HOM-DAMPED STRUCTURE OF THE ARES CAVITY

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Abstract

The ARES cavity, developed against difficulties associated with heavy beam loading conditions in the high-luminosity electron-positron collider KEKB, is a three-cavity system operated in the $\pi/2$ mode, in which an accelerating cavity is resonantly coupled with a high-Q energy storage cavity via a coupling cavity equipped with a parasitic mode damper on the 0 and π modes. Furthermore, to reduce the HOM impedance, the accelerating cavity itself needs to be a HOM-damped structure fairly compatible with this ARES scheme. This paper briefly reviews major features of the HOM-damped structure of the ARES cavity system and reports the recent operational status.

1 INTRODUCTION

The ARES cavity is a three-cavity system [1] developed to solve difficulties such as couled-bunch instabilities due to the accelerating mode under heavy beam loading conditions in KEKB. In the ARES system, an accelerating cavity is resonantly coupled with an energy storage cavity operated in the TE_{013} mode via a coupling cavity. The couplng cavity is equipped with an antenna-type coupler to damp the parasitic 0 and π modes emerging at both sides of the $\pi/2$ accelerating mode.

Needless to say, the accelerating cavity itself must be a HOM-damped structure against coupled-bunch instabilities due to HOMs also limiting the performance of KEKB. Furthermore, the HOM-damped structure needs to be structurally and electromagnetically compatible with the ARES scheme. That is an inevitable boundary condition, i.e. two coupling apertures at both sides of the accelerating cavity: one toward the coupling cavity, and the other toward a half-cell coupling cavity for the $\pi/2$-mode termination keeping the accelerating field symmetrical with respect to the vertical mid plane including the beam axis.

2 HOM-DAMPED STRUCTURE

Figure 1 schematically shows front and side views of the HOM-damped structure for the ARES cavity system. Currently, the number of ARES cavities operated in the double-ring collider KEKB is 26 in total: 16 for the low-energy ring (LER), and 10 for the high-energy ring (HER). The recent operational status of the ARES cavities is reported in a companion paper [2]. The design of the production cavity shown in Fig. 1 is based on a conceptual demonstrator named ARES96 [3], which had been successfully verified in a series of stringent high-power tests and high-current beam experiments carried out in the TRISTAN accumulation ring (AR) in 1996.

2.2 Accelerating Cavity

The accelerating cavity is made mainly of OFC (Oxygen Free Copper) parts brazed stepwise in a vacuum furnace. The accelerating cell was designed as simple as possible from the viewpoint of structural stability in thermal deformation rather than increasing the shunt impedance, leading to a simple design, i.e. a pillbox-type cavity with nosecones of 10 mm high. Compensating for thermal detuning, a movable tuning plunger with a diameter of 70 mm and a travel of 60 mm is installed in the upper right port, as seen in the front view of Fig. 1. The coupling cavity and the half-cell coupling cavity of the $\pi/2$-mode terminator are brazed directly to both sides of the accelerating cavity. Through a rectangular aperture of 120 mm× 160 mm, each coupling cavity is coupled with the accelerating cavity.

2.2 Rectangular HOM waveguides

Four straight rectangular waveguides are brazed directly to the upper and lower sides of the accelerating cavity in order to damp monopole HOMs and dipole ones deflecting the beam in the vertical direction. The waveguide width is 240 mm, giving a cutoff frequency of 625 MHz for the dominant TE_{10} wave. The extracted HOM power is guided through an E-bend waveguide in the horizontal direction and is finally dissipated in two bullet-shape sintered SiC ceramic absorbers (55 mm in diameter and 400 mm in length including a tapered section) at the end of each waveguide. The SiC absorbers are loaded through circular ports at the end plate, where metal o-rings are used for vacuum seal. Each absorber is directly cooled by water (~ 4 L/min.) flowing in a circular bore with a diameter of 12 mm, into which a alumina ceramic pipe with an outside diameter of 8 mm and an inside diameter of 5 mm is inserted to form a cooling-water circuit. The power capability per absorber was verified up to 3.3 kW, using a HOM-load test bench with a L-band CW klystron. Details of the HOM loads for the ARES cavity were reported in Ref. [4].

2.3 Grooved Beam Pipes

Grooving the inner wall of a circular beam pipe can selectively lower the cutoff frequency of the TE_{11} wave, which couples with dipole modes in the cavity. That is the Grooved Beam Pipe (GBP) method [5], which can heavily damp dipole modes without sacrificing the accelerating mode. As seen in Fig. 1, the beam pipe with an inside diameter of 150 mm attached to each end plate of the accelerating cavity has two deep grooves at the upper and lower sides in order to damp dipole modes deflecting the beam in the horizontal direction. The groove dimensions are 30 mm in width and 95 mm in depth, lowering the cutoff frequency of the TE_{11} wave below 650 MHz. In each groove, there are eight SiC tiles arranged in a line, where the extracted HOM power is dissipated. Each SiC tile is brazed to a water-cooled copper plate with a copper compliant layer between. The GBP HOM load was also tested up to 0.5 kW per groove at the test bench mentioned earlier.

