FIRST TESTS OF A HOM-DAMPED HIGH POWER 500 MHZ CAVITY*

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Abstract

A normal conducting high power 500 MHz prototype cavity with a broadband higher order mode (HOM) damping scheme designed for 3rd generation synchrotron radiation (SR) sources has been fabricated. We report on the first tests including impedance measurements as well as vacuum and high power conditioning.

1 INTRODUCTION

Longitudinal and transverse coupled multibunch instabilities driven by the beam induced HOM's in RF cavities can severely deteriorate the photon beam brightness, which is an essential figure of merit in undulator dominated 3rd generation SR sources. To avoid this class of instabilities the most straight forward way is to damp the cavity HOM's below the critical impedance thresholds of a given storage ring. A cylindrically shaped 500 MHz cavity with nose cones was optimized numerically utilizing three circular double ridged damping waveguides with homogeneous cross-section terminated by a perfectly matched load. This configuration gives the potential to reduce all HOM impedances down to the level of 2 kΩ and 50 kΩ/m for longitudinal and transverse modes respectively [1]. For the present prototype cavity tapered circular waveguide to coaxial transitions (CWCT's) with external loads have been adopted [2].

2 LOW POWER MEASUREMENTS

Based on numerical results and measurements with a low power cavity, a high power prototype cavity made of OFHC copper has been fabricated at ZANON s.p.a. and delivered in January 2004 (see Fig. 1). The most critical monopole and dipole modes of the cavity were measured applying a "two bead pull measurement" method. The resulting impedances are plotted in Fig. 4, where the European definition of the shunt impedance $R_{eff}=U_{eff}^2/2P_V$ is assumed with U_{eff} the transit time corrected voltage and P_V the total wall power loss. Results are given in comparison with those of the low power aluminium cavity. Impedance spectra are shown as well evaluated numerically using a realistic 3D MAFIA cavity model as described in [3]. The maximum monopole and dipole mode impedances of the high power cavity are 4.8 kΩ at 1536 MHz and 180 kΩ/m at 1513 MHz respectively. The damping of the HOM's is dominated by the external absorbers with negligible dependency on the wall material conductivity as expected.

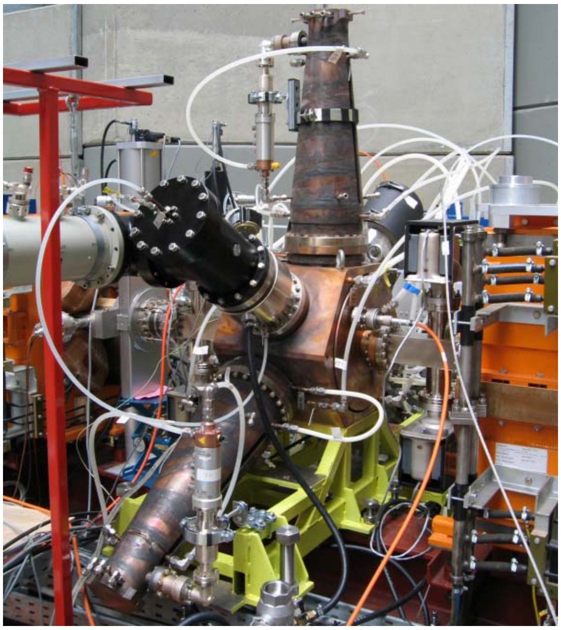

Figure 1: The prototype high power cavity prepared for beam measurements in the DELTA storage ring.

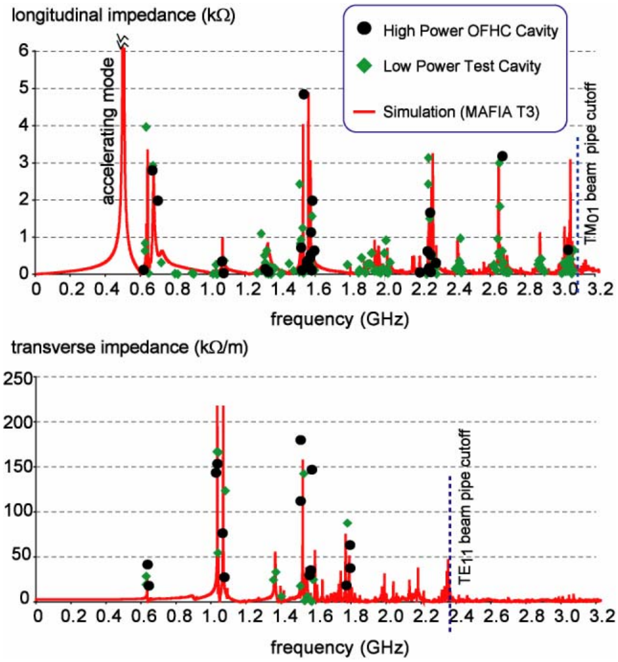

Figure 2: Longitudinal (top) and transverse HOM impedances (bottom) as measured for the high power (dots) and low power (diamonds) prototype cavity respectively together with the numerically predicted impedance spectra (lines).

