PROTOTYPE FABRICATION OF AN ACTIVE NORMAL CONDUCTING THIRD HARMONIC CAVITY FOR THE ALBA STORAGE RING*

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Abstract

ALBA has designed a normal conducting active 1.5 GHz HOM damped cavity for the active third harmonic RF system for the ALBA Storage Ring (SR), which also will serve for the upgraded ALBA II. The third harmonic cavity at ALBA will be used to increase the bunch length in order to improve the beam lifetime and increase the beam stability thresholds. A prototype has been constructed by the company AVS in collaboration with VITZRO TECH. This paper presents the design of the cavity, the constructed prototype, the Acceptance Tests measurements, and future plans.

INTRODUCTION

ALBA has designed a prototype of a 1.5 GHz normal conducting HOM damped cavity, based on the 500 MHz EU damped cavity design [1]. In addition to scaling down the dimensions to adapt to the higher resonant frequency, the HOM absorbers have been replaced by transitions to coaxial N-type connectors named Transdampers. This design allows extracting the power of HOMs excited by the beam to external loads, eliminating the need for complicated ferrite absorbers [2].

The cavity has been manufactured in collaboration between the Spanish company AVS and the South-Korean company VITZRO TECH.

CAVITY COMPONENTS

The main part of the cavity comprises the resonant cavity body, the waveguide sections of the three HOM dampers, the beam pipe ports as well as ports for the rest of components: Transdampers, pick-up antenna, tuner and input coupler, see Fig. 1.

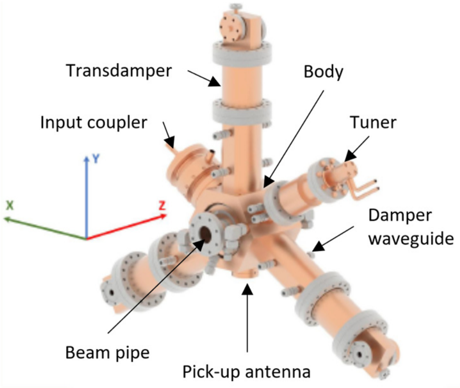

Figure 1: Components of the 1.5 GHz cavity.

Body and Damper Waveguides

The cavity is a pillbox-type resonator with nose cones [3]. In order to damp HOM excited by the beam into the cavity, three circular ridged waveguides with a cut-off frequency of 1.72 GHz are brazed into the body in such a way that there are no discontinuities in the copper to avoid overheating in the base of the dampers, see Fig. 2, as experienced with the 500 MHz original design [4].

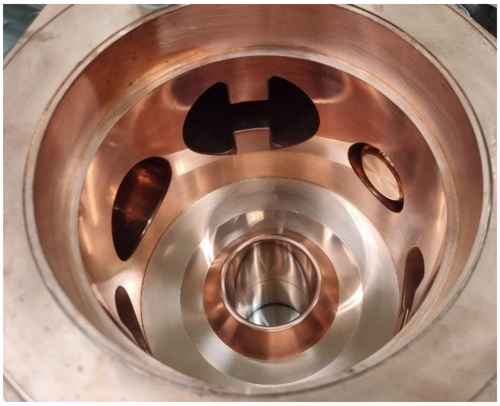

Figure 2: Inner view of the cavity body. Courtesy of VITZTRO TECH.

After manufacturing all components of the cavity, the resonant frequency was adjusted by shortening the length of the nose cones, as the resonant frequency of the cavity has a strong linear dependency on this dimension. The length of the nose cones is controlled by the radius of the roundness at the end of the nose cone. Figure 3 shows the simulated and measured values during the adjustment of the resonant frequency.

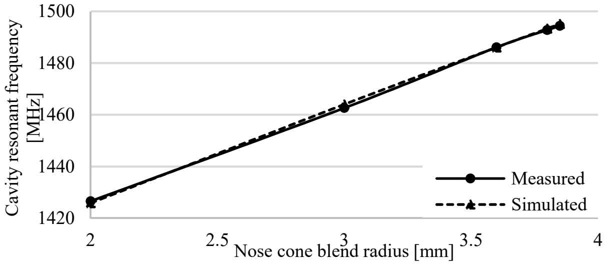

Figure 3: Simulated and measured resonant frequencies during adjustment. Data courtesy of VITZRO TECH.

