REDUCED LENGTH DESIGNS OF 500 MHZ DAMPED CAVITY USING SIC MICROWAVE ABSORBER

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Abstract

Shorter designs of the 500 MHz damped cavity using silicon-carbide (SiC) microwave absorber have been studied. Two possible designs to reduce the cavity length efficiently are presented in this paper. One is a conservative design to adopt a shorter SiC beam duct and a shorter taper transition. The other is a design basing on a parallel-plate radial transmission line, which has SiC absorbers at the outer end. The feasibility of applying them to the straight-section upgrade project of the Photon Factory (PF) storage ring is also described.

INTRODUCTION

We have developed a 500 MHz rf cavity with a simple damped structure of higher order modes (HOMs) [1]. The cavity has a large diameter beam duct (140 mm) made of an SiC microwave absorber. Figure 1 shows a cross sectional view of the damped cavity. The HOMs excited in the cavity are guided out of the cavity and dissipated by the absorber. Since the frequency of accelerating mode is sufficiently below the cutoff frequency of 140 mmϕ beam duct, accelerating mode is not affected by the absorber. Only several HOMs, which have a frequency lower than the cutoff (The cut off frequencies of the 140 mmϕ duct are 1.64 GHz for TM01 and 1.26 GHz for TE11), are trapped in the cavity and remain having high impedance. To avoid the instabilities due to the “trapped modes”, the frequency-shift method using two fixed tuners is applied [2]. The fixed tuner is a blank-flange, which have a properly chosen block length to adjust the HOM frequencies so as not to coincide the coupled-bunch mode frequencies.

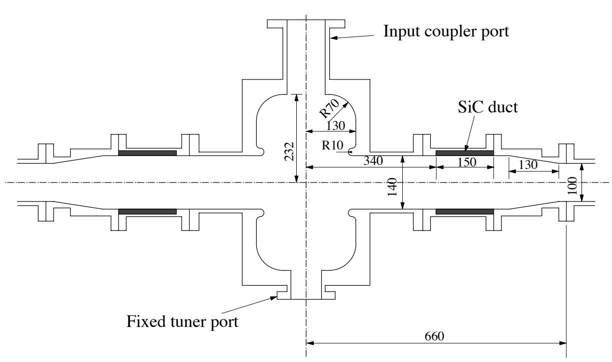

Figure 1: The original design of the damped cavity.

The damped cavities have been installed in the PF ring at KEK in 1996 and 1997. They have been operating without any serious troubles for more than seven years [3] and the cavity-induced coupled-bunch instabilities are completely overcome by the damped cavities. The cavity has also been adopted to the New SUBARU storage ring in University of Hyogo [4] and the SAGA light source, a 1.4-GeV storage ring under construction in Saga prefecture [5]. In addition, the cavity will be applied to the Super SOR storage ring, a future Japanese high-brilliance synchrotron light source in the vacuum ultraviolet and soft x-ray region [6].

Main parameters of the damped cavity are listed in Table 1. The damped cavity has a total length of 1.32 m or 1.38 m depending on the beam duct shape, which is connected to the cavity section. The length is relatively long and a shorter design is preferable for the Super SOR ring to save space of the cavity section and to make room for the other components, such as steering magnets, beam monitors and pumping ports.

In 2005, the PF ring will be reconstructed for straight-section upgrade project. The new lattice will lengthen the straight-sections for the rf cavities and make possible to install a short undulator to each section together with the cavities. Therefore, reducing the cavity length enables to install a longer undulator.

Table 1: Main parameters of the original damped cavity.

Frequency [MHz]	500.1
Shunt impedance [MΩ]	6.8
Unloaded Q	39000
Maximum wall loss [kW]	150
Coupling coefficient	2.3 for the PF ring
	1.7 for the Super SOR ring
Cavity diameter [mm]	464
Cavity gap length [mm]	220
Total length [mm]	1320 for 100mmϕ duct
	1380 for 90 mmϕ duct

In this paper, we present two reduced length designs of the damped cavity by modifying the beam duct and absorber. The design of central part of the cavity is the same as the original one shown in Fig. 1 and the property of the accelerating mode is not changed. One reduced length design is obtained by a straightforward way, shortening the lengths of the SiC absorber and the taper transition of beam duct. The other design is adopting a new damping scheme using parallel-plate radial transmission line. In these design studies, target values of HOM impedance were set to be a few kΩ for the longitudinal modes and a few tens of kΩ/m for the transverse modes. These values are the same orders as the HOM impedances of the original design [1].

REDUCED LENGTH DESIGNS OF THE DAMPED CAVITY

Cavity with SiC duct

Figure 2 shows the cross sectional view of the shorter design of the cavity obtained by reducing the absorber and taper lengths.

