DEVELOPMENT OF HIGH-POWER ARES CAVITIES

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Abstract

The ARES (Accelerator Resonantly coupled with Energy Storage) structure is a three-cavity system operated in the π/2 mode, where a HOM-damped accelerating cavity is coupled with an energy storage cavity via a coupling cavity equipped with a coaxial antenna damper to reduce the impedances of the parasitic 0 and π modes. Two high-power prototypes with different HOM-damping schemes have been developed, where one is with a quadrupole counter-mixing (QCM) choke structure and the other with grooved beam pipe one. Both prototypes have been tested with an electron beam of about 500 mA in the TRISTAN accumulation ring (AR). This paper reports their RF structures together with some results of the high-power and high-current beam tests.

1 INTRODUCTION

The operation of conventional copper cavities under heavy beam loading in KEKB will give rise to a serious instability problem. That is the longitudinal coupled bunch instability driven by the accelerating mode itself. The resonant frequency of the accelerating mode should be detuned from the RF frequency toward the lower side so as to compensate for the reactive component of the cavity voltage induced by the beam. In KEKB, the required detuning frequency will exceed the revolution frequency, leading to the large excitation of a coupled-bunch synchrotron oscillation.

An RF structure named ARES [1] has been developed as a countermeasure against the above problem. In the ARES scheme, an accelerating cavity and an energy storage cavity operated in a high-Q mode (TE_{013}) are resonantly coupled via a coupling cavity. The storage cavity is employed to reduce the required detuning frequency, which is inversely proportional to the ratio of the electromagnetic stored energy with respect to the reactive part of the beam-field interaction energy. Needless to say, the accelerating cavity itself must be a HOM-damped cavity in order to reduce the HOM impedances also driving coupled-bunch instabilities.

The ARES structure operated in the π/2 mode employing a coupling cavity has several advantages listed in Ref. [2] over a non-ARES one, where the accelerating and the storage cavities are directly coupled and operated in the π (or 0) mode. In addition, the coupling cavity functions as a kind of filter for some HOM's to isolate the accelerating cavity from the storage cavity.

2 HIGH-POWER PROTOTYPES

Two high-power ARES cavities with different HOM-damping schemes have been developed and constructed. The first one constructed in 1995 was named ARES95, and the second one ARES96.

2.1 ARES95

The RF design and characteristics of ARES95 were reported in the previous conference in Europe [2]. The accelerating cavity of ARES95 employs a HOM-damping scheme named Quadrupole Counter Mixing (QCM) choke structure [3]. The HOM characteristics of ARES95 are reported in Ref. [4].

2.2 ARES96

In parallel with the construction of ARES95, another prototype has been developed taking into account the cavity structure symmetry, the HOM-damping performance, and the total cost including HOM loads.

Figure 1 shows a schematic drawing of ARES96. Figure 2 is a photograph of ARES96 installed in the TRISTAN AR tunnel. The accelerating cavity has four rectangular waveguides brazed to the upper and lower sides in order to damp monopole and dipole (V) HOM's, where the capital V means deflecting the beam in the vertical direction. The waveguide width was chosen 240 mm, which gives a cutoff frequency of 625 MHz for the dominant TE_{10} wave. As the HOM load, two bullet-shape SiC ceramic absorbers are inserted at the end of each waveguide. The absorber dimensions are 55 mm in diameter and 400 mm in length including a tapered section. Both beam pipes with an inner diameter of 150 mm are grooved at the upper and lower sides as shown in Fig. 1 in order to damp dipole (H) HOM's deflecting the beam in the horizontal direction. The structure of grooved beam pipe [5] is effective to damp dipole HOM's in a cavity by selectively lowering the cutoff frequency of the TE_{11} wave for a circular beam pipe. The groove dimensions for ARES96 are 30 mm in width and 85~95 mm in depth, which lowers the TE_{11} cutoff frequency below 650 MHz. Eight SiC ceramic tiles are arranged in a line in each groove to absorb the HOM power. Details of the HOM loads for ARES96 are reported in Ref. [6].

The coupling cavity structure is almost the same as that of ARES95. A coaxial antenna coupler [7] is installed into the central port of the coupling cavity. To terminate the coupler, a water-cooled dummy load capable of 40 kW of RF power (CW) was used in the high-power and beam tests. Figure 3 shows the π/2 accelerating mode and the damped 0 and π modes measured for ARES96 with $Q_c \approx 55$, where Q_c is the loaded Q value of the coupling cavity and adjustable from 30 to 100 by changing the antenna insertion. A slight asymmetry of the 0 and π modes with respect to the π/2 mode came from a tuning error, where the coupling cavity frequency was lower than that of the accelerating mode by about 300 kHz. The fixed tuner for the coupling cavity should have been inserted a little more.

