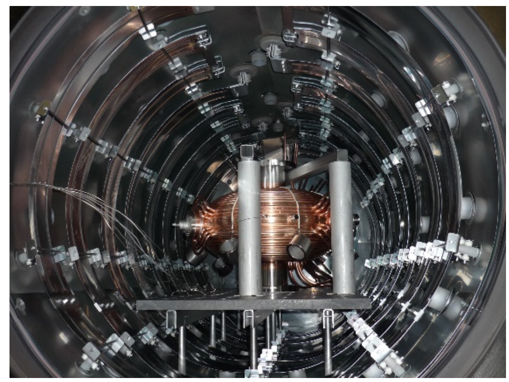

Figure 4: Last cavity' manufacture step done in the under vacuum brazing oven: the two shells are already brazed together but the external cooling pipes.

Eventually the cavity cell is completed and installed on the cavity tuning cage designed to apply the required stretching and compression along the beam axis by means of a servomotor and suitable gearboxes. The cavity tuning cage is arranged on an aluminium Bosch Rexroth frame girder designed to reach the storage ring beam axis height, to provide the alignment tools and to host the inlet and outlet manifolds of the cavity cooling circuits.

Several inspections and quality control checks are usually carried out during the cavity and its equipment fabrication process, but ultimately the cavity and associated equipment are accepted only if they pass the UHV leak test and water pressure leak test: localized vacuum leaks below 2 10^{-10} mbar l/s and overall vacuum leaks below 5 10^{-10} mbar l/s. The cooling circuits are tested at 18 bar for a time longer than 15 minutes

Cavity Equipment

The IPC, the picks up and the HOMFS are fabricated by Strumenti Scientifici CINEL too.

The IPC has the most challenging fabrication procedure due to the ceramic to copper brazing and mainly the brazed water cooling pipes that operate under UHV. For this reason, the IPC loop size has been carefully redesigned to strengthen the water channels brazing joints.

Also, these components are subjected to the same factory acceptance tests of the resonant cell itself: UHV leak and water pressure tests. The last test is not performed for the RF pick up.

Cooling Rack

Four cooling racks have been built according to the Elettra specifications and have been tested only from a mechanical and hydraulic point of view at the manufacture premises. All the commissioning tests have been carried out at Elettra with the real cavity as a load. The cavities set is completed with two free-standing units with thermal control process for the UHV bake-out (up to 140 ºC).

CAVITY COMMISSIONING

At the Elettra RF laboratory the cavity is fully commissioned according to the following steps:

- Characterization of the fundamental mode
- Identification and characterization of the high order modes
- Bake-out and UHV leak test
- RF high power conditioning

Characterization of the resonant mode frequencies are carried out with the IPC and pick up set at the nominal final values even though this may not have the requested coupling with the modes to be measured. For example, the longitudinal L9 mode can be measured only when additional brackets are connected on both ends of the cavity beam ports to prolong the beam path since this mode begins to propagate well beyond the cavity beam port boundary.

Table 2: Longitudinal Modes Measured Data

Mode index	Frequency [MHz]	Unloaded Q-factor	R/Q [Ω]
L0	499.6	41000	80.7
L1	946.4	44500	30.2
L2	1056.6	40000	0.5
L3	1419.1	43300	3.9
L4	1510.3	36900	4.7
L5	1604.1	48000	8.9
L6	1875.3	48400	0.3
L7	1944.8	74200	1.4
L8	2076.2	---	0.1
L9	2118.1	28200	7.9

Table 2 lists the main longitudinal modes parameters. L8 quality factor measurement could not be measured because the mode has a real weak coupling. The R/Q measurement set up is described in [3]. These values are evaluated from a row needle perturbing object measurement campaigns and may need further analysis to minimize the impact of systematic errors.

HOMs frequency shift versus the plunger position and cavity temperature reference setting have also been characterized to implement the proper cavity model to cope with the HOM driven coupled bunch instabilities.

The bake-out procedure must be performed to achieve the UHV pressure required to deliver the high RF power to the cavity.

Using the provided free standing bake-out unit the cavity cooling water has been slowly raised up to 140 ºC. At the same time the stainless steel flanges are baked up to 200 ºC with customized electrical heaters. The temperature flat top duration shall last more than 12 hours.

With a pre-vacuum turbo pump capability of 520 l/s available in the RF lab the low 10^{-9} mbar ultimate pressure range is reached at room temperature.

Three of four cavities have been conditioned at RF power up to 50 kW that is currently the power availability at the Elettra RF lab. Typically, the RF conditioning is first performed with amplitude modulation in duty cycle mode, 100 Hz repetition rate. After the completion of this process the frequency modulation is adopted to conditioning the IPC for the full reflected power, that’s the case when sudden storage ring beam loss occurs.

Finally, using the cavity fully conditioned, each cooling rack has been completely and through tested and the PID control parameters set to be ready for the final installation.

The cavities must once again be air-vented before their installation in the SESAME storage ring. Nevertheless, the bake-out and the RF high power conditioning performed at Elettra had helped to reduce the cavity commissioning time at SESAME.

CONCLUSION

Four cavities have been delivered to SESAME ready for the storage ring operation, including the complete set of RF pickups, the IPC, the HOMFS, cooling circuits and cooling rack as well as the set of the proper interlock switches, stepper and DC motors, encoders and electrical cables interface box for each cavity. Two water thermal control units have been delivered to perform the cavity bake-out together with the electrical heaters and insulating jackets. All the equipment has been extensively commissioned at Elettra with the appropriate features to meet the SESAME storage ring RF system requirements [4].

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