DESIGN AND COLD MODEL TEST OF 500 MHz DAMPED CAVITY FOR ASP STORAGE RING RF SYSTEM

Junko Watanabe, Koichi Nakayama, Kiyokazu Sato, Hidenori Suzuki, Alan Jackson*,
Gregory Scott LeBlanc*, Karl Zingre*, Norio Nakamura**, Hiroshi Sakai**, Hiroyuki Takaki**,
Masaaki Izawa ***, Tadashi Koseki****
TOSHIBA Corporation, Yokohama 235-8523 Japan
*Australian Synchrotron Project, Melbourne Victoria 3000, Australia
**ISSP, the University of Tokyo, Chiba, 277-8581, Japan
***Photon Factory, KEK, Ibaraki 305-0801, Japan
****Cyclotron Center, RIKEN, Saitama 351-0198, Japan

Abstract

TOSHIBA is manufacturing the storage ring RF system for the Australian Synchrotron Project(ASP). Two pairs of the 500MHz Higher Order Mode(HOM) damped cavities will be applied for this system. The cavity is a modified KEK-PF type with silicon-carbide(SiC) microwave absorber and has three rod-shaped HOM couplers for damping the longitudinal HOM impedance less than 20kΩ/GHz to comply with ASP Performance Specification. The shunt impedance has been improved more than 5% in comparison with the original design by reducing the beam bore diameter without degrading HOM damping capability. The design of the cavity and the test results of an aluminum (Al) cold model are described.

INTRODUCTION

We are designing the 500 MHz damped cavity for Australian Synchrotron Project (ASP) storage ring which is under construction in Melbourne. The ASP project aims to construct a third-generation 3.0GeV ring with a beam current of 200mA and a circumference of 216m.

The KEK-PF type cavity[1] is the basis of our structural design. Main parameters of the KEK-PF and ASP cavities are listed in Table 1. The cavity has SiC beam ducts for damping the HOM's. The HOM's excited in the cavity are guided out of the cavity through the beam duct and dissipated in the SiC microwave absorber.

Table 1:The parameters of the KEK-PF and ASP cavities

	KEK-PF	ASP
RF frequency	500.1[MHz]	499.654[MHz]
Number of cavity	4	4
RF voltage/cavity	0.43[MV]	0.75[MV]
Coupling factor	2.3	1.7
Shunt impedance	7.7[MΩ]	8.2[MΩ] (designed)
Unloaded Q-value	44000	>30000 (designed)
Nominal beam current	200[mA]	200[mA]

REDUCED LENGTH AND BORE DIAMETER DESIGN

The KEK-PF type damped cavity needs approximately 1.5m straight space. In order to fit a pair of cavities into 2m straight space, we reduced the length of the cavity set. Figure 1 shows the typical cross sectional view of the shorter design of the cavity obtained by combining two cavities together.

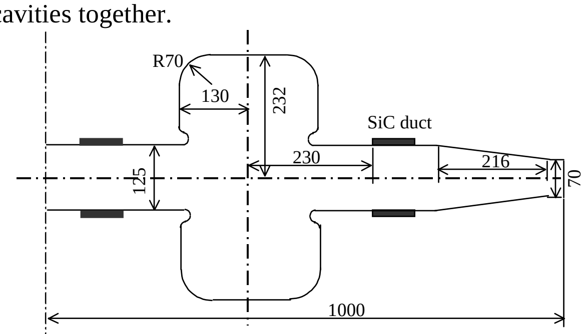

Figure 1:The cross sectional view for a half of 2 cavities

We accomplished the downsizing by eliminating tapered duct between cavities and adjusting the length of SiC duct. In addition, we tried optimising SiC position and beam bore diameter to slightly increase shunt impedance of accelerating mode (Rsh) for improvement of acceleration efficiency. As a result, Rsh larger than 6 % from the original KEK-PF cavity (beam bore diameter of 140mm) will be achievable with the beam bore diameter of 125mm. At the same time, if we select the position of the SiC HOM absorber 230mm from the cavity centre, the damping of accelerating mode by the absorber will be less than 0.1%.

TRAPPED HOM'S IN THE CAVITY

On the other hand, since symmetry will collapse without tapered ducts between the cavities, the number of HOM increases. Furthermore, decreasing beam bore diameter causes increase of HOM's impedance to some extent and the number of trapped mode also increases. Figures 2 and 3 show the calculated longitudinal and transverse HOM impedances, which were obtained by a 2-D simulation of the cavity. The solid line indicates the critical impedances for the ASP ring. The critical impedance denotes the maximum impedance above which a coupled-bunch instability may occur at the nominal beam current.

The HOM's with frequencies higher than the cut off frequencies of the 125mmϕ beam duct (1.84GHz and 1.41GHz for the TM01 and TE11 modes, respectively) are absorbed by the SiC part. In consequence, their impedances are reduced to the value below the critical impedances. However, the several HOM's with frequencies lower than cut off, are trapped in the cavity itself and can not be absorbed by the SiC part.

