An RF Cavity with SiC Absorbers

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Abstract

RF properties of a 500 MHz damped cavity for a 2.0 GeV high-brilliant VUV-SX storage ring were investigated. The feature of the cavity is that beam ducts with large diameter are attached to the cavity and that a part of the beam ducts is made of SiC. The higher-order modes (HOM's), which propagate out from the cavity through the beam duct, are damped by the SiC parts. A prototype cavity made of aluminum was fabricated to measure the RF characteristics of the cavity and two types of SiC ducts were tested. It was confirmed that these SiC ducts strongly reduce the Q-values of HOM's in the cavity. In order to estimate wall heating of the SiC ducts, we measured the loss parameters of the SiC ducts using the wire method with the synthetic pulse technique.

1. INTRODUCTION

A 2.0-GeV electron/positron storage ring for high brilliant synchrotron radiation experiment in the region of soft x-ray and vacuum ultraviolet is being designed at the Institute for Solid State Physics of the University of Tokyo in collaboration with the Photon Factory at KEK (National Laboratory for High Energy Physics). The VUV-SX storage ring is aimed at obtaining a low emittance of several nm•rad and maximum beam current of 400 mA. The detailed description of the storage ring is given in ref. [1]. As one of the R&D's for the storage ring, we have designed a new cavity which has a simple damped structure, and carried out its low power test on a prototype model.

In order to reduce the HOM's impedance, beam ducts with large diameter are attached to the cavity and a part of the beam ducts is made of a SiC. Since the frequency of accelerating mode is sufficiently below the cutoff frequency of the beam duct, the accelerating field is fully trapped in the cavity. On the other hand, the HOM's, of which frequencies are above the cutoff frequency of the beam duct, are damped by the SiC region.

The Schematic of a quadrant of the designed cavity is shown in Fig. 1. The cavity shape was optimized with SUPERFISH and URMEL. In these calculations, the power loss of HOM's on the SiC duct was estimated by taking into account the conductivity of the SiC's. Small nose cones are effective not only to increase the shunt impedance of accelerating mode but also to prevent the accelerating field from reaching to the SiC region.

Table 1 shows the parameters of RF system of the VUV-SX storage ring.

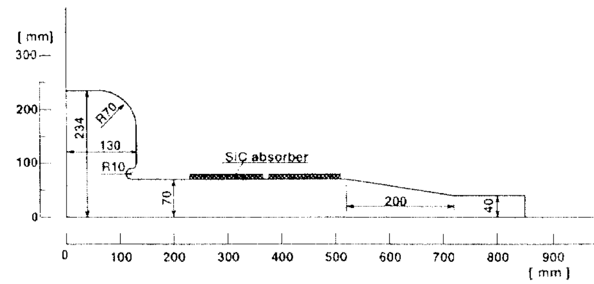

Figure 1 : Schematic view of the cavity.

Table 1 : RF parameters of the VUV-SX storage ring.

Frequency	500 MHz
Harmonic number	624
Energy loss / turn	213.8 keV
Bunch length (σ_b)	13.3 ps
Number of the cavity	3
Gap voltage	0.5 MV
Bucket height	3.0 %
Shunt impedance (R_s)	7.68 MΩ
Unloaded Q	44000

2. LOW POWER MEASUREMENTS ON THE PROTOTYPE CAVITY

Three types of beam duct were prepared for the low power test. One duct was made of aluminum and the other two ducts were made of SiC. A type of SiC duct is made of TPSS("reaction-bonded SiC", Toshiba Ceramics) and its resistivity is about 0.2~0.4 Ωcm in the frequency range between 1.5 GHz and 4.5 GHz. The other type of SiC duct is made of CERASIC-B("pressureless sintered SiC", Toshiba Ceramics) and its resistivity is 20 Ωcm in the same frequency region. The TPSS duct is 135 mm long and two TPSS ducts were installed in each side of the cavity as shown in Fig. 1. Then the SiC part was positioned at 230 mm away from the cavity center. On the other hand, CERASIC-B duct is 98 mm long and since its resistivity is larger than TPSS, only one CERASIC-B duct was installed in each side of cavity 300 mm away from the cavity center. The RF characteristics of both fundamental and HOM's were measured using a network analyzer (HP8510C).

2.1 Field distribution

The field distribution in the cavity was measured with the method of perturbation technique[2,3,4]. For longitudinal modes, a metallic sphere was used as a field perturbing object, while for the transverse modes a stainless needle was used. The sphere was moved on-axis and the needle was moved at a radial offset of 20 mm. A measured result of the fundamental mode is shown in Fig. 2. The value of Rs/Q, obtained from the field distribution, was 168Ω and the value calculated by SUPERFISH was 177Ω. We measured the field distributions of all longitudinal HOM's below the cutoff frequency of the 80 mmø duct, and the field distributions of some of transverse HOM's. The measured field distributions well agree with those calculated by SUPERFISH and URMEL. Figure 3 shows a measured example of a longitudinal HOM (TM0-ME-15 according to the URMEL notation).

