

THE ARES CAVITY FOR THE KEK B-FACTORY

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Abstract

The ARES (Accelerator Resonantly coupled with Energy Storage) cavity is an effective countermeasure against the coupled-bunch instability due to the accelerating mode in the KEK B-factory. The ARES structure is a three-cavity system operated in the $\pi/2$ mode, where an accelerating cavity is coupled with an energy storage cavity via a coupling cavity. The energy storage cavity is a large cylindrical cavity operated in the TE_{013} mode, and the accelerating cavity is a HOM-damped cavity with a Quadrupole Counter-Mixing (QCM) choke structure. The coupling cavity equipped with a coaxial antenna coupler reduces the parasitic 0 and π mode impedances and plays the most important role as the keystone of the ARES structure. This paper describes the RF design and characteristics of the first high-power ARES cavity.

1 INTRODUCTION

The key issue in the RF cavity design for KEKB is how to reduce the HOM impedances which will drive coupled-bunch instabilities limiting the stored beam current. A straightforward way to reduce the HOM impedances is to damp the HOMs in the cavity by guiding them out through dedicated waveguides.

In addition, the operation of the RF cavities under heavy beam loading in KEKB will give rise to another serious 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 for a conventional copper cavity will exceed the revolution frequency, leading to the large excitation of a coupled-bunch synchrotron oscillation.

An RF cavity named ARES [1] has been developed as a countermeasure against the above problem. Figures 1 and 2 are a schematic drawing and a photograph of the first high-power ARES cavity, respectively. In the ARES scheme, a HOM-damped accelerating cavity and a large energy storage cavity operated in a high-Q mode (TE_{013}) are coupled via a coupling cavity, where these three coupled cavities are operated in the $\pi/2$ mode. The storage cavity is employed to reduce the required detuning frequency, which is inversely proportional to the amount of the electromagnetic stored energy with respect to the reactive part of the beam-field interaction energy.

The ARES structure has the following advantages over a non-ARES one [2], where the accelerating cavity and the storage cavity are directly coupled like the LEP normal conducting cavity [3] and operated in the π (or 0) mode.

- The $\pi/2$ mode has excellent field stability against the heavy beam loading.
- The stored energy ratio $U_s : U_a$, where U_s is the stored energy in the storage cavity and U_a for the accelerating cavity, can be easily adjusted by changing the coupling factor ratio $k_s : k_a$, where k_s is the coupling factor between the storage and coupling cavities and k_a for the accelerating and coupling cavities.

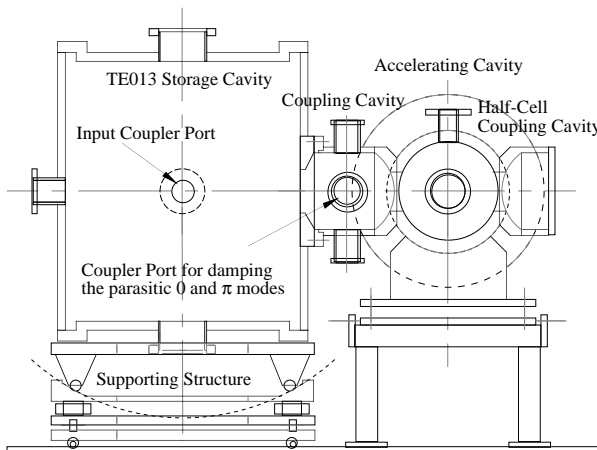


Figure 1: A schematic drawing of the first high-power ARES cavity.

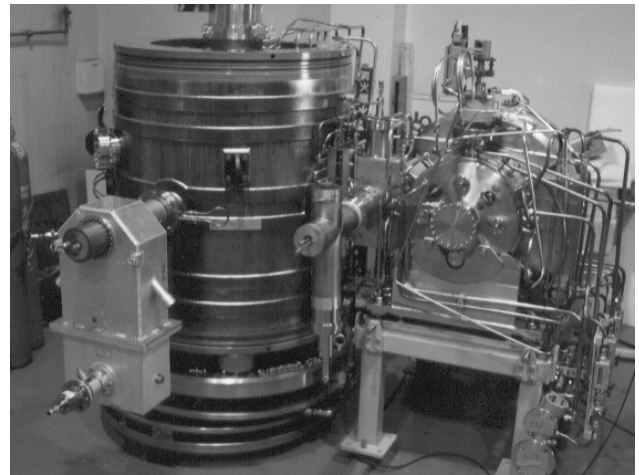


Figure 2: A photograph of the first high-power ARES cavity.

- For the parasitic 0 and π modes, the stored energy U_c in the coupling cavity is nearly equal to U_a . On the other hand, the $\pi/2$ mode has almost no field excitation in the coupling cavity. Therefore, both parasitic modes can be selectively damped by installing a coaxial antenna coupler into the coupling cavity.
- The parasitic 0 and π modes are located nearly symmetrically with respect to the $\pi/2$ mode. Therefore, the contributions from these damped parasitic-mode impedances to the instability cancel each other out to some extent.

