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LOW-POWER MODEL TESTS OF THE WIDE-BAND CAVITY TO COMPENSATE THE TRANSIENT BEAM LOADING IN THE NEXT GENERATION LIGHT SOURCES*

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Abstract

In the 4th generation light sources, the bunch lengthening using the combination of fundamental and harmonic cavities is useful to mitigate harmful effects due to intrabeam scattering. The performance of the bunch lengthening is significantly limited by the changes in the cavity voltages caused by the transient beam loading effect. To compensate the voltage changes, we proposed and designed a wide-band kicker made by a normal conducting cavity. We manufactured a low-power model of the cavity and measured its performance. We found that the external *Q* of the cavity, which should be small to achieve the wide bandwidth, agreed with the simulation results. We also confirmed that the RF absorbers sufficiently damped the harmful higher-order modes (HOMs).

INTRODUCTION

In the 4th generation light sources, the horizontal beam emittance is expected to be an order of 100 pm-rad or lower. In such ultra-low-emittance rings, the emittance growth induced by the intrabeam scattering (IBS) is a serious issue [1]. To reduce the IBS, bunch-lengthening using the combination of fundamental and harmonic cavities is one of the effective solutions [2].

When the large gaps are introduced in the fill pattern of stored beam, the performance of the bunch lengthening is significantly affected by the transient beam loading (TBL) effect [3]. To compensate the TBL effect, we proposed a compensation technique using a kicker cavity that has a wide bandwidth of 5 MHz and can provide an RF voltage of 50 kV [4]. We examined the optimal parameters of the kicker cavity and investigated its practical design [5]. In this paper, we reported the manufacturing of the low-power model cavity and its performance tests. In the performance tests, we measured the properties of the TM010 mode and checked the damping effect of the HOMs by RF absorbers.

DESIGN OF THE KICKER CAVITY

The design of the kicker cavity was optimized [5] for the use of TBL compensation in the proposed KEK Light Source (KEK-LS) [6] as an example of the 4th generation light sources. The TM010 mode is used to produce the required RF voltage to compensate the TBL effect, and its resonant frequency (1.5 GHz) is the 3rd harmonic of the fundamental radio frequency. Figure 1 shows the 3D view of the kicker cavity and Table 1 shows its parameters. The kicker cavity consists of a normal conducting cavity equipped with two input waveguides, two silicon-carbide (SiC) absorbers, and tapered beam pipes. The RF power is supplied from the two waveguides to the cavity through large coupling holes; this is effective to achieve a small loaded *Q* of accelerating mode. Since the bandwidth is defined as the resonant frequency divided by the loaded *Q*, the small loaded *Q* is essential to achieve the wide bandwidth. We adopted SiC pipes for damping HOMs

The coupling impedances were estimated by an electromagnetic simulation code, CST [7]. Figures 2 and 3 show the estimated longitudinal and transverse coupling impedances. The black and red lines show the impedances without and with absorbers, respectively. The green line shows the threshold condition for the coupled-bunch instabilities using the parameters of the KEK-LS. In the simulations, we used the properties of SiC, CERASIC-B [8]. We found that the coupling impedances were sufficiently reduced by the SiC absorbers.

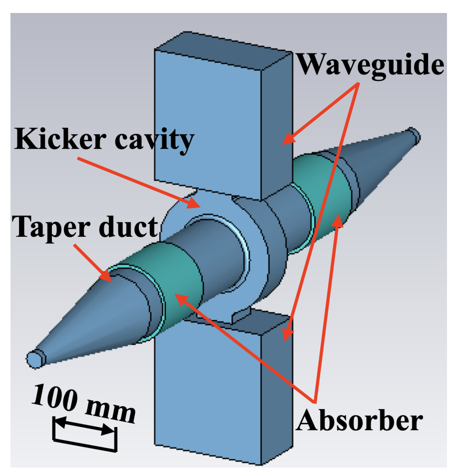

Figure 1: 3D view of the kicker cavity [5].