Transdampers

The Transdampers take the HOM power extracted by the damper arms out of the cavity. They are made out of two components: a transition from circular ridged waveguide to rectangular waveguide and a wideband transition from rectangular waveguide to coaxial [3]. Finally, a commercial

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broad band coaxial vacuum feed-through is used to take the power to a standard RF load.

After manufacturing of the Transdampers finished, they were tested by connecting transitions in pairs directly and checking the S parameters. The reflection is in the order of -5 dB or better until approximately 4 GHz, Fig. 4. Further optimization is possible by adjusting the dimensions and position of the antenna in the rectangular to coaxial transition.

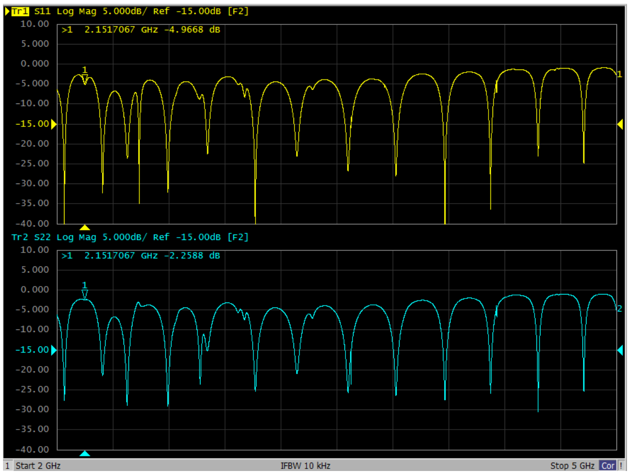

Figure 4: 2 GHz to 5 GHz S_{11} (top) and S_{22} (bottom) of a pair of Transdampers. Courtesy of VITZRO TECH.

Input Coupler

Power is coupled with an inductive loop fed by a standard EIA 3-1/8 coaxial line. Two alumina disks hold the inner conductor in place and provide vacuum isolation.

Measurements on the initial prototype revealed that the fundamental mode of the cavity could not be excited with the coupler. Simulations showed that the ceramic windows were causing a high reflection. The distance between ceramics was increased and the thickness of one of the alumina windows was reduced to fix the issue, Figs. 5 and 6.

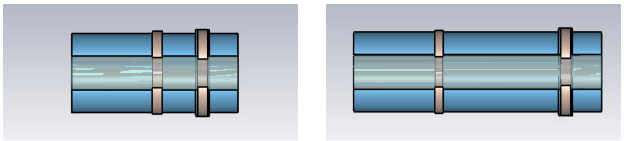

Figure 5: Original coaxial (left) and modified (right).

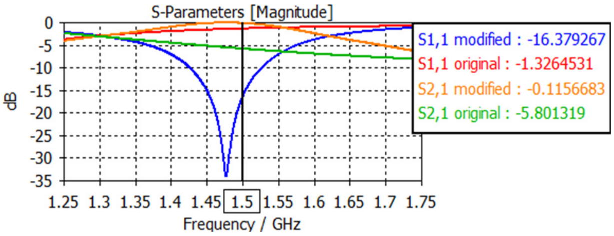

Figure 6: S parameters of the old and new coaxial lines.

In order to find the position of the loop with respect to the cavity body that allows critical coupling, both the height of the loop and the angle of it respect to the magnetic field of the mode have to be adjusted. The angle was set by design at 45° in order to keep the ability to undercouple or overcouple the cavity. For the simulations, using the CST eigenmode solver, the height of the loop base was modified trying to match the cavity quality factor Q_0 to the external quality factor Q_{ext} to obtain $\beta=1$ in (1), where β is the coupling factor.

$$\beta = \frac{P_{ext}}{P_{cav}} = \frac{Q_0}{Q_{ext}} \tag{1}$$

In order to confirm the simulation before manufacturing the loop, a wire test was performed by installing the coupler with a wire of roughly the same length, Fig. 7.

