HIGHER ORDER MODE (HOM) DAMPER OF 500MHZ DAMPED CAVITY FOR ASP STORAGE RING

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Abstract

TOSHIBA has delivered the storage ring RF system for the Australian Synchrotron Project (ASP). Two pairs of the 500MHz Higher Order Mode (HOM) damped cavities were applied for this system. Two types of dampers were attached for damping the longitudinal HOM impedance down to less than 20kΩ/GHz. In order to reduce the coupling of off-centred damper with accelerating mode and to reduce the heat load of damper, new HOM damper was designed by optimizing SiC absorber structure and damper antenna length using HFSS [1] code. The design and manufacture of the new HOM damper and the results of high power test are described.

INTRODUCTION

We have designed the 500MHz HOM damped cavity for Australian Synchrotron Project (ASP) storage ring, which is under commissioning in Melbourne [2]. The ASP project aims to construct a third-generation 3.0GeV ring with a beam current of 200mA and a circumference of 216m[3].

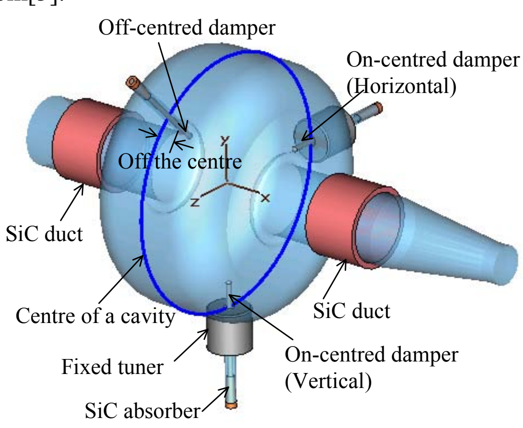

Figure 1: A schematic diagram of a half of the pair cavities with three original dampers

Figure 1 shows a schematic diagram of a half of the pair cavities with three HOM dampers. The HOMs excited in the cavity are guided out of the cavity through the beam duct and dissipated in the SiC absorber at SiC ducts. The several HOMs with frequencies lower than the cut-off frequency however, trapped in the cavity. In order to dump them, horizontal and vertical rod-shaped coupling antennas on the cavity centre (on-centred dampers)[4] and one off the cavity centre (off-centred damper) are attached as shown in Figure 1. They are able to damp well the trapped HOMs whose electric field concentrate on or off the cavity centre. Each on-centred dampers has a fixed tuner block to apply the frequency shift method to the HOMs whose resonant frequencies strongly depend on the length of those blocks [5].

In our previous study, we confirmed that the longitudinal HOM impedances were damped less than 20kΩ/GHz with these three dampers [2].

DESIGN OF THE ORIGINAL AND NEW HOM DAMPER

On the other hand, since off-centred damper is at asymmetrical position to the electric field pattern of the accelerating mode, there would be some coupling with the accelerating mode [6]. The coupling with the accelerating mode of off-centred damper measured 2.5%, which would cause 2kW absorption into SiC absorber at 80kW operation power. In order to reduce the effect of coupling with accelerating mode, we started to design new HOM damper for high power operation.

The original HOM damper had been developed to apply in the centre of the cylindrical wall of the cavity for KEK-PF and does not couple with the accelerating mode [7]. Figure 2 shows the cross-sectional view of the original HOM damper. The SiC absorber is fixed between the inner and outer conductors at the end of the coaxial line.

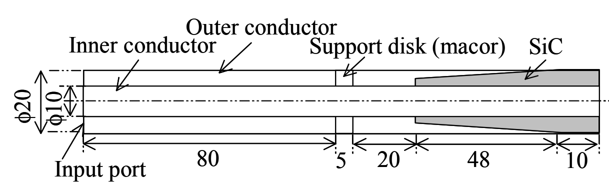

Figure 2: Cross-sectional view of the original HOM damper

In order for new off-centred damper to improve the heat load distribution, the volume of SiC absorber and the area of thermal contact with Cu conductor are increased by moving the position of SiC absorber which has cylindrical shape, from inner to outer conductor. The cross-sectional view of new off-centred damper is shown in figure 3. We also changed the diameter of inner conductor from 10mm to 15mm to prevent multipacting between inner and outer conductor gaps.

