THE RF CAVITY FOR THE INDUS-2 STORAGE RING

C. Pasotti†, M. Bocciai, P. Pittana, M. Rinaldi, Elettra-Sincrotrone Trieste, Trieste, Italy

Abstract

A new Elettra-type cavity has been delivered to the Raja Ramanna Centre for Advanced Technology (RRCAT) Indus-2 facility. This cavity is the very same of those already installed several years ago with some optimization of the cooling channels. It is the Elettra-type cavity, normal conducting copper single cell but resonating at 505.8 MHz. The cavity description, the full characterization of the accelerating mode (L0) and high order modes (HOM) and the acceptance tests are presented in this paper.

DESCRIPTION

The delivered RF cavity is fully equipped to be installed in the storage ring including the ultrahigh vacuum (UHV) bellows with RF contacts and UHV taper sections to connect the cavity to the Indus-2 vacuum chamber. Cavity equipment consists of input power coupler (IPC), four RF picks up, HOM frequency shifter plunger (HOMFS), tuning and cooling systems, bake-out components, temperature monitoring sensors but the vacuum components as shown in Figs. 1 and 2.

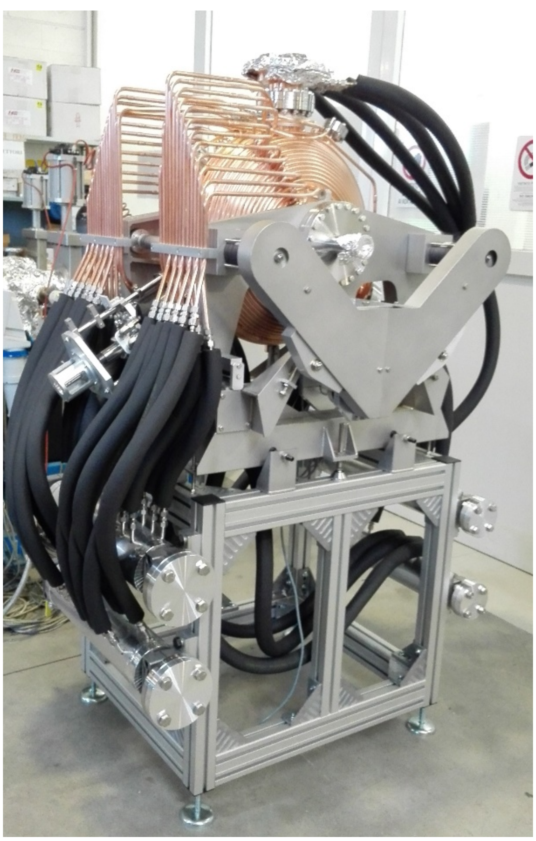

Figure 1: Cavity with tuning cage, cooling and girder.

Two inductive RF picks up are dedicated to the low level RF feedback and tuning system, while the last inductive and the antenna ones are intended to monitor HOM frequencies during storage ring operation.

The cavity fabrication process is described in [1] including the new cooling jacket designed to improve the IPC port cooling. The resonant frequency increase from 499.6 MHz to 505.8 MHz is achieved decreasing the cavity radius by 3 mm.

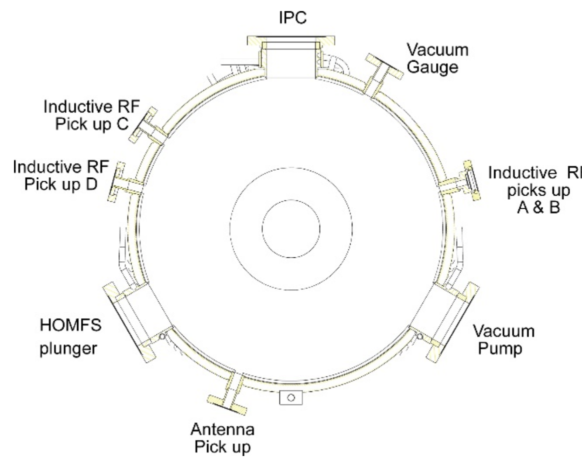

Figure 2: Cavity cross section with all the equatorial bracket ports, CF 100 and CF 35 flanges, and their use.

The Elettra-type cavity has a narrow band HOM spectrum and no HOM absorbers. The typical operation with this cavity is to avoid the overlapping of the HOM frequencies with those of the accumulated beam, so that no coupled bunch mode instability could rise, or, on the contrary, to excite a strong and constant longitudinal instability to kill any transverse ones during the energy ramping procedure [2]. This task is performed by adjusting the cavity volume with a precise reference temperature setting on the cavity body and/or shifting the HOM spectrum with the movable plunger. The accelerating mode resonant frequency is always restored by the tuning system.