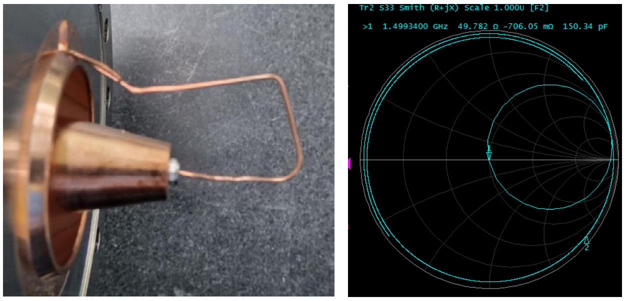

Figure 7: Wire loop (left) and S_{11} of wire inserted in the cavity body (right). Courtesy of VITZRO TECH.

Plunger

The cavity is equipped with a plunger that allows to change the resonant frequency. Initially when inserting the plunger in the cavity, a degradation of the quality factor was measured around the central frequency of the cavity, see Fig. 8.

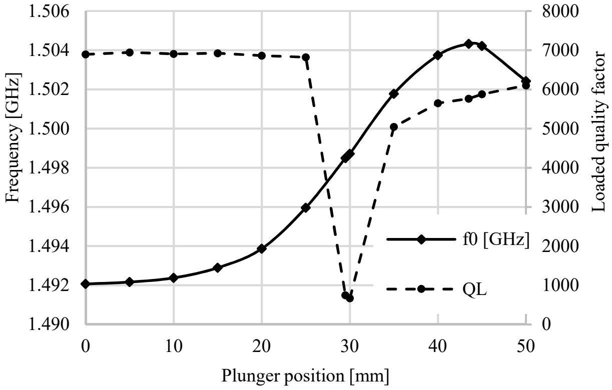

Figure 8: Resonant frequency of the cavity and loaded quality factor versus plunger position.

EM simulations using the CST eigenmode solver revealed a mode in the plunger caused by an undesired cavity present in the top of the manipulator, see Fig. 9. The resonant frequency of this mode is very close to the fundamental mode of the cavity, to the point where both modes resonate at the same frequency for a plunger position of approximately 30mm. In order to avoid exciting the plunger mode, the top of the manipulator was filled with a metal cylinder that divided the undesired cavity in two smaller cavities, shifting the resonant frequency of that mode away from the fundamental frequency of the cavity.

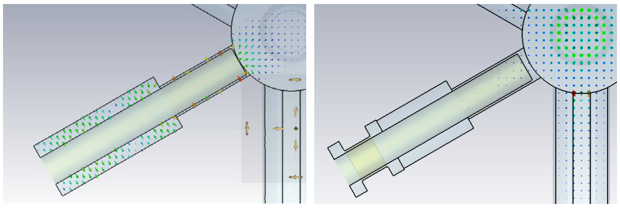

Figure 9: Plunger cavity with mode (left) and with suppressor installed (right).

After installing the suppressor, the quality factor was measured again to confirm that the mode is no longer disturbing the cavity and that the quality factor remains almost constant along the tuning range, see Fig. 10.

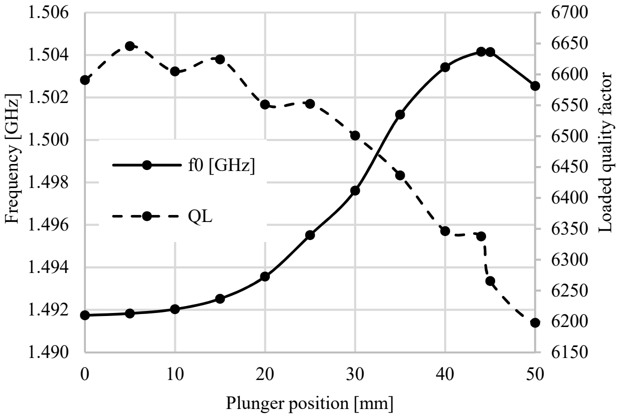

Figure 10: Resonant frequency of the cavity and loaded quality factor versus plunger position after installation of suppressor.