3 HIGH-CURRENT OPERATION

The commissioning of the HER was first started with 6 ARES cavities and 4 superconducting cavities [5] in December 1998, and followed by the commissioning of the LER with 12 ARES cavities in January 1999. In the summer shutdown of 1999, the number of ARES cavities in the LER was increased from 12 to 16, and in the HER from 6 to 10. The real high luminosity operation for the Belle experiment was started in the fall of 1999. The beam currents of both rings were increased stepwise: overcoming many difficulties, for example, with movable masks; and improving the machine performance, for example, with solenoid windings in the LER. As a whole, the ARES cavities have performed well in supporting the beam currents up to 950 mA in the LER and up to 780 mA in the HER while we have encountered many troubles and accidents, some of which are reported in a companion paper [2]. However, focusing on the HOM-damped structure alone, we have not encountered any troubles so far.

For each of the 10 ARES cavities installed at the LER RF section D7, the HOM power dissipated in the four bullet-shape SiC absorbers at the downstream side was obtained from the temperature rise of the cooling water flowing through those absorbers in series and the flow rate adjusted in advance. Figure 2 shows the data obtained for every cavity as a function of the LER beam current in a range from 600 mA to 900 mA. The bunch pattern was a single train of 1152 bunches with 4-bucket spacing followed by a gap of 512 vacant buckets. The mirror symmetry of the cavity structure with respect to the beam direction assures that twice the power in Fig. 2 is roughly equal to the total HOM power dissipated in the four rectangular waveguides of each cavity, which amounts to about 1.6 kW at 900 mA. Each curve drawn in Fig. 2 is a fit to the data for each cavity, assuming a quadratic dependence of the HOM power on the beam current. Figure 3 shows the coefficient of the quadratic term obtained from data fitting for every cavity. It can be said that there is a slight tendency for the cavities at both ends of the RF section to have smaller HOM power dissipations. It may be due to higher order modes above the beam pipe cutoff frequency. At each end of the RF section, the inside diameter of the beam pipe is tapered down from 150 mm to 96 mm. Before each tapered section, a cylindrical SiC duct with an inside diameter of 150 mm and an effective length of 240 mm is installed as a broadband terminator to absorb outgoing HOM power and as an isolator to absorb incoming HOM power from the arc section outside.

Also, the HOM power dissipated at the SiC tiles in the grooved beam pipe at the down-stream side of each cavity was obtained in a similar way stated above. Figure 4 shows the data obtained for every cavity at the LER RF section D7. Again, twice the power in Fig. 4 is roughly equal to the total HOM power dissipated in both grooved beam pipes of each cavity. Figure 5 shows the coefficient of the quadratic term for every fitted curve in Fig. 4. Comparing Fig. 5 with Fig. 3, then, there can be seen a clear tendency of nonuniformity in distribution of the HOM power dissipations along the RF section. However, we need further investigation to confirm this tendency. That is because unfortunately the two cavities at the RF station D7C were not operated due to a vacuum trouble when these data were taken. An irregular boundary condition, where the storage cavity is not properly tuned to the accelerating cavity in the $\pi/2$ mode, deforms the accelerating field and may introduce a dipole component around the beam axis.

4 CONCLUSION

Focusing on the HOM-damped structure alone, the ARES cavities have functioned well without any troubles to support the high current beams stably in both LER and HER. Furthermore, the HOM loads have ample margins for high-current operation. These two facts make us confident of the performance and growth potential of the HOM-damped structure for the ARES cavity system toward high-luminosity frontiers beyond 4.49×10^{33} cm^{-2} s^{-1} explored with the KEKB collider.

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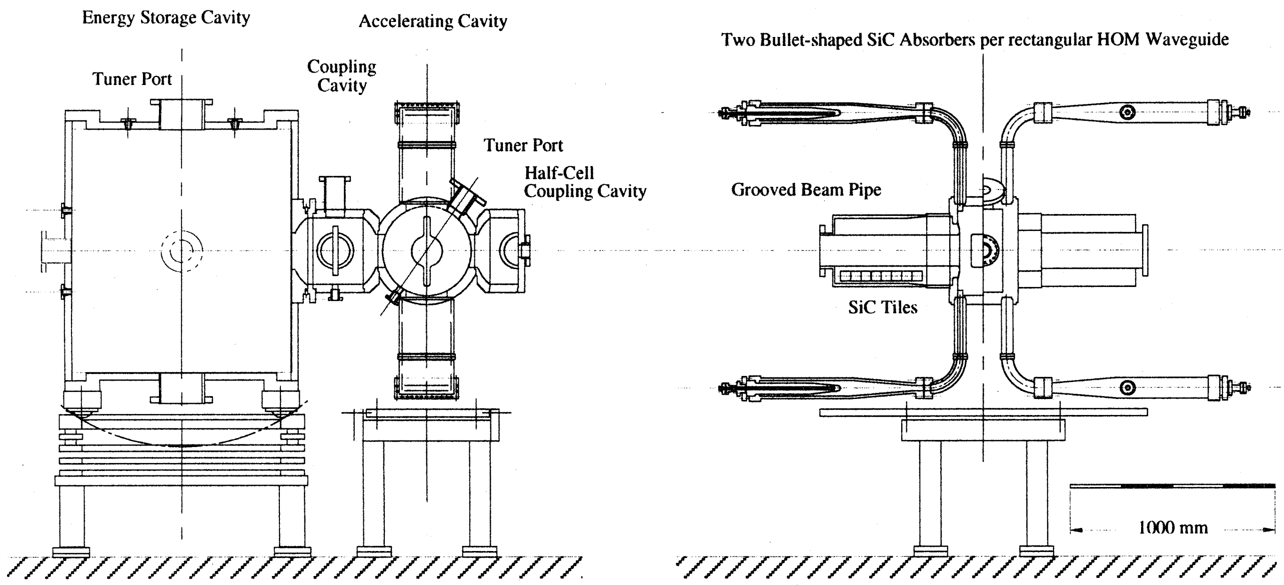