The knowledge of the numerical and measured parameters of the most effectively HOM is therefore mandatory to foresee any interaction with the electron beam. The limiting frequencies are the cut off frequency of transverse magnetic (TM) and transverse electric (TE) modes of the cavity beam port, internal diameter of 100 mm that behaves as a circular waveguide.

CAVITY MEASUREMENT

The cavity characterization is done with the IPC and all the RF picks up installed with their final coupling and

† cristina.pasotti@elettra.eu

choosing for each mode the ports that better suit the HOM frequency excitation and the cavity beam port connected to two additional pipes, 130 mm length each, to test the cavity more close to final installation and functional environment. Moreover the evanescent behaviour of those resonances close to the cut off falls on the field pattern displacement.

First all the HOM resonances up to 2.3 GHz shall be checked to identify the monopole TM and dipole TE modes that could have the strongest impact on the beam stability. The bead pull field perturbation technique is therefore used using a copper sphere with a 10 mm diameter, see Fig. 3.

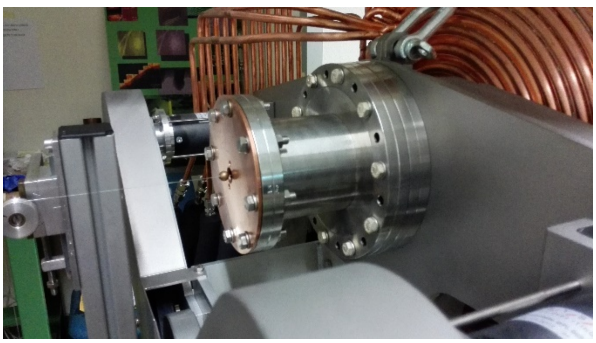

Figure 3: Cavity bead pull measurement with the additional pipes along the beam axis.

More than hundred resonances have been scanned along the beam axis. Electrical and magnetic fields are affected by the metallic spherical bead regardless their orientation in the space. No frequency shift have therefore been recorded when no field exists along the bead perturbation area but noise due to thermal drift and systematic measurement errors.

After this measurement session the TM and TE modes have been doubtlessly tagged. Nevertheless, successive sessions have been repeated with different bead shapes: metallic needle and disk and a dielectric sphere to confirm the mode identification, to single out magnetic and electric field and the field orientation of the two dipole modes polarizations [3].

Table 1: Longitudinal Modes Measured Parameters

Mode index	Frequency [MHz]	Unloaded Q-factor	R/Q [Ω]
L0	506.0	40900	82.6
L1	950.3	43900	31.0
L2	1072.2	35300	0.9
L3	1434.6	35200	5.4
L4	1517.2	24000	4.4
L5	1626.6	26900	8.4
L6	1893.9	6400	0.2
L7	1961.2	26400	2.2
L8	2101.2	---	0.1

Table 1 shows the longitudinal modes measured unloaded quality factor and shunt impedance, transit time corrected. These data are taken with the IPC coupling to the fundamental mode was set at 3.0, over coupled.

The R/Q values of Table 1 is averaged among three measurement's sessions performed with three different beads: needle, copper and dielectric sphere.

These beads have been calibrated with a brass cylindrical cavity resonating at TM_{010} = 1.148 GHz, see Table 2. The theoretical frequency shift is calculated for an ideal bead shape, perfect rotation symmetry object and a perfect cylindrical pill-box cavity with no openings.

Table 2: Bead Calibration Factor

Bead shape	Theoretical Δf [kHz]	Measured Δf [kHz]
Metallic needle	347.6	335.0 ± 0.3
Copper sphere	968.2	970.2 ± 0.4
Dielectric sphere	292.3	293.2 ± 0.7

Dipole mode transverse impedance is calculated combining the copper and dielectric bead pull measurements. Results is shown in Table 3 where the “a” label means the polarization perpendicular to the beam direction.

Table 3: Dipole Modes Measured Parameters

Mode index	Frequency [MHz]	Unloaded Q-factor	R/Q $_{transverse}$ [Ω/m]
D1a	746.5	42500	88.4
D2a	756.9	45500	286.1
D3a	1119.4	35900	343.6

HOMs frequency shift has been characterized versus the reference temperature of the cavity. Each mode experiences a different frequency shift for a unitary change of the reference temperature setting. This shift is linear with the temperature and has slope ψ [kHz/ ºC]. Results are summarized in Table 4 and Table 5. The minus sign takes in account that the frequency decreases for larger cavity volume due to the reference temperature increasing.

Table 4: Longitudinal Modes Temperature Coefficient

Mode	ψ [kHz/ ºC]	Mode	ψ [kHz/ ºC]
L0	-10.1	L4	-33.0
L1	-18.7	L5	-21.8
L2	-18.5	L6	-33.7
L3	-23.9	L7	-33.7

Table 5: Dipole Modes Temperature Coefficient

Mode	ψ [kHz/ ºC]	Mode	ψ [kHz/ ºC]
D1a	-10.1	D5a	-33.0
D2a	-18.7	D6a	-21.8
D3a	-18.5	D7a	-33.7
D4a	-23.9	D9a	-33.7

HOMs frequency shift is evaluated also for the L0 detuning due to any changes in the cavity volume caused by

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any new plunger position or temperature. This effect adds linearly with the temperature and HOMFS position shift.