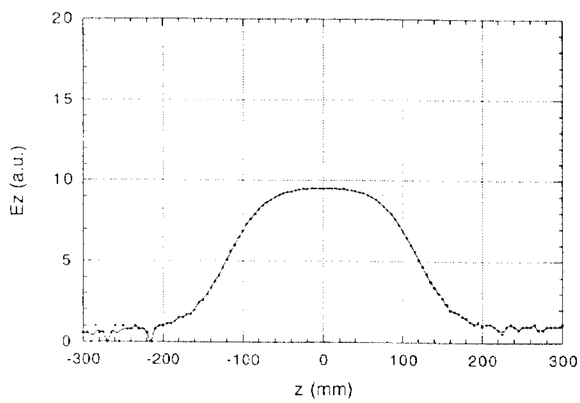

Figure 2 : Field distribution of the accelerating mode.

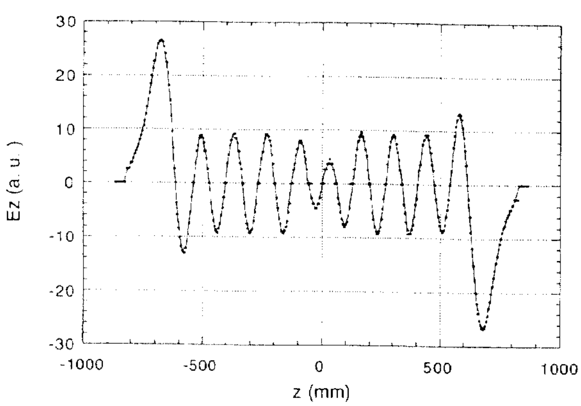

Figure 3 : An example of the field distribution of a longitudinal HOM.

2.2 Q-value measurement

The measured resonant frequencies and Q-values are summarized in Table 2 and Table 3. The measured and calculated Q-values are denoted as Q_m and Q_c, respectively. For the calculations, we assumed that the resistivity for Al alloy is 5.0×10^{-6} Ωcm, for TPSS 0.3 Ωcm and for CERASIC-B 20 Ωcm. As seen in these tables, the measured Q-values are consistent with calculated ones.

The Q-values for most of HOM's were largely reduced in the case of the SiC ducts. Since the resistivity of the CERASIC-B is larger than that of TPSS, CERASIC-B is more suitable than TPSS for our purpose.

3. LOSS PARAMETER MEASUREMENTS OF THE SIC DUCTS

The wall heating due to ohmic loss in the SiC duct is one of the important problems for our cavity. We measured the loss parameters of the SiC ducts by using the wire method with the synthetic pulse technique[5,6]. The span of the bunch length σ_b is ranging from 23.0 ps to 78.0 ps in this measurement. The results are shown in Fig. 4 and 5. The solid curves are the loss parameters calculated by [7]:

$$k(\sigma_b)=\frac{1}{\pi}\int_0^{\infty} Re\,\{Z(\omega)\}e^{-\omega^2\sigma_b^2}d\omega,$$

where $Z(\omega)$ is the impedance of the duct and we assumed it to be resistive wall impedance[8]:

$$Z(\omega)=(1+i)\frac{L}{2\pi\delta b\sigma}.$$

Here δ is the skin depth, σ the conductivity of the duct. The b and L are radius of the duct and its length. As shown in the figures, the measured loss parameters are well reproduced by these simple formulae.

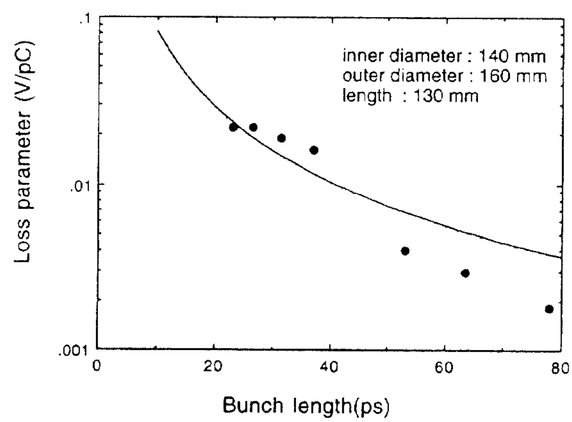

Figure 4 : Loss parameter of the TPSS duct.

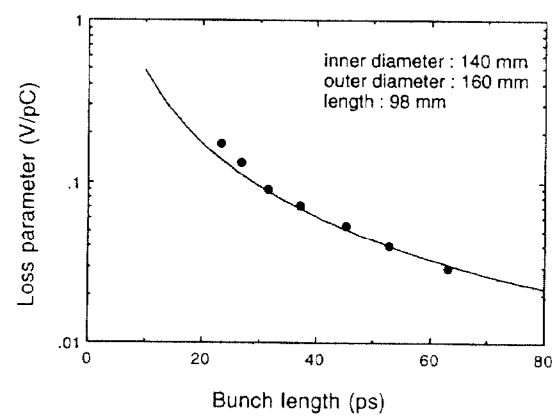

Figure 5 : Loss parameter of the CERASIC-B duct.

