HOM Coupler for the Damped Cavity of High Brilliance SR Source

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Abstract

The higher-order mode (HOM) coupler with a rod-shape antenna has been designed to reduce Q-values of the trapped HOM's. The antenna is inserted in the cavity from a small opening on the fixed tuner block and strongly couples some of HOM's. Two model couplers have been fabricated and tested in low-power levels. It was found that they can reduce Q-values of the six trapped HOM's without influence on the accelerating mode.

1 INTRODUCTION

We developed a 500 MHz RF cavity in collaboration between Institute for Solid State Physics (ISSP) of the University of Tokyo and KEK. 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 of 140 mm in inner diameter, and dissipated in SiC microwave absorber [1, 2].

In 1996, two cavities of this new type were installed in the Photon Factory (PF) storage ring to replace two out of four cavities. The new cavities operated successfully and no transverse and longitudinal instabilities due to them were observed. As a result, the maximum stored current of 773 mA was achieved; it is a new record of the PF ring and is about 250 mA larger than the last record up to then [3]. The remaining two old-type cavities of the ring have also been replaced by the new ones in the summer of 1997.

Table 1: The parameters of the VSX RF system.

	First phase	Second phase
RF frequency	500.1 [MHz]	
Number of cavity	1	3
RF voltage /cavity	0.4 [MV]	0.5 [MV]
Coupling factor	1.5	1.9
Shunt impedance	7.7 [MΩ] (designed)	
Q-value	44000 (designed)	
Nominal beam current	200 [mA]	400 [mA]

The cavity also aims at being installed in the storage rings of Japanese VUV and SX synchrotron radiation source project, the VSX project. The project is a future plan of the University of Tokyo to construct third-generation rings at the Kashiwa campus of the university, and it is composed of two phases; the first phase is to construct a 1.0-GeV racetrack ring with an emittance of 0.7 nm·rad and a circumference of 230 m [4], and second phase is to construct a 2.0-GeV four-fold symmetric ring with an emittance of 5.1 nm·rad and a circumference of 388 m [5]. The parameters of the VSX RF system are listed in Table 1. Though the new cavities are operating at the PF ring quite successfully, our R&D effort is continuing in order to obtain still better performance of HOM's damping for these third-generation low-emittance rings.

2 TRAPPED HOM'S IN THE CAVITY

Figure 1 and 2 shows the calculated longitudinal and transverse HOM impedances, which were obtained by a 2-D simulation of the cavity and these values are listed in Ref. [2]. The solid and dashed lines indicate the critical impedances for the VSX rings of the first and second phases, respectively. 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 140 mmϕ beam duct (1.64 GHz and 1.26 GHz for TM01 and TE11 modes, respectively) are absorbed by the SiC part. In consequence, their impedances are reduced to the values below the critical impedances. However, the several HOM's, with frequencies lower than the cutoff, are trapped in the cavity itself and can not be absorbed by the SiC part.

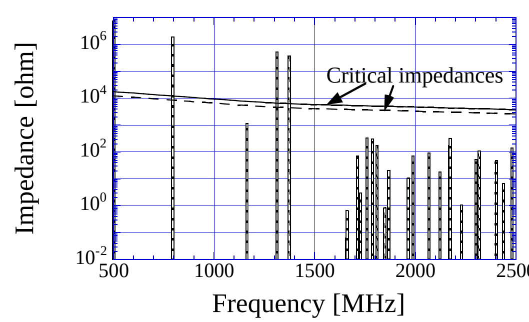

Figure 1: The longitudinal impedances of HOM's.

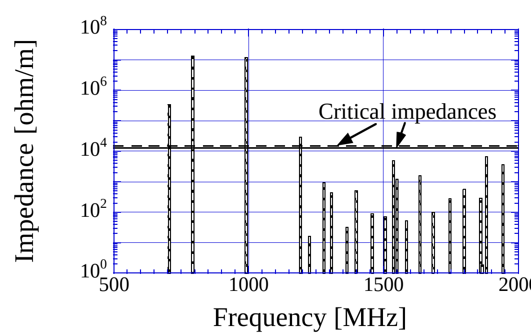

Figure 2: The transverse impedances of HOM's.