SITE ACCEPTANCE TEST (SAT)

Once the cavity was received at ALBA, see Fig. 11, the central frequency of the cavity ant tuning range was measured, results show in Table 1.

Table 1: Tuning Range Measurements

Parameter	Value	Unit
Central frequency (f_0)	1.497948	GHz
Plunger position at f_0	31	mm
Maximum frequency (f_{max})	1.504156	GHz
Plunger position at f_{max}	44	mm
Minimum frequency (f_{min})	1.491739	GHz
Plunger position at f_{min}	0	mm
Tuning range	12.417	MHz

At the central frequency position of the plunger and with the input coupler adjusted to provide a β =1, the cavity's fundamental parameters were measured, which are summarized in Table 2.

The cavity was connected to a turbo molecular pump. After 72 hours of pumping the achieved pressure was 3e-7 mbar. An RGA analysis was also made in which contamination of hydrocarbons was around 3 orders of magnitude below the partial pressure of water.

Table 2: Center Frequency Measurements

Parameter	Value	Unit
S11	-50.8	dB
β	1.006	
Bandwidth	214	kHz
Loaded quality factor (Q_l)	6995	
Unloaded quality factor (Q_0)	14.031	
Transmission from input coupler to pick-up antenna	-45.9	dB

Finally, the transmission from one Transdamper to another Transdamper through the cavity body was measured, Fig. 12. This confirmed that the dampers operate only above the predicted 1.7 GHz [3] and also confirm that the dampers can effectively couple and damp modes from the cavity body, even though a bead-pull measurement is still required to quantify the achieved damping.

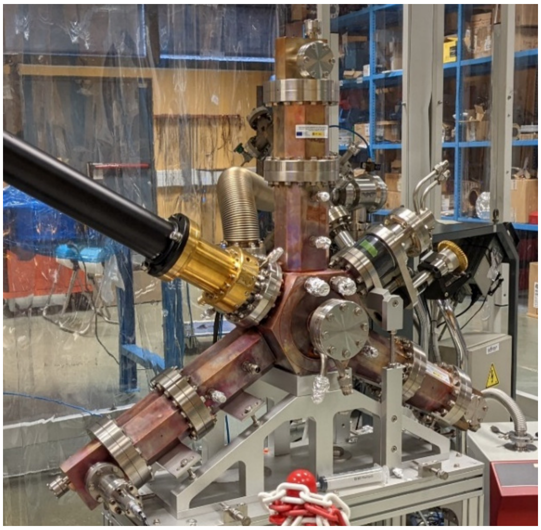

Figure 11: Cavity prototype during the SAT.

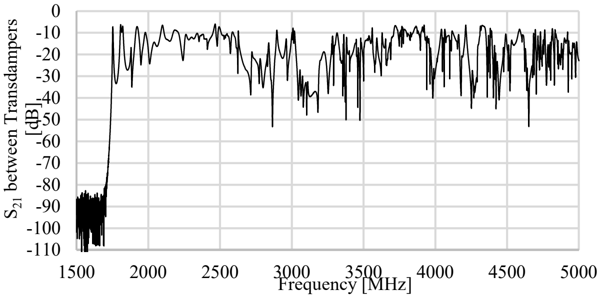

Figure 12: Transmission between two Transdampers through the cavity body.

CONCLUSION

A 1.5 GHz normal conducting HOM damped cavity prototype has been successfully manufactured and preliminary tests confirm the performance predicted in simulations. Further testing such as bead-pull, RF conditioning and test with electron beam to validate the design as a viable cavity for a 3rd harmonic system is being conducted in the frame of a collaboration between HZB, DESY and ALBA [5].

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