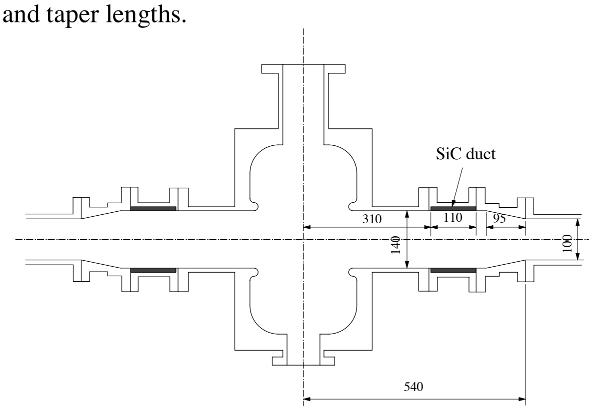

Figure 2: The shorter length design of the damped cavity.

The HOMs calculated using MAFIA 2D are listed in Table 2 up to the cutoff frequencies of the 100 mmϕ beam duct (2.30 GHz for TM01 and 1.76 GHz for TE11). In these calculations, the resistivity of the SiC was assumed to be 20 Ωcm. All HOMs with frequencies higher than the cutoff value of 140 mmϕ duct are dissipated well.

Table 2: HOMs of the cavity with SiC duct.

Longitudinal modes			Transverse modes		
Frequency [GHz]	Q	Rs [kΩ]	Frequency [GHz]	Q	Rt [kΩ/m]
0.7948	36554	1908.19	0.7061	44076	327.43
1.1624	54656	1.18	0.7927	47194	12976.66
1.3130	56808	527.09	0.9915	20036	8997.53
1.3738	41206	366.38	1.1925	802	22.61
1.6678	36	0.01	1.2250	1153	0.04
1.6717	31	0.00	1.2826	109	2.42
1.7304	65	0.08	1.3017	25	0.00
1.7567	60	0.04	1.3268	23	0.81
1.7827	116	0.77	1.4005	38	0.01
1.8037	164	0.10	1.4518	54	0.71
1.8301	215	0.03	1.5109	111	2.26
1.9196	90	0.18	1.5299	729	13.14
1.9440	77	0.16	1.5641	236	0.01
2.0483	96	0.07	1.6057	127	3.96
2.1045	73	0.05	1.6524	85	0.00
2.1670	106	0.28	1.7258	84	0.00
2.1720	561	1.06			
2.2323	130	0.32			

Since the frequency-shift method is effective for the modes with high Q-value, the SiC duct should be positioned keeping the appropriate distance from the center of cavity so as not to damp the Q-values of trapped modes by halves. Especially, to maintain high Q-value of the TM111-like mode (transverse 0.99 GHz), it is preferable that the SiC duct is not set closer to the center than the position shown in Fig. 2.

Cavity with radial line damper

The other reduced length cavity, proposed in this paper, has parallel-plate radial transmission lines on the beam duct instead of the SiC duct. Figure 3 shows the schematic view of the cavity with radial line. The outer end of the radial line is terminated by the SiC absorbers, the same material as the beam duct absorber. The HOMs, extracted from the center of the cavity through the beam duct, couple the radial waves in the radial line and are dissipated in the absorber. As shown in this figure, the radial line damper scheme can realize much shorter length than the SiC duct.

The choke mode cavity [7] developed in KEK also employs the radial transmission line to extract HOMs. Since the lowest radial transmission line mode does not have a cutoff frequency, the radial line requires a choke structure to block the accelerating mode. However, the cavity shown in Fig, 3 does not need any filters in the radial transmission line because the frequency of the accelerating mode is sufficiently below the 140 mmϕ cutoff and it is not affected by the radial transmission line.

The calculated HOMs are summarized in Table 3. The HOM impedances are damped to the same order as the case of SiC beam duct.

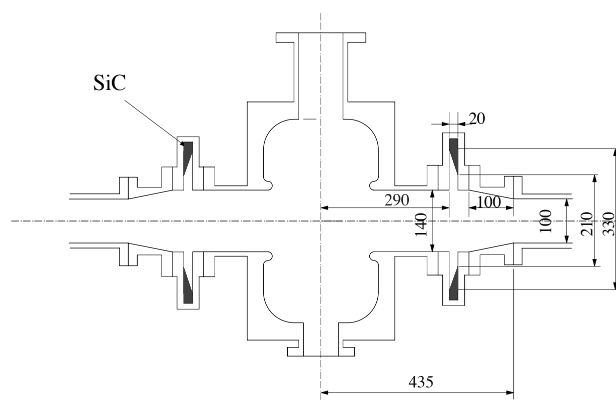

Figure 3: The damped cavity with radial line damper

In order to estimate the wall heating in the radial line damper, loss parameter has been calculated using 2D time domain solver of the MAFIA code. The bunch length dependence of loss parameter is shown in Fig. 4. The loss parameters of the SiC beam duct of 110 mm long are also shown in this figure. For example, the dissipation power at the single bunch operation of 30 mA in the Super SOR ring (the natural bunch length is 4 mm) is calculated to be 120 W from the figure. Although it is not so large power loss, the radial line damper should have a cooling system in the same way as the SiC duct [8].