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. The cavity has a side and a bottom ports for fixed tuners. The fixed tuner is a cylindrical copper block with an ICF-flange and used to pad the port space [6]. Since the resonant frequencies of HOM's are shifted by changing the lengths of the copper blocks, we can detune the HOM's not so as to induce the instabilities by choosing proper lengths of the blocks [7, 8]. In the PF ring, this frequency-shift method is applied to the cavities and dangerous HOM's are detuned well [3]. For a ring with a larger circumference, however, the frequency detuning becomes less effective, because of its low revolution frequency.

Another way to avoid the instability is to reduce the impedances of trapped modes without affecting the accelerating mode. For this purpose, we have designed and fabricated low-power models of HOM coupler with a rod-shaped coupling antenna. As the cavity shape resembles a simple pill-box form, it is expected that the rod antennas inserted from the side and the bottom ports can couple HOM's with good mode selectivity.

3 A LOW POWER STUDY OF THE HOM COUPLER

We attached the low-power models of the HOM coupler to both side and bottom fixed-tuner ports of the cavity. The coupler at the side port is called "horizontal coupler" and at the bottom port is "vertical coupler". Figure 3 shows the schematic view of the coupler mounted on the port. The rod antenna is inserted in the cavity from a small opening on the fixed tuner block. The antenna is followed by a 20D coaxial waveguide and terminated by a 50 Ω load. The tuner block and the flange of the model are made of aluminum, and the rod-antenna and inner conductor of the waveguide are made of copper.

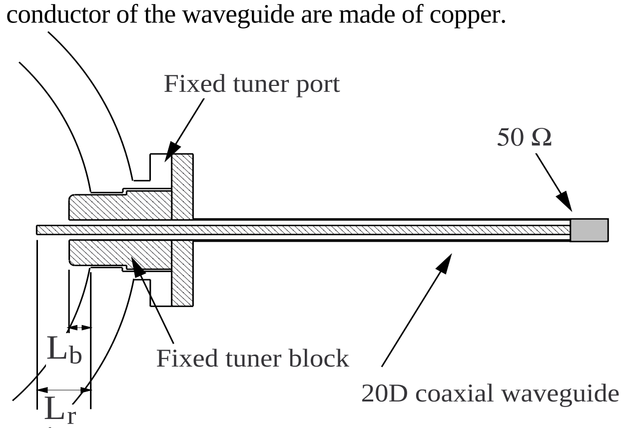

Figure 3: Schematic view of the HOM coupler.

We measured the RF characteristics of the trapped modes changing the rod-antenna lengths, L_r, in Fig. 3, and the fixed-tuner block lengths, L_b, in the same figure.

Table 2 summarizes the measured frequencies and Q-values of the trapped modes for various lengths of rod-antennas. The measurement were carried out in four cases for the lengths of rod-antennas of horizontal (H) and vertical (V) couplers. In the case (I), the H and V couplers were mounted but not loaded with 50 Ω, and in the case (II), (III) and (IV), the couplers were terminated by a 50 Ω load. The Lengths of the fixed tuner blocks, L_b, were set to be 0.0 mm for the all cases. The required Q-values which do not induce the coupled-bunch instabilities for the VSX rings of the first and second phases are also given in Table 2.

Table 2: Measured characteristics of the trapped modes. All data were taken under atmospheric pressure.

	(I)		(II)		(III)		(IV)			
L_r (H)	25 mm (not loaded)		25 mm (50 Ω)		41 mm (50 Ω)		57 mm (50 Ω)			
L_r (V)	25 mm (not loaded)		25 mm (50 Ω)		41 mm (50 Ω)		57 mm (50 Ω)			
									Required Q	
Mode	f [MHz]	Q	f [MHz]	Q	f [MHz]	Q	f [MHz]	Q	VSX1	VSX 2
Longitudinal modes										
TM010	500.10	37000	500.10	37000	500.10	37000	500.10	36600		
TM011	792.79	22000	792.30	2000	790.15	350	785.9	100	250	170
TM020	1312.1	9000	1312.0	9400	1312.1	9000	1312.2	8700	720	500
TM021	1371.2	10000	1371.0	1200	1371.0	160	1379.3	~80	720	500
Transverse modes										
TE111H	700.96	36000	701.04	3700	700.00	640	not measurable		1700	2000
TE111V	706.53	32000	706.64	3200	704.88	500	not measurable		1700	2000
TM110V	788.85	~5000	788.85	~5000	788.88	~5000	788.88	~5000	46	54
TM110H	792.80	42000	793.56	41000	793.51	40000	793.47	40000	46	54
TM111H	985.24	11000	985.92	1300	983.39	160	not measurable		28	33
TM111V	990.34	10000	990.84	1800	988.80	~160	not measurable		28	33

As shown in Table 2, all HOM's except the TM010, TM110 and TM020 modes were strongly damped by the HOM couplers. When the rod antennas of both horizontal and vertical couplers were insert at L_r = 57 mm (case VI), TE111 and TM111 were completely damped and no longer measurable, and TM011 and TM021 were also reduced below the required values. On the other hand, the Q-value of accelerating mode, TM010, was not affected by the HOM couplers.