Each mode has therefore a coefficient φ dimensionless that represents its linear frequency shift, in kHz, against the L0 frequency shift of 1 kHz as shown in Tables 6 and 7.

Table 6: Longitudinal Modes L0 De-Tuning Coefficient

Mode	φ	Mode	φ
		L4	0.13
L1	0.82	L5	0.39
L2	-0.22	L6	-1.22
L3	-2.21	L7	-2.32

Table 7: Dipole Modes L0 De-Tuning Coefficient

Mode	φ	Mode	φ
D1a	-2.96	D5a	-4.26
D2a	-0.06	D6a	-0.09
D3a	0.36	D7a	-2.34
D4a	-0.07	D9a	-0.56

Finally the HOMs frequency shift is measured versus the HOMFS plunger position. The plunger stroke is 40 mm and its effect increases exponentially as far as it dips gradually into the cavity body, as shown in Fig.4.

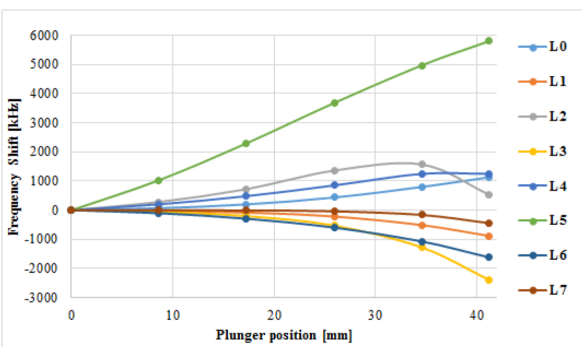

Figure 4: TM modes frequency shift versus the plunger position. During the beam operation L0 mode is always set back to the resonant frequency by the tuning system.

The TM modes have both positive and negative frequency shifts while the temperature works only in one direction. The HOMFS beneficial use comes after the cavity reference temperature set and mainly to de-tuning the L1 mode which have the largest impedance, after the L0 one. The same characterization have been repeated for all the dipole modes.

COMMISSIONING

The cavity and the associated equipment undergo several acceptance quality test during the fabrication process as described in [1]. Nevertheless the cavity has been tested again at the Elettra RF lab to check any vacuum leak. Then the bake out has been performed, see Fig. 5. Few days after the bake out the 10^{-10} mbar ultimate vacuum pressure range has been successfully reached.

Due to the Indus-2 frequency, 505.8 MHz, it is not possible to RF power conditioning the cavity at Elettra RF lab.

All these measurements and tests have been performed in presence of RRCAT representative.

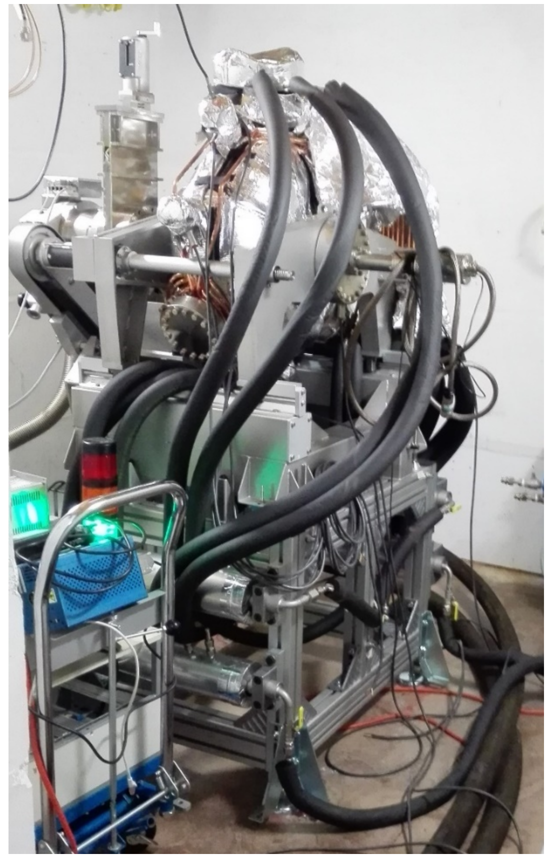

Figure 5: Indus-2 Cavity during the bake out.

CONCLUSION

In 2002 four cavities have been delivered to Indus-2 and have been operating with no major faults. A new cavity has been intensively tested, checked and arranged to be ready for beam operation. It has been delivered to RRCAT together with RF bellows, vacuum tapers and bake-out unit equipment.

ACKNOWLEDGEMENT

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