Table 3: HOMs of the cavity with radial line damper.

Longitudinal modes			Transverse modes		
Frequency [GHz]	Q	Rs [kΩ]	Frequency [GHz]	Q	Rt [kΩ/m]
0.7941	36514	1899.63	0.7059	45191	339.08
1.0567	4	0.21	0.7924	49024	13491.64
1.0567	4	0.03	0.9906	21981	9910.39
1.1625	38439	0.95	1.1915	309	13.08
1.3121	56659	525.66	1.2242	210	2.02
1.3725	27859	245.59	1.2611	5	1.75
1.7022	88	0.03	1.2612	6	0.01
1.7195	50	0.03	1.2898	40	2.83
1.7617	74	0.53	1.3319	65	0.49
1.7916	109	0.11	1.3695	349	1.77
1.8158	89	0.01	1.4581	1264	30.22
1.8808	42	0.05	1.5173	942	10.18
1.9062	56	0.02	1.5450	777	2.09
2.0352	2009	0.24	1.5781	321	9.83
2.0983	794	0.00	1.6214	204	0.64
2.1646	100	0.02	1.6999	174	0.11
2.1718	286	1.07	1.7570	451	3.22
2.2267	39	0.00			

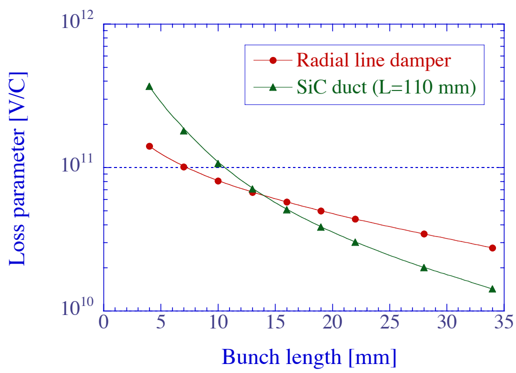

Figure 4: Bunch length dependence of the loss parameters of the radial line damper and the SiC duct.

THE CAVITIES IN UPGRADE PROJECT OF THE PF RING

At KEK, a straight-section upgrade project of the PF ring is now in progress [9]. The project aims at to create six new straight sections and to lengthen the existing eight straight sections for future installation of state-of-arts insertion devices. The reconstruction work will be started in March 2005 and finished in September 2005.

In the present lattice configuration, two 4.23-m straight sections are used for the rf sections and each section has two damped cavities. After the reconstruction, the rf sections will be lengthened and a vacant space of 1.5 m will be created for an undulator. To make more free space and enable to install the longer undulator in the rf sections, we have investigated the feasibility of replacing the beam ducts of cavities by the shorter ones, which are presented in this paper.

The growth rate of the coupled-bunch instabilities for the PF ring after the reconstruction was estimated using the Wang formalism for Gaussian bunches [10]. Figure 5 shows the longitudinal and transverse critical impedances per one cavity. They are calculated from the balance between growth time and radiation damping time at the nominal stored current of 450 mA. Impedances of the most of HOMs, which are listed in Tables 2 and 3, are below the critical impedances except for trapped modes. For the trapped modes, it will be detuned well by the frequency-shift method in the same manner as the present operation. Both of the reduced length designs are applicable to the PF ring after the reconstruction. The shorter SiC-duct scheme and the radial-line damper scheme can make the vacant space in the cavity section for undulater of 2 m and 2.4 m, respectively.

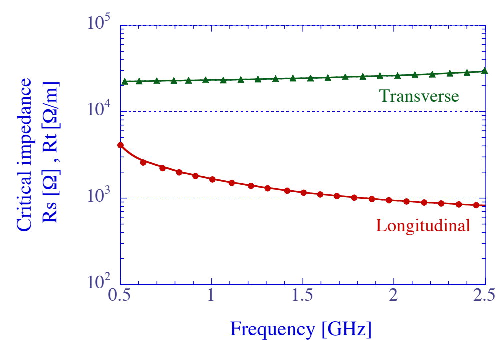

Figure 5: Critical impedances of the coupled-bunch instabilities for 450 mA operation of the PF ring.

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