Consequently, with the HOM couplers, only three modes namely TM110H, TM110V and TM020 remain, which have a possibility to induce the coupled-bunch instabilities.

Figures 4, 5 and 6 show the measured results of frequency dependence of these three modes on the lengths of the fixed tuner blocks, L_b. For the measurements, lengths of the rod antennas were set L_r = 57 mm for both horizontal and vertical couplers. Since the resonant frequencies of TM110V and TM110H modes strongly depend on the length of fixed tuner block (Figs. 4 and 5), the frequency-shift method is very suitable to avoid the instabilities due to them. However, for the TM020 mode, frequency shift by the fixed tuner is not large (Fig. 6), so that frequency detuning is not effective. If the instability due to TM020 were strong for the VSX rings, the other way should be applied to suppress the instability, such as a bunch-by-bunch feedback method.

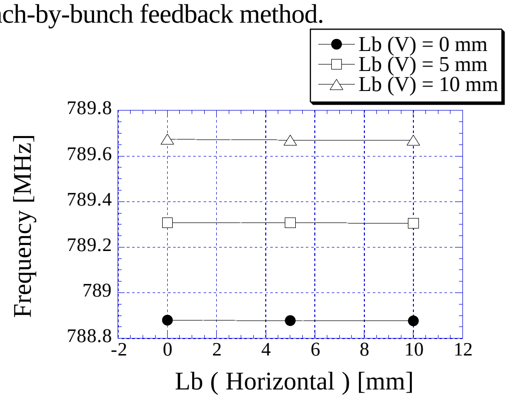

Figure 4: Frequency dependence of TM110V on L_b.

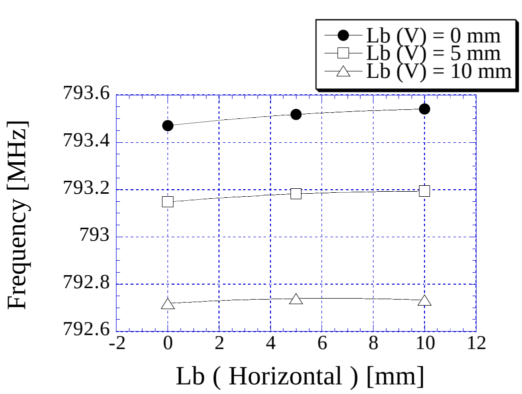

Figure 5: Frequency dependence of TM110H on L_b.

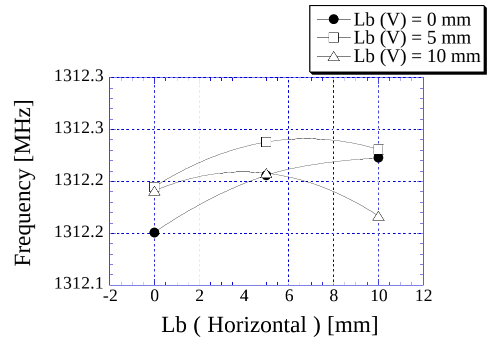

Figure 6: Frequency dependence of TM020 on L_b.

4 CONCLUSION

The HOM coupler with a rod-shape antenna has been designed and tested in low-power levels. It strongly couples some of trapped HOM's and can reduce their Q-values without influence on the Q-value of the accelerating mode. Only three HOM's, TM110V, TM110H and TM020, are not damped by the HOM coupler and remain with high impedance. For the TM110 modes, however, they can be easily detuned by adjusting the lengths of fixed tuner blocks to suppress the instability.

Meanwhile, we are designing a high power model of the HOM coupler. For the high-power model, the rod-shape antenna and inner conductor is made of OFHC copper and cooled by water. The fixed-tuner block is also made of OFHC copper. To dissipate extracted HOM power, the sintered SiC ceramics, which is the same material as the microwave absorber at beam-ducts [9], is mounted on the end of the coaxial waveguide.

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