Figure 1: Front and side views of the HOM-damped structure for the ARES cavity system

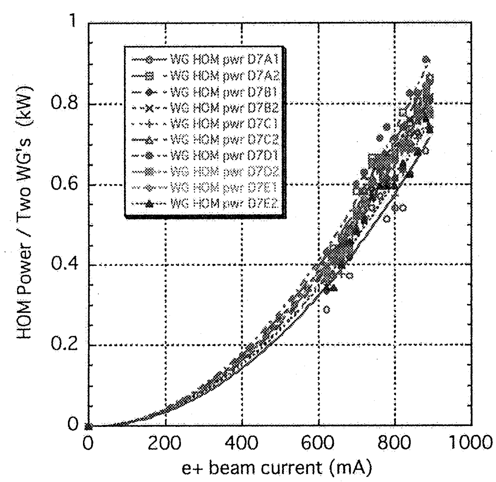

Figure 2: For every ARES cavity at the RF section D7 in the LER, the HOM power dissipated in the four bullet-shape SiC absorbers at the down-stream side is plotted as a function of the beam current.

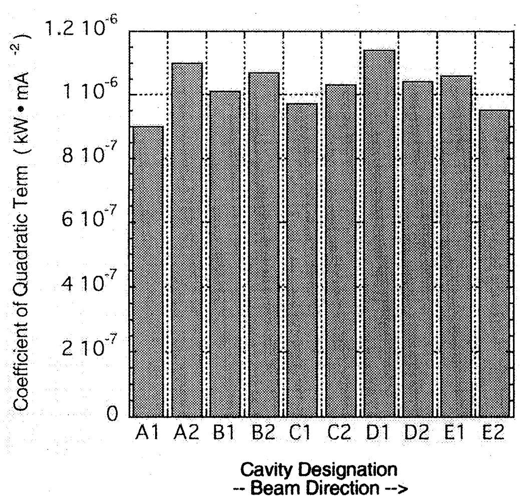

Figure 3: A graph showing the coefficient of the quadratic term of the beam current for every cavity, obtained from fitting the HOM power data in Fig. 2.

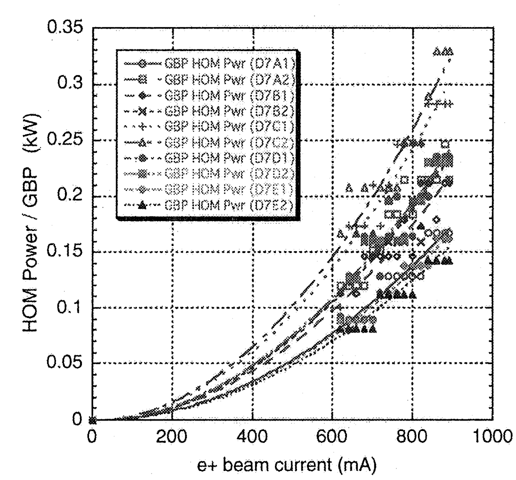

Figure 4: For every ARES cavity at the RF section D7 in the LER, the HOM power dissipated at the SiC tiles in the grooved beam pipe at the down-stream side is plotted as a function of the beam current.

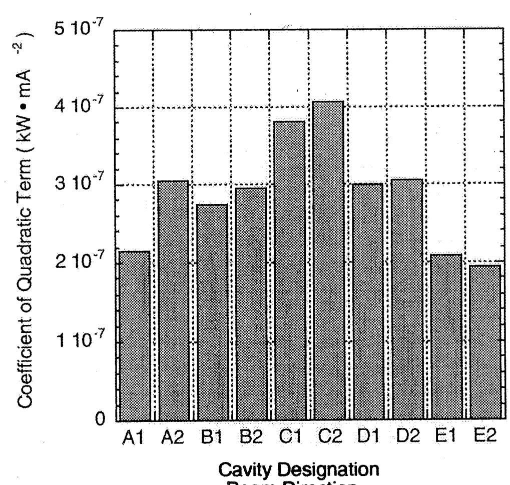

Figure 5: A graph showing the coefficient of the quadratic term of the beam current for every cavity, obtained from fitting the HOM power data in Fig. 4.