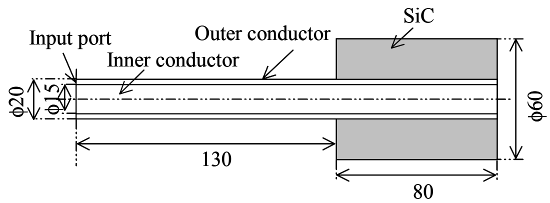

Figure 3: Cross-sectional view of new off-centred damper

In addition, we carried out electromagnetic simulation using HFSS to evaluate the heat load by absorption of the accelerating mode. In the original design, the power reflection for frequency ranging from 0.8GHz(TM011) to 1.7GHz (TM022) could be less that 5% as shown in figure 4 (solid line with square). However, the power reflection for accelerating mode (TM010 around 0.5GHz) is about 35% and it is assumed that 65% of accelerating mode is absorbed by SiC absorber.

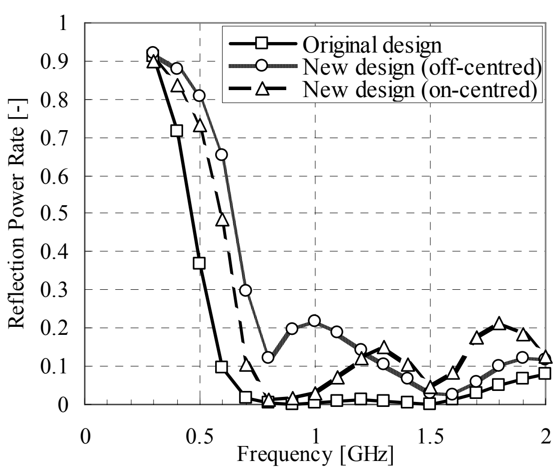

Figure 4: Reflection characteristic of HOM damper for original design and new design by HFSS code

The grey line with circle in figure 4 shows the reflection coefficients in power vs. frequency for new off-centred damper. By adjusting the length and diameter of SiC as 80mm and 60mm respectively, we achieved the reflection coefficient for off-centred damper effective HOM's frequency around 0.8GHz, 1.3GHz(TM012) and 1.7GHz less than 20% and that for the accelerating frequency around 500MHz approximately 80%, which is more than twice as large as the original design.

As for on-centred dampers, although they do not couple with accelerating mode, we changed the position of SiC from inner to outer conductor to improve the heat load distribution. The diameter of inner conductor is kept 10mm to utilize original HOM's fixed tuner part. The cross-sectional view of new on-centred damper is shown in figure 5.

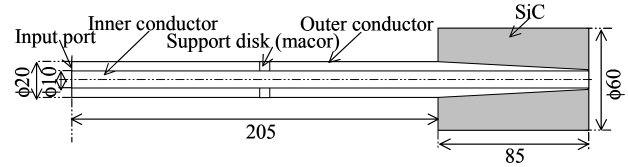

Figure 5: Cross-sectional view of new on-centred damper

The dotted line with triangle in figure 4 shows the reflection characteristic for new on-centred damper, which has good transmissions for HOM's frequency ranging from 0.8GHz to 1.7GHz.

LOW POWER TEST USING A MODEL DAMPER

Furthermore, we performed low power test using modified coaxial damper with inner diameter of 15mm in order to optimize the antenna length for new off-centred damper. The antenna of a modified damper is followed by a waveguide and terminated by a load of 50Ω. In this test, two original on-centred dampers are set to their position at the same time. The Q-value vs. insertion length of the antenna was measured as shown in table 1. From these results, we selected 30mm as the insertion length of the antenna for off-centred damper to satisfy the HOM damping requirements. The coupling with accelerating mode measured 0.25% if the antenna length was 30mm. The absorption power at normal operation power of 80kW is estimated as 200W that is ten times lower than that of the original damper.

Table 1: Low power test results using model damper

Type		Original	TEST1	TEST2	TEST3
Insertion length of antenna		45mm	20mm	30mm	45mm
Diameter of inner conductor		10mm	15mm	15mm	15mm
Coupling with TM010		2.5%*	0.09%	0.25%	0.9%
Q-value	TM011	135	206	209	190
	TM012	n.m.	719	n.m.	n.m.
	TM021	n.m.	n.m.	n.m.	n.m.
	TM022	n.m.	n.m.	n.m.	n.m.

n.m.: not measurable, *measured using original off-centred damper

LOW POWER TEST FOR THE NEW HOM DAMPERS

Based on the study mentioned above, we designed and manufactured new HOM dampers. In order to check the performance of new dampers, we carried out low power test with a pair of ASP cavities. At first, we measured the frequency of accelerating mode with and without bellow between paired cavity. The frequency difference is about 10kHz. This result shows that the coupling of paired cavity is negligible.

We measured Q-value of HOMs with and without dampers changing off-centred damper type (Doff), horizontal and vertical on-centred damper types (DonH and DonV). The antenna length of the new on-centred damper remained the same 50mm as the original one. Table 2 summarizes the measured Q-value of accelerating mode and the trapped modes. For longitudinal HOMs, TM011, TM012, TM021 and TM022, Q-value could be damped below the required values by new dampers even without vertical on-centred damper. Consequently, we confirmed that all longitudinal HOMs could be damped less than the required values if we would use new off-centred damper and horizontal on-centred damper.