It should be noted that the coupling cavity damped with a coaxial antenna coupler plays the most important role as the keystone of the ARES structure.

2 THE HIGH-POWER ARES CAVITY

The construction of the first high-power ARES cavity was almost completed as shown in Fig. 2. Some RF design parameters of the cavity are listed in Table 1, together with the results of low-power measurements.

Table 1: RF parameters of the ARES cavity

f_{RF}	(MHz)	508.6	
V_c	(MV)	0.5	
$U_a : U_s$		1 : 8.9	
R/Q	(Ω)	14.8	
Q		1.18×10^5 (meas.)	1.32×10^5 (cal.)

2.1 Accelerating Cavity

Figure 3 shows a schematic drawing of the HOM-damped accelerating cavity structure with the coupling and half-cell coupling cavities.

A prototype of HOM-damped accelerating cavity without coupling cavities was constructed and tested up to an input power of 150 kW [4]. At present, the prototype accelerating cavity is being under beam test in the TRISTAN accumulation ring (AR). The HOM characteristics and the

results of the beam test will be found in Ref. [5]. The development of the HOM absorber, for which we adopted SiC ceramics, will be reported in Ref. [6].

The first high-power ARES cavity employs an accelerating cavity with a HOM-damping scheme named Quarupole Counter Mixing (QCM) choke structure [7]. In the ARES accelerating cavity, the two apertures to the coupling cavities at both sides mixes the accelerating mode with a quadrupole mode. The distorted field will excite the TE_{21} coaxial-waveguide mode even at the accelerating frequency [4]. The TE_{21} wave propagating along the HOM-damping coaxial waveguide cannot be blocked by an axially symmetric choke. The QCM choke structure was developed in order to prevent the leakage of the accelerating field energy to the HOM absorbers. The details of the QCM choke structure will be found in Ref. [7] in this conference.

2.2 Storage Cavity

The storage cavity is a large cylindrical cavity operated in the TE_{013} mode. The dimensions are 1070 mm in diameter and 1190 mm in axial length. Major cavity parts are a cylindrical steel pipe and two steel endplates, whose inner surfaces are copper-plated. Each endplate has a circular port for a movable tuning plunger, and a groove for shifting the resonant frequency of the TM_{113} mode from that of the TE_{013} mode. At the middle of the cylindrical pipe, there is a rectangular aperture of 120 mm by 180 mm to the coupling cavity. The storage and coupling cavities are mechanically connected with rectangular flanges, and vacuum seal is obtained by TIG-welding thin flange sleeves. In addition, the storage cavity has three circular ports, one of which the input coupler [8] is to be installed, and four vacuum ports.

Figure 4 shows the performance of the copper plating obtained from a full-scale cold storage cavity constructed in the same method as for the high-power one. The Q values measured for major modes are compared with the theoretical ones by SUPERFISH, and plotted as a function of the

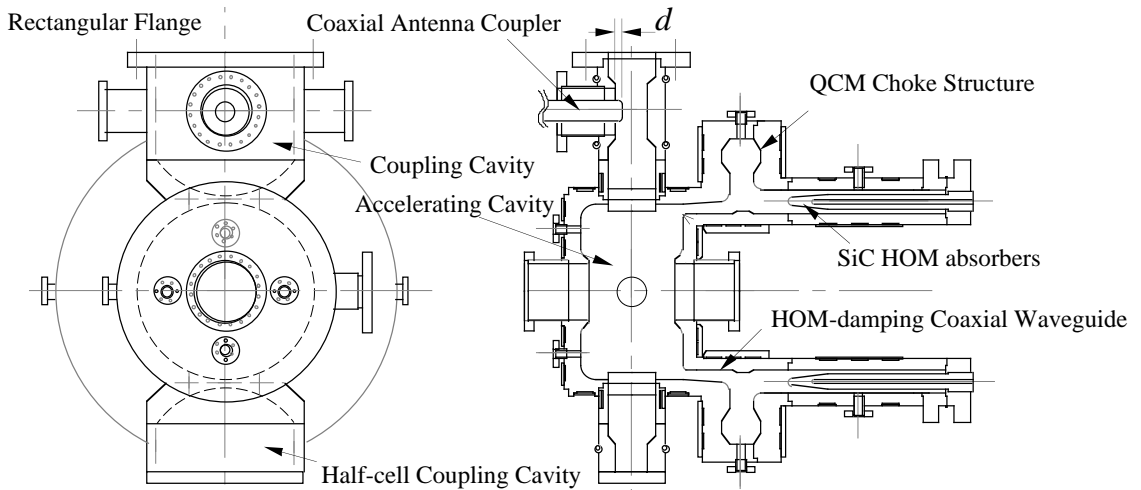


Figure 3: A schematic drawing of the HOM-damped accelerating cavity with the coupling and half-cell coupling cavities