MANUFACTURING OF A LOW POWER MODEL

To confirm the small loaded *Q* of the TM010 mode and the damping performance of the HOMs, we manufactured a low-power model of the cavity with aluminum alloy. Figure 4 shows the photo of the low-power model. The cavity

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Table 1: The parameters of the kicker cavity

Parameter	Value
Resonant frequency	1.500 06 GHz
R/Q	60.38 Ω
Q_0	17937
Q_L	292.41
Synchronous phase	0 degree
Generator voltage	53 kV
Cavity voltage	44.2 kV
Generator power	40.4 kW
Power loss in cavity	2.59 kW
Reflecting power	15.7 kW
Max power density	21.7 W/cm^2
Absorber loss	3.38 %

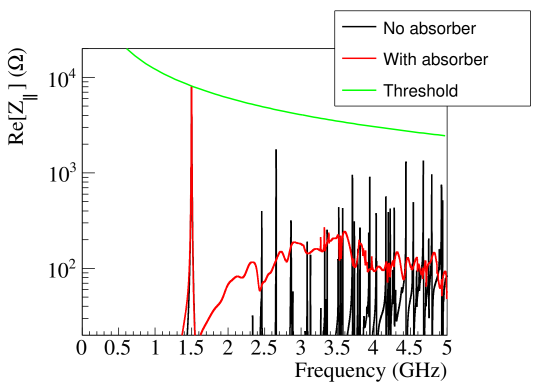

Figure 2: Calculated longitudinal coupling impedances with and without the SiC absorbers.

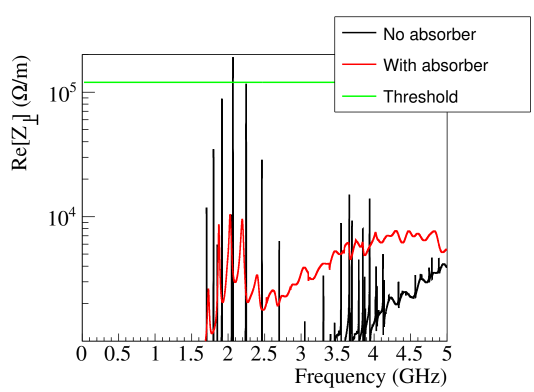

Figure 3: Calculated transverse coupling impedances with and without the SiC absorbers.

was composed of two parts fixed by four bolts. At the end part of the cavity, we arranged two ports to probe the fields of HOMs using loop antennas. We used WR-650 waveguides for feeding RF power. To install the RF absorbers, we prepared ducts having inner diameters of 110 mm. Inside the duct, we inserted the CERASIC-B tube, whose thickness was 5 mm, the inner diameter was 100 mm, and the length was 100 mm. We also prepared ducts having inner diameters of 100 mm in which no material was inserted. After the manufacturing, we measured the dimensions of the all components and found that deviations from design values were within ±5 μm.

LOW POWER MEASUREMENT

We carried out two measurements: one measurement was the S parameters of the TM010 mode to confirm the small loaded Q, the other was that of the HOMs to evaluate the HOMs damping.

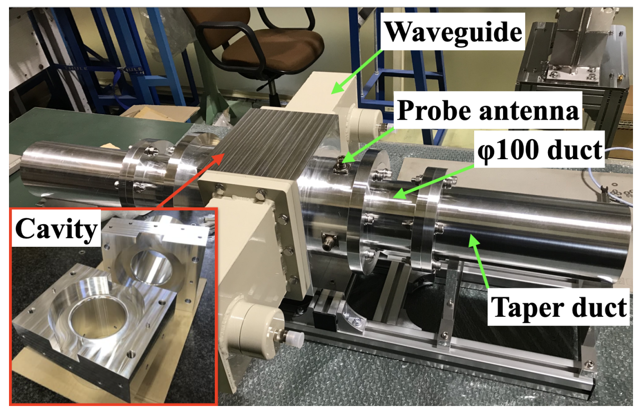

Figure 4: Photo of the low-power model.

S Parameters of the TM010 Mode

To measure the properties of the TM010 mode, we connected both waveguides to the network analyzer through waveguide-coaxial transformers. Figure 5 shows the measured S parameters together with those estimated by the simulations when the SiC absorbers were inserted in the beam ducts. The upper left, upper right, and down figures show the S11, S22, and S21, respectively. From the S21 curve, we found that the measured resonant frequency and bandwidth agreed with those from the simulation satisfactorily.

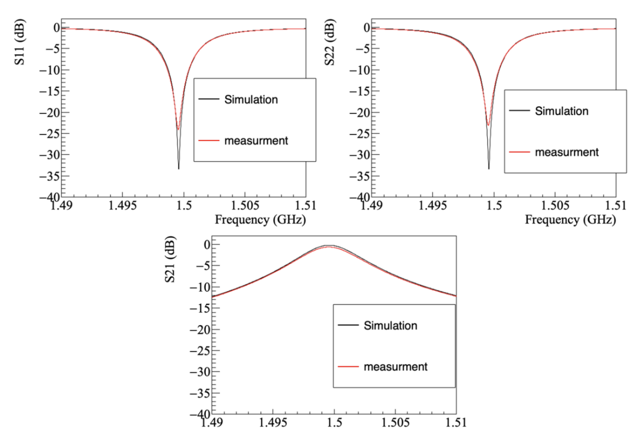

Figure 5: Comparison of the S parameters between measurement and simulation associated with the TM010 mode.