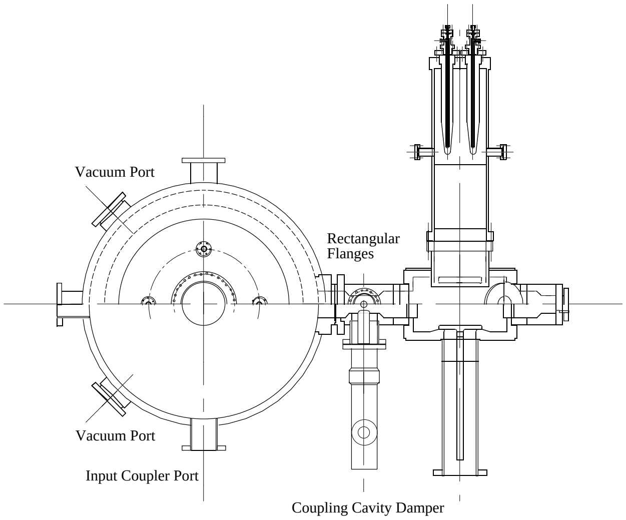
The storage cavity is also almost the same as that of ARES95, which is a large cylindrical cavity (1070 mm in diameter and 1190 mm in axial length) operated in the TE_{013} mode. The cavity is a steel structure whose inner surfaces are copper-plated. The storage and coupling cavities are mechanically connected with rectangular flanges, and vacuum seal is obtained by TIG-welding thin flange sleeves.

3 HIGH-POWER TESTS

Fundamental RF parameters for ARES95 and ARES96 are listed in Table 1. The first high-power test of ARES95 was carried out at an RF test hall in July 1996. After the test was completed, ARES95 was installed in the TRISTAN AR tunnel. On the other hand, ARES96 was directly installed in the tunnel, and the high-power test was started there about two weeks before the beam experiment scheduled in October 1996..

In high-power testing, the cavity was fully equipped with an input coupler [8], a coupling cavity damper, tuners, and HOM loads. ARES95 was tested up to the design RF power of 160 kW, which generates a cavity voltage of 0.5 MV. The cavity was stably operated for a long time at that power level. However, a slow vacuum pressure rise probably due to local heating was observed beyond ~180 kW. On the other hand, ARES96 was tested up to 240 kW without any problem.

In high-power operation at 150 kW, the RF power leakage to the coupling cavity damper was measured