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The achievable quality factor Q_0 and shunt impedance R_{eff} of the accelerating mode in the OFHC cavity depend sensitively on fabrication and surface quality. For the prototype cavity a $Q_0 = 26692$ and $R_{eff} = 3.1$ MΩ have been measured. This is significantly lower than expected based on earlier 3D numerical estimates. Standard numerical codes like MAFIA or Microwave Studio (MWS) [4] generally overestimate the Q_0 and R_{eff} in 3D since the tangential magnetic surface fields giving rise to wall power losses P_V are underestimated. Using MWS an impedance of $R_{eff} = 3.7$ MΩ has been calculated initially, however a recently implemented method to evaluate the Q_0 from interpolated surface magnetic fields allows a more accurate estimation, yielding $R_{eff} = 3.25$ MΩ. Table 1 summarizes the measured and calculated parameters of the accelerating mode. Measurements are in good agreement with numerical results giving only a 5% impedance error compared with the new MWS simulation method, whereas at least 20% have to be accepted with the old MWS method or MAFIA.

Table 1: Accelerating mode parameters of the high power cavity with three CWCT's, a plunger and a loop coupler

Parameter	**3D MWS Simulation Standard/New Method**	**Measurement**
f_0 (MHz)	500.98	499.65
Q_0	32557/28410	26692
R_{eff}/Q_0 (Ω)	114.5	115.4
R_{eff} (MΩ)*	3.73/3.25	3.1

* $R_{eff}=U_{eff}^2/2P_V$

The broadband damping characteristic of each of the three CWCT's has been checked before the assembly with a time domain reflectometry measurement yielding a satisfyingly low reflection characteristic from the waveguide cutoff of 615 MHz up to the relevant beam tube cutoff (f_{TM01}=3.1 GHz). Results are shown in Fig. 3 including the contribution of the 7/8" coaxial RF window which separates the HOM absorbers from the cavity vacuum.

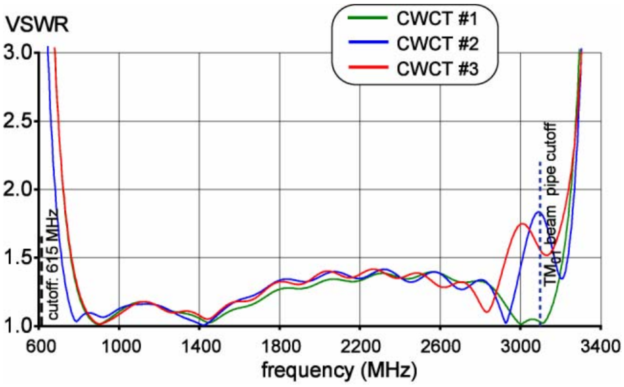

Figure 3: VSWR as measured for each CWCT.

The length of the CWCT's has been designed such that the fundamental mode power absorbed is only about 1% of the power dissipated in the cavity. The RF input coupler and the tuner are standard components as developed for 500 MHz DORIS type cavities. The 6 1/8" coaxial type loop coupler can be rotated to adjust the RF coupling factor β within a range of β = 0-8 to easily account for the requirements of different SR sources. The frequency range covered by the tuner plunger is depicted in Fig. 2. Also shown in Fig. 2 are corresponding MWS simulations giving a difference of about 1.4 MHz for the resonant frequency of the fundamental mode. This numerical uncertainty has to be taken into account when manufacturing the cavity.

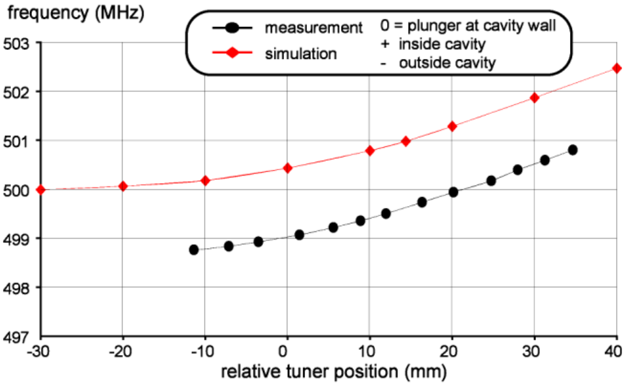

Figure 2: Resonant frequency vs. plunger position as measured and calculated.

Table 2 summarizes all relevant cavity parameters. The cooling scheme of the cavity has been numerically optimized for a maximum average input power of 100 kW as described in [5].