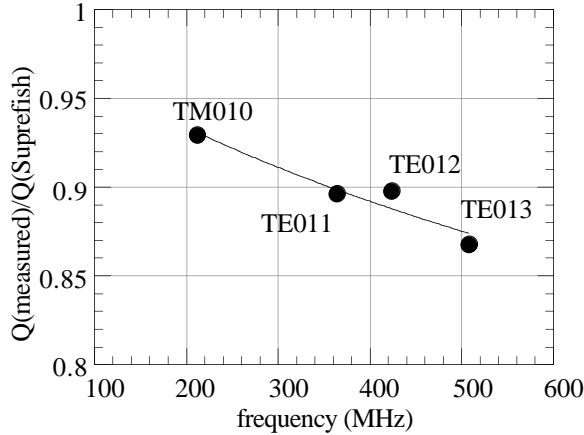


Figure 4: The Q values measured for major modes of the full-scale cold storage cavity are compared with the theoretical ones by SUPERFISH.

resonant frequency. The performance of copper plating decreases as the frequency increases. This phenomenon may be explained by the relation of the surface imperfections and the skin depth. For the TE_{013} mode at 509 MHz, the obtained Q value was 1.74×10^5 , which is 87% of the theoretical one 2.00×10^5 .

2.3 Coupling Cavity as the Keystone

The coupling cavity is brazed to the accelerating cavity, and the half-cell coupling cavity for the $\pi/2$ -mode termination at the opposite side as shown in Fig. 3. A coaxial (120D) antenna coupler for damping the 0 and π modes is installed into the central port of the coupling cavity. For the 0 and π modes, the stored energy ratio is $U_a : U_c : U_s \approx 1 : 1 : 0$ [1]. Therefore, the loaded Q values (Q_0 and Q_π) of the two parasitic modes will be damped $\sim 2Q_c$, where Q_c is the loaded Q value of the coupling cavity.

Figure 5 shows a photograph of the coaxial antenna coupler [9] developed for the high-power ARES cavity. The coupler has a ceramic window of coaxial-disk type. The required power-handling capability is estimated about a few kW [10] when installed in the KEKB low-energy ring (LER).

In addition, the coupling cavity is equipped with two fixed tuners in order to adjust the frequencies of the 0 and π modes. These two modes should be located as symmetrically as possible with respect to the $\pi/2$ mode in order to cancel out their impedance contributions to the longitudinal coupled-bunch instability.

Figure 6 shows the $\pi/2$ accelerating mode and the damped 0 and π modes measured for the high-power ARES cavity with the coaxial antenna coupler (Fig. 5) installed. The 0 and π modes are almost symmetrically located with respect to the $\pi/2$ mode. The loaded Q values of the two modes were about 100 when the antenna insertion (indicated by d in Fig. 3) was 10 mm. With the RF parameters in Table 2, the growth time of the longitudinal coupled instability will be ~ 10 ms when twenty ARES cavities installed in KEKB-LER.

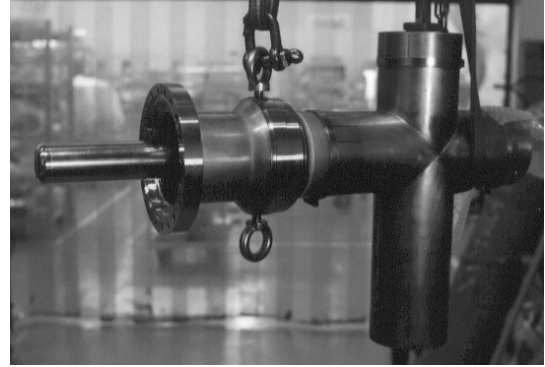


Figure 5: Coaxial (120D) antenna coupler for damping the 0 and π modes.

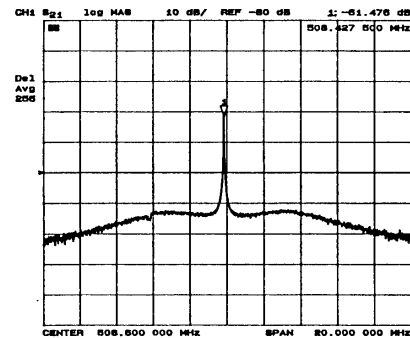


Figure 6: The $\pi/2$ accelerating mode and the damped 0 and π modes measured for the high-power ARES cavity.

Table 2: RF parameters of the 0 and π modes

	f (MHz)	R/Q (Ω)	Q
0 mode	504.5	70	~ 100
π mode	512.5	68	~ 100

3 SUMMARY

The construction of the first high-power ARES cavity was almost completed. The high-power test is scheduled in July and the beam test in the TRISTAN accumulation ring (AR) will be carried out in November.

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