For transverse modes, TE111H,V and TM111H, Q-values could be damped below the required values by new dampers. HOM tuners would shift the frequency of TM110H,V and TM111V in order to lower the effective shunt impedance for coupled bunch instability.

Table 2: Low power test results for new dampers

Cavity	Single	Pair	Pair	Pair		
Doff	-	Original	New	New		
DonH	-	Original	New	New		
DonV	-	Original	New	-		
mode name	Q value	Q value	Q value	Q value	Qcal	Required Q
TM010	43020	42482	39545*	39591*	41504	□
TM011	5011	143	337	447	36096	453
TM012	1331	n.m.	828	914	57989	1538
TM021	9854	n.m.	n.m.	n.m.	36692	1002
TM022	1681	n.m.	n.m.	n.m.	6222	1173
TE111H	2351	261	529	489	31778	27119
TE111V	1442	204	382	4839	31778	27119
TM110H	21792	26169	31886	31319	31193	249
TM110V	2887	3585	3862	3667	31193	249
TM111H	7394	n.m.	n.m.	n.m.	9402	148
TM111V	8180	378	n.m.	1903	9402	148

n.m.: not measurable, *measured by S21 transmission method

THERMAL TEST FOR THE NEW HOM DAMPER

We performed a thermal test for new off-centred damper to confirm the heat load of SiC absorber. We attached off-centred damper to the beam port of an ASP cavity as shown in figure 5.

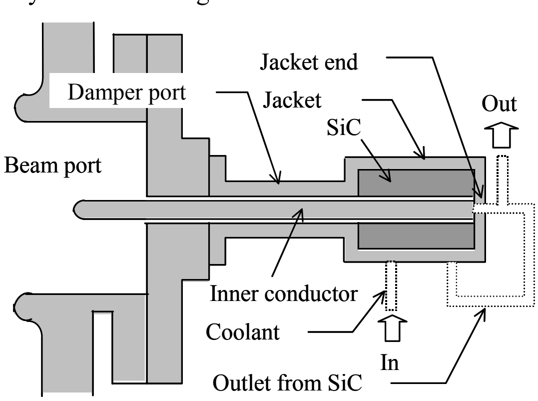

Figure 5: Draft design of the thermal test

The results are shown in figure 6. The SiC input power by HOM absorption increases almost linearly as the klystron power increases. The temperature rise at various position of off-centred damper is proportional to SiC input power. We measured the coupling of the new off-centred damper with accelerating mode in advance and that was estimated as 0.17%. On the other hand, we can roughly evaluate SiC input power by HOMs from the low power test results. Assuming that TM012 and TM022 are absorbed mainly by the off-centred damper, SiC input power is estimated at beam current of 200mA. Estimated SiC input powers at normal operation are plotted in figure 6. The temperature rise at estimated SiC input power is lower than 20 degreesC. As a result, the heat load of the new off-centred damper is appropriate for ASP cavity operation with beam current of 200mA.

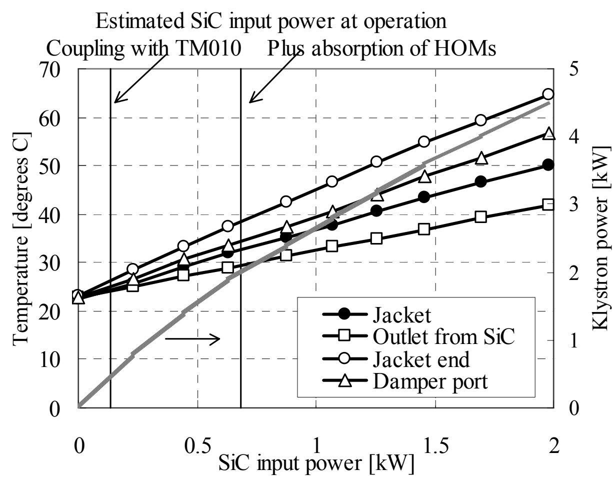

Figure 6: Thermal test result of off-centred damper

CONCLUSION

In conclusion, we have designed and manufactured HOM dampers for ASP project. The off-centred damper has been optimized to have a coupling with accelerating mode as low as 0.25%. These HOM dampers with SiC absorber could damp the trapped HOM at the ASP cavity. The heat load of this SiC absorber up to 2kW is confirmed by high power thermal test. High power test with ASP cavity at operation power will be done as well to confirm high power performance.

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