Table 2: Parameters of the high power cavity

Nominal Frequency	499.65	MHz
Tuning Range	2	MHz
Accelerating Shunt Impedance	3.1	MΩ
Unloaded Quality Factor	26692	
Thermal Power Capability	100	kW
Longitudinal HOM Impedance	≤ 4.8	kΩ
Transverse HOM Impedance	≤ 180	kΩ/m
Cutoff of Damping Waveguides	615	MHz
Coupling Range	0-8	
Insertion Length	50	cm
Beam Hole Diameter TE_{11} Cutoff TM_{01} Cutoff	74 2.37 3.10	mm GHz GHz

3 CAVITY CONDITIONING

The cavity has been vacuum conditioned with a bakeout period of several days at a maximum temperature of 150°C. A base pressure of 2E-10 mbar has been reached finally at room temperature using four ion getter pumps (60 l/s each), two installed on each side of the cavity at the beam tubes. Figure 5 shows the evolution of the average cavity temperature and the cavity pressure.

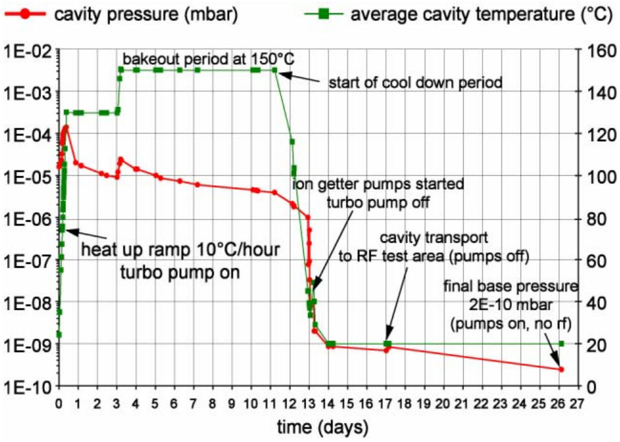

Figure 5: Vacuum conditioning procedure.

After bakeout the cavity has been conditioned with RF using a 30 kW klystron amplifier. In this process potential multipacting or field emission effects can deteriorate the cavity surfaces or metallize the RF vacuum window. For instance the tapered ridge profile of the damping waveguides could not be excluded as a possible source of multipacting. An interlock system has been installed to rapidly switch off the RF power in case of larger vacuum bursts, and with the help of a Labview [6] program the amplitude and pulse width of the klystron output power was controlled with respect to the tolerable vacuum pressure threshold.

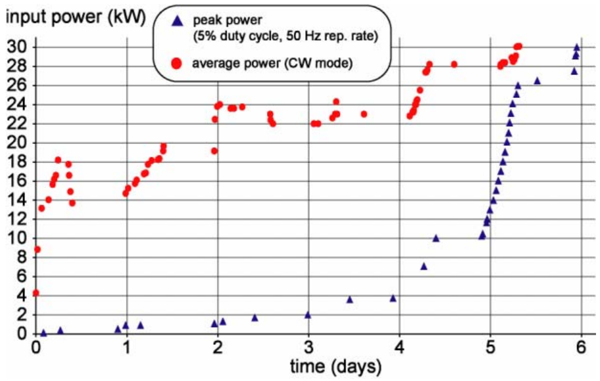

Figure 6: The peak and average cavity input power during the RF conditioning.

RF conditioning has been started in a pulsed mode with a low duty cycle (typically 5%) followed by continuous wave (CW) operation, slowly increasing the power up to 30 kW. Vacuum thresholds have been observed at power levels around 600 Watts exhibiting a breakdown of the cavity voltage and a peak in the reflected power. Hence a glass window has been installed for diagnosis, however no correlated sparks could be identified. Figure 6 illustrates the RF conditioning history after venting the cavity. Off-periods over night due to vacuum interlock triggers are not included. After venting the vacuum pressure slowly recovered during RF conditioning without the need of an additional bakeout of the cavity.

4 CONCLUSION AND OUTLOOK

A normal conducting high power 500 MHz HOM-damped prototype cavity has been fabricated. Vacuum and RF conditioning have been carried out successfully up to 30 kW thermal power. The cavity has been installed into the DELTA ring in Dortmund where beam tests and instability studies will start soon. Low power impedance measurements using CWCT's as HOM-dampers have shown, that a good broadband damping efficiency of longitudinal (≤ 4.8 kΩ) and transverse HOM's (≤ 180 kΩ) can be achieved together with an accelerating mode shunt impedance of 3.1 MΩ. These results are in good agreement with numerical simulations, which also indicate the possibility to further reduce the HOM impedances by using non-tapered damping waveguides [1,3]. First experiments have already been started using ferrite loaded double ridged waveguides with constant cross-section to replace the CWCT's. A low power model was built demonstrating that a VSWR ≤ 1.5 can be achieved up to 4 GHz. Further studies are under way towards a high power model. As the tapered CWCT's are relatively complicated structures there is also significant room for mechanical simplifications when using homogeneous waveguides.

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