Table 2 : Summary of Q-values for Al and TPSS ducts.

	Longitudinal mode					Transverse mode			
	Al duct		TPSS duct			Al duct		TPSS duct	
Freq.(MHz)	Q_m	Q_c	Q_m	Q_c	Freq.(MHz)	Q_m	Q_c	Q_m	Q_c
496.47	24000	25000	24000	25000	702.93	24000	30000	22000	27000
790.91	22000	22000	21000	22000	786.05	26000	33000	24000	28000
1153.1	32000	35000	31000	34000	985.81	18000	25000	12000	14000
1308.6	32000	33000	33000	33000	1189.5	24000	31000	-	1500
1362.3	24000	27000	23000	25000	1216.2	39000	49000	-	2900
1660.2	17000	24000	100	110	1276.8	19000	21000	200	210
1662.7	18000	23000	-	120	1287.3	15000	18000	-	90
1710.6	24000	27000	290	300	1305.9	16000	20000	130	120
1729.5	22000	24000	200	200	1363.7	18000	20000	210	170
1754.7	23000	25000	350	310	1399.5	17000	21000	180	150
1786.3	29000	31000	690	570	1456.5	17000	23000	270	220
1801.8	40000	42000	690	590	1502.1	30000	38000	510	490
1852.6	24000	27000	290	270	1529.6	30000	33000	1300	690
1869.7	24000	28000	320	280	1547.9	19000	24000	480	370
1968.7	25000	30000	320	270	1581.1	31000	35000	640	470
1995.7	24000	26000	300	240	1635.9	20000	28000	410	340
2067.3	33000	33000	350	390	1685.3	23000	27000	290	320
2127.4	28000	28000	320	290	1749.8	21000	29000	390	340
2160.1	23000	28000	350	360	1798.9	22000	27000	540	410
2177.4	22000	26000	-	1100	1850.1	-	75000	33000	25000
2232.6	29000	29000	510	450	1869.3	27000	33000	550	450
2292.6	25000	27000	340	310	1881.0	21000	27000	560	580
2320.4	26000	29000	510	460	1945.9	-	35000	960	760
2402.4	29000	33000	460	540	1986.9	24000	30000	600	470
2449.1	27000	28000	420	340					
2479.0	38000	43000	630	710					
2541.4	28000	34000	770	370					
2581.9	27000	30000	450	400					
2590.4	35000	35000	4500	3900					

Table 3 : Summary of Q-values for CERASIC-B duct.

Longitudinal mode			Transverse mode		
Freq.(MHz)	Q_m	Q_c	Freq.(MHz)	Q_m	Q_c
496.41	25000	24000	702.87	22000	28000
785.99	23280	22000	785.99	23000	30000
1153.0	30000	34000	985.72	12000	14000
1308.5	33000	33000	1189.0	500	800
1362.2	23000	25000	1215.8	-	1420
1663.9	-	40	1279.7	-	130
1669.4	40	30	1302.8	-	30
1720.5	120	60	1393.3	70	40
1756.5	90	70	1447.8	110	60
1777.5	160	130	1509.4	190	130
1806.5	200	120	1520.0	790	840
1827.0	200	160	1558.8	370	250
1931.5	120	100	1602.5	170	130
1955.0	100	70	1648.5	100	90
2044.0	160	100	1726.9	160	100
2126.0	130	80	1779.9	160	120
2155.0	-	2500	1845.2	-	3300
2186.5	90	130	1855.9	200	150
2246.5	170	140	1872.0	240	180
2307.3	-	140	1945.0	210	230
2310.5	-	80	1989.0	150	140
2402.3	-	170	2014.0	620	470
2471.9	120	110	2076.0	190	170
2553.8	180	130			
2590.0	800	700			
2612.0	150	150			
2645.7	-	200			
2695.9	170	120			
2761.0	180	160			

For the design value of bunch length of VUV-SX ring, the loss parameter of the CERASIC-B duct is calculated to be ~0.3 V/pC. In addition to the ohmic loss, there is wall heating caused by HOM losses. According to a rough estimation of the HOM losses, SiC duct should be water-cooled in single-bunch operation of the VUV-SX storage ring.

4. ON-GOING R&D

For the result of this low power test, we decided that we use CERASIC-B as the HOM's absorber of the damped cavity. The low power study of the prototype model is still in progress, in particular to optimize the cavity shape and the position and length of the CERASIC-B section. And then, the effects of the tuner and coupler on the RF characteristics will be investigated using the prototype. In addition, we are also fabricating a high power model of the cavity. A high power test of the CERASIC-B duct is well under way.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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