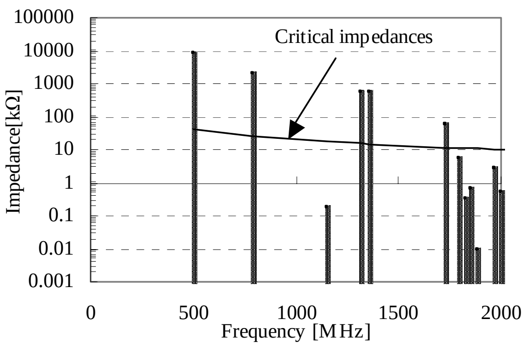

Figure 2: The longitudinal impedances of HOM's

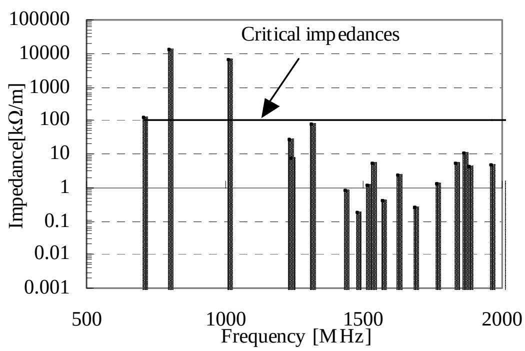

Figure 3: The transverse impedances of HOM's

There are a few methods to avoid the instability due to these trapped HOM's. Frequency detuning of HOM's is one of proper methods. In the PF ring, this frequency-shift method is applied to the cavities and dangerous HOM's are detuned well. Another way to avoid the instability is to reduce the impedances of trapped modes without affecting the accelerating mode by HOM coupler with a rod-shaped coupling antenna. ISSP/KEK people studied the damped cavity with horizontal and vertical rod-shaped coupling antennas which we call "on-centred dampers"[2]. They reported that the HOMs except for TM110 and TM020 could be damped sufficiently when they inserted the rod antennas of dampers at 60mm. Therefore, we tried damping dangerous HOMs by HOM dampers.

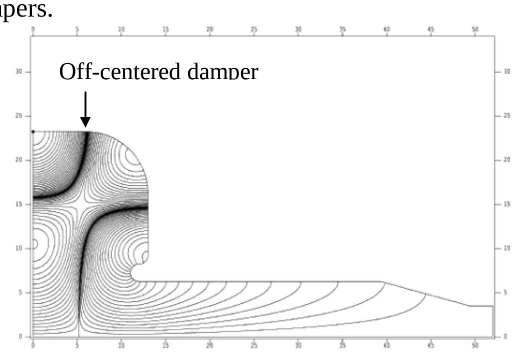

Figure 4: The example of the electric field pattern of HOM (Beam bore diameter 125 mm, TM022-like mode)

Figure 4 shows an example of the electric field pattern calculated for the trapped HOM. According to the electric field pattern shown in Figure 4, it is expected that this type of HOM will be damped by the rod-shaped antenna (off-centred damper) inserted at the position indicated in Figure 4.

Figure 5: Al model cavity with off-centred damper

AN ALMINUM MODEL LOW POWER TEST OF THE HOM COUPLER

In order to study the effect of the off-centred damper as shown in Fig. 5, we carried out the low power test for Al low-power model cavity. This Al model cavity is composed of two beam ports, three tuner ports on the cavity centre, an input coupler port, and eight monitor ports. The taper ducts are symmetrically attached to the beam ports. Coupling coefficient β is adjusted about 2 by rotating loop angle of the input coupler. One movable tuner is attached horizontally which is used to adjust the frequency of fundamental mode. We attached fixed-tuners with a coaxial damper to the remaining tuner ports in both horizontal and vertical directions. The rod antenna is inserted from a small opening on the fixed tuner block. The cavity has two “on-centred” and six “off-centred” monitor ports. The off-centred ports are located 40mm or 50mm from the cavity centre. The off-centred damper was attached to one of these monitor ports. The antenna is followed by a coaxial waveguide and terminated by a load of 50Ω. The length of the antenna can be adjusted by replacing its tips. We measured HOMs through these monitor ports with a small rod or loop monitor. The tuner block and the flange of the model are made of Al, and the rod-antenna and inner conductor of the waveguide are made of copper. All data were taken under atmospheric pressure.

We measured Q value of both the fundamental and the trapped modes changing the rod-antenna lengths and the position of off-centred damper. The measurement were carried out for various lengths of rod-antennas of horizontal (Lh), vertical (Lv) and off-centred (Loff) dampers ranging from 0 mm to 50mm. The distance of the off-centred damper from the cavity centre (Poff) was set to be 40mm or 50mm. Figure 6 shows the measured Q-value of TM020 mode as a function of the antenna length of off-centred damper. The required Q-value which does not induce the coupled-bunch instabilities for the ASP ring is given as a dotted line. As discussed in

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previous section, TM020 mode could be damped by the off-centred damper with antenna length of longer than 40mm.