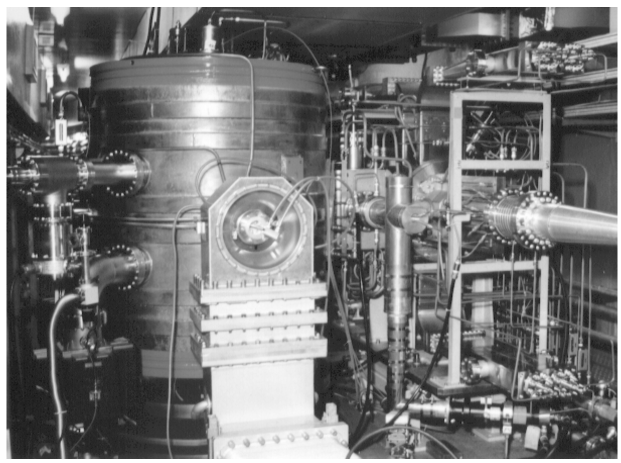


Figure 2: ARES96 installed in TRISTAN AR

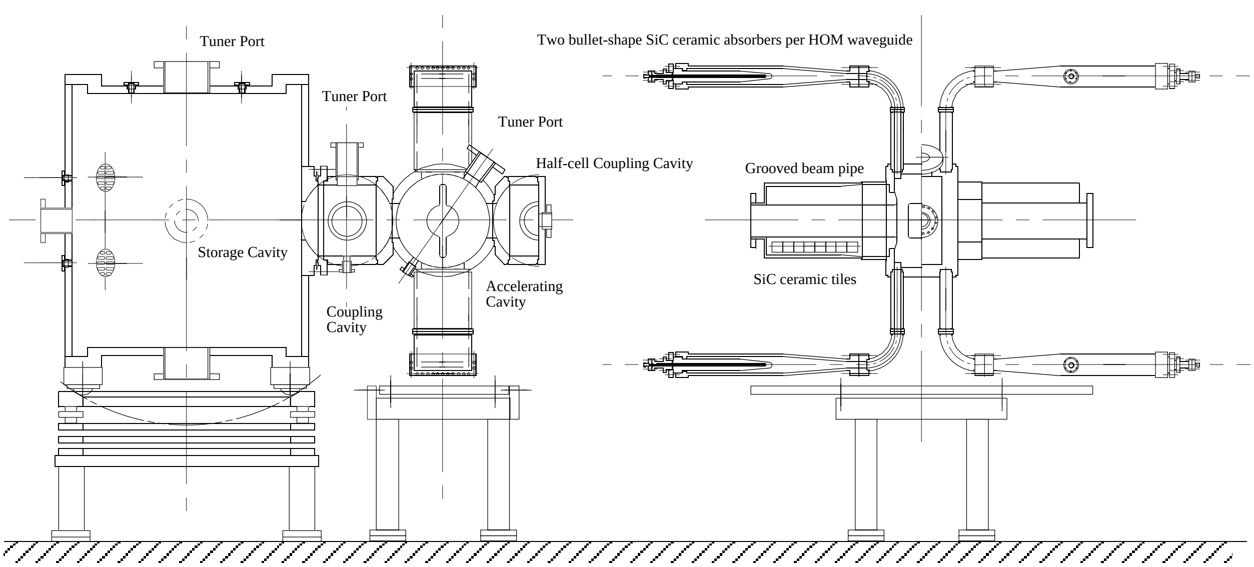


Figure 1: A schematic drawing of ARES96

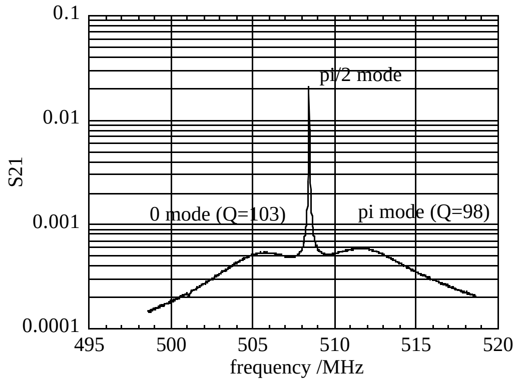


Figure 3: The $\pi/2$ accelerating mode and the damped 0 and π modes of ARES96 when $Q_c \approx 55$.

Table 1: Fundamental RF parameters

	ARES95	ARES96
U_a/U_s	1 / 8.9	1 / 8.3
Rsh/Q (Ω)	14.8	16.3
Q	1.12×10^5	1.17×10^5

~180 W, while a coupled resonator model predicts 150 W. This power leakage is resulting from the energy flow from the storage cavity to the accelerating cavity.

4 BEAM EXPERIMENTS

Beam experiments were carried out for both of ARES95 and ARES96 in TRISTAN AR. The major items were:

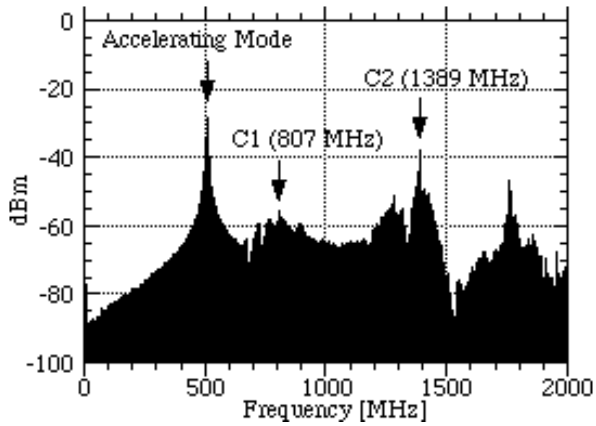
• To check out whether the ARES scheme functions as expected.

• To check out the performances of devices such as the tuners, the input coupler, the coupling cavity damper, and the HOM loads.

• To survey HOM spectra excited by the beam for various conditions changing the tuner insertion and the beam position with respect to the cavity axis.

Some results of the beam experiments are reported elsewhere [4], [9].

Figure 4 shows a HOM spectrum of ARES96 observed with a probe antenna at the endplate of the accelerating cavity when a single bunch of 100 mA was circulating. A simulation with the MAFIA-T3 code (a time-domain simulation code for three-dimensional structures) reproduced the observed spectrum shape well, including several sharp peaks in Fig. 4. According to further simulation, it was found that the longitudinal impedances of the two modes at 807 MHz and 1389 MHz, indicated by C1 and C2 in Fig. 4, are critical and may possibly exceed the design threshold for the KEKB low-energy ring (LER). The modes C1 and C2 are trapped in the coupling cavity and have almost no fields in the accelerating cavity. The mode C1 has a TM_{110}-like field pattern in the coupling cavity and the mode C2 has a TE_{111}-like pattern. These dipole modes in the coupling cavity can be damped by attaching a rectangular waveguide at the opposite side of the circular port for the coupling cavity damper. At present we are planning to



Figuire 4: HOM spectrum of ARES96

make a rectangular spare port (240 mm by 28 mm) for the coupling cavity in order to damp the modes C1 and C2 if necessary.

Similar sharp peaks were also observed for ARES95 [4]. One of them is a TM_{110}-like trapped mode in the coupling cavity and has almost the same frequency as the C1 mode of ARES96. That is because the coupling cavity structures of ARES95 and ARES96 are almost the same.

4 SUMMARY

Two high-power prototypes ARES95 and ARES96 with different HOM-damping schemes have been constructed and demonstrated in high-power and high-current beam experiments. Final design of the production cavity based on ARES96 is being in progress.

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