Table 2 shows the comparison on the parameters of the TM010 mode between the measurement and the simulation when the SiC absorbers were put in the beam ducts.

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Table 3 shows the similar comparison without the SiC absorbers. The resonant frequencies in Tables 2 and 3 were deduced from the peaks of the measured S-parameter curves. The loaded Q's were deduced from the 3 dB bandwidth of the S21 curves, and the coupling coefficients were deduced from the curves of the S11 and S22. Other parameters were calculated from the loaded Q and the coupling coefficient. Except for the unloaded Q, all parameters from the measurement agreed with the simulation results. We thought that the difference in the unloaded Q would be caused by the insufficient electrical connection of the cavity parts or the electric conductivity difference between the real one and the assumed one in the simulations. Because the measured external Q agreed satisfactorily with calculated value, we concluded that our kicker cavity realized a sufficiently wide bandwidth. The bandwidth deduced from the measured external Q was 5.15 MHz. Because the measured properties of TM010 mode given in Tables 2 and 3 were almost the same, we also concluded that the SiC absorbers did not affect the TM010 mode.

Table 2: Comparison on the parameters of the TM010 mode between the measurement and the simulation with the SiC absorbers

Parameter	**Measurement**	**Simulation**
Resonant frequency	1.499 55 GHz	1.4996 GHz
Loaded Q	282	291
Coupling coefficient	14.2	45.6
Unloaded Q	4273	13555
External Q	302	297

Table 3: Comparison on the parameters of the TM010 mode between the measurement and the simulation without the SiC absorbers

Parameter	**Measurement**	**Simulation**
Resonant frequency	1.499 55 GHz	1.4996 GHz
Loaded Q	280	291
Coupling coefficient	15.6	46.0
Unloaded Q	4639	13667
External Q	297	297

S Parameters of the HOMs

To measure the properties of HOMs with S parameters, two loop antennas were inserted as shown in Fig. 4. The shape of the antenna was decided so that they coupled to the principal three HOMs having high transverse impedances. Expected resonant frequencies of these HOMs were 1.916 GHz, 2.066 GHz, and 2.247 GHz, respectively.

Figure 6 shows the comparison of the S21 between the measurement and the simulation. Black solid and dashed lines indicate the measured and calculated S21 of the three HOMs, respectively, when no absorbers were installed in the beam ducts. The red solid and dashed lines indicate the measured and calculated S21, respectively, when the SiC absorbers were installed in the ducts. When the SiC absorbers were installed, the three HOMs were heavily damped; the peaks due to these HOMs could not be observed with the loop antennas. Although we could not measure the loaded Q's of these HOMs, reasonable agreement between the measurement and simulation indicated that the three HOMs were effectively damped by the SiC absorbers as expected from the simulation.

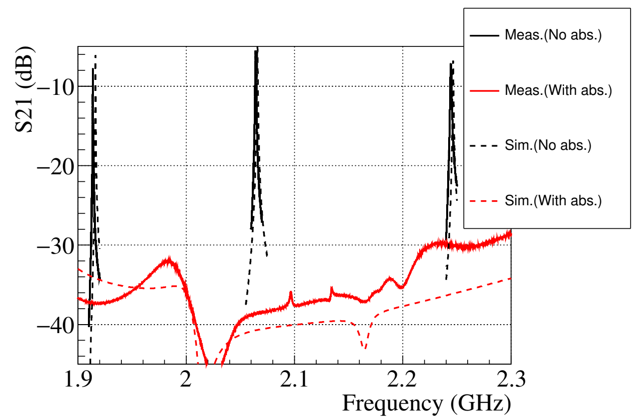

Figure 6: Comparison of the S21 between the measurement and the simulation.

CONCLUSION

We have designed the wide-band kicker cavity used to compensate the TBL effect, and thus, to improve the bunch-lengthening performance in the 4th generation light sources. To confirm the performance of the kicker cavity, we manufactured the low-power model of the cavity and measured the properties of the TM010 mode and HOMs. The measured properties of the TM010 mode agreed with those simulated. The bandwidth of the kicker cavity was measured to be 5.15 MHz which met the requirement. We observed that the three major HOMs almost disappeared with S21 measurement when the SiC absorbers were installed. This indicated that these HOMs were sufficiently damped by the SiC absorbers. From above results, we successfully established the design of the wide-band kicker cavity.

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