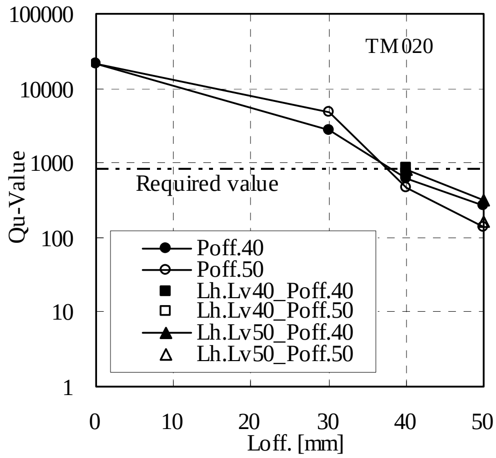

Figure 6: The antenna length of off-centred damper vs. HOM Q-Value

Table 2 summarizes the measured frequencies and Q-values of fundamental and the trapped modes without dampers and with dampers for optimised lengths of rod-antennas. All HOM's except the TM110V and TM110H modes were damped below the required values when we used two centre dampers with the antenna length of 50mm and also used off-centred damper installed at a distance of 40 mm from centre with the antenna length of 40mm. On the other hand, the Q-value of the fundamental mode was not affected by the HOM dampers. For the TM110H and TM110V modes, we would apply the HOM tuner for the frequency shift method that was used for KEK-PF cavity, since the resonant frequencies of those modes strongly depend on the length of fixed tuner block [3].

Table 2: Measured frequencies and Q-values of fundamental and trapped modes

Lh	0mm		50mm(50Ω)			
Lv	0mm		50mm(50Ω)			
Poff	0mm		40mm			
Loff	0mm		40mm(50Ω)			
					Requied Q	
Mode	f[MHz]	Q	f[MHz]	Q	Cu	Al
Longitudinal modes						
TM010	500.4	22225	500.5	20812	-	-
TM011	791.1	12414	784.9	165	453	250
TM020	1314.9	21162	1314.1	790	1538	849
TM021	1357.6	3520	1354.9	518	1001	553
TM022	1719.6	598	not measureble		1175	649
Transverse modes						
TE111H	704.6	19567	692.3	482	27112	14972
TE111V	710.6	12697	707.9	253	27112	14972
TM110V	797.6	2431	797.8	2190	249	138
TM110H	802.6	23844	802.9	21243	249	138
TM111H	1005.8	10957	993.6	71	148	82
TM111V	1011.3	6899	1005.0	75	148	82

Consequently, we confirmed that almost all of the trapped modes could be damped if we would use three rod-shaped dampers, horizontal, vertical and off-centred.

The tapered duct installed actually in the ASP ring is not symmetric. In order to evaluate the asymmetric effect, we carried out 3-D calculation. The electric field pattern, frequencies, Q values and shunt impedances of HOM's up to 2GHz are calculated and compared with 2-D calculation. Figure 7 shows an example of 3-D electric field patterns. As a result, the trapped modes up to 2GHz are found to be consistent with 2-D calculation results. Combined with the cold model test results and 2-D calculation, we could conclude that our final design could comply with the specification of ASP cavity.

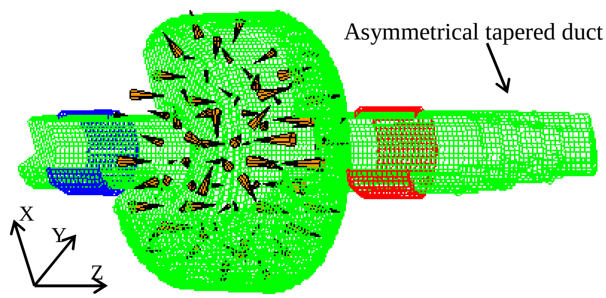

Figure 7: The 3-D electric field pattern (TM022-like mode)

CONCLUSION

In conclusion, we could design the HOM damped cavity whose RF voltage was approximately 0.75 MV/m. The cavity has a SiC microwave absorber and three rod-shaped antennas for damping the longitudinal HOM impedance less than 20kΩ/GHz. According to the low-power test results using Al model, these requirements of ASP specification have been ensured to be satisfied. For this Al model test, HOM measurements were done without SiC duct. We will carry out HOM damping measurements using Cu cavity with SiC duct to optimise the antenna length of the dampers. For two transverse trapped HOMs which could not be damped by HOM dampers, they can be treated so as not to coincide the coupled-bunch mode frequencies by the frequency shift method. We will also test and adjust the HOM tuner for this method using the Cu cavity mentioned above. Up to now the experimental results obtained from Cu cavity low-power test are consistent with the Al model test.

REFERENCES

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