RF CHARACTERISTICS OF ARES COLD MODELS

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RF characteristics were measured for aluminum 1/5 scale cold models of accelerator resonantly-coupled with an energy storage (ARES) for KEKB. The main purpose of ARES is to reduce the frequency shift due to the detuning of the accelerating cavity. Measurement has shown that the frequency shift of the accelerating ($\pi/2$) mode was substantially reduced compared to that of the accelerating cavity itself. Two parasitic modes (0 and π) of ARES have to be damped so that they should not cause longitudinal coupled bunch instability. The coupling waveguides attached at the coupling cavity sufficiently damped these parasitic modes, while having negligible effect on the Q value of the $\pi/2$-mode.

I. INTRODUCTION

The coupled bunch instability associated with the accelerating mode is a serious problem for successful operation of large ring accelerators with a high current. Its growth rate can be reduced by keeping the detuning frequency sufficiently smaller than the revolution frequency at the maximum current. The original idea of a storage cavity (s-cavity), which was directly coupled to an accelerating cavity (a-cavity), was proposed to reduce the detuning frequency by reducing R/Q of the accelerating mode [1]. Accelerator resonantly-coupled with an energy storage (ARES) was devised to refine the original idea to a practical level, where the two cavities are coupled through another cavity called "coupling cavity" (c-cavity) [2-4]. Three coupled modes are generated according to a coupled-resonator model of ARES. They are designated as 0-, $\pi/2$- and π-mode in order of increasing frequency, respectively. The $\pi/2$-mode is used as the accelerating mode. This three-cavity system has several advantages compared with the original two-cavity scheme: (i) the accelerating mode is stable against a heavy beam loading, (ii) the coupled bunch effects due to the parasitic 0- and π-modes almost cancel each other since their frequencies can be adjusted to be equally separated from the RF frequency, (iii) furthermore, the two parasitic modes can be damped without damping the $\pi/2$-mode by a damping device coupled to the c-cavity, since there are no fields at the center of the c-cavity for the $\pi/2$-mode. Choke-mode cavity [5] will be used as the a-cavity. An separate test of a choke-mode cavity power test model was very successful [6,7].

Two aluminum 1/5 scale cold models were fabricated to confirm the design described above. As the s-cavity mode, the TE015 mode of a cylindrical cavity is used. Their a-cavity is a simple pillbox cavity since a choke-mode cavity introduces undesirable complexities in the present measurement. No coupler for damping of the 0- and π-modes are installed on the model fabricated first, which is used for studying the basic characteristics of ARES without damping, while the c-cavity of the other model is damped. The results of the RF measurement of the two cold models are presented in this paper.

II. MEASUREMENT

A. First Model without Damping

The first cold model without a damper is shown in Fig. 1. In order to realize the above mentioned advantages, the individual frequencies of the three cavities must be tuned properly. The cold models are equipped with two tuners for each of the a-, c- and s-cavities driven by micrometers, by which the resonant frequencies of the three cavities were adjusted to coincide with each other. First, the frequencies of the a- and s-cavities were tuned independently to the aimed frequency of the accelerating mode while the c-cavity was detuned by a metallic bar in it to decouple the a- and s-cavities. Then the frequency of the c-cavity was tuned using Slater's tuning curve method with the a-cavity detuned. In Fig. 2, the frequencies of the two coupled modes between the c- and s-cavity are plotted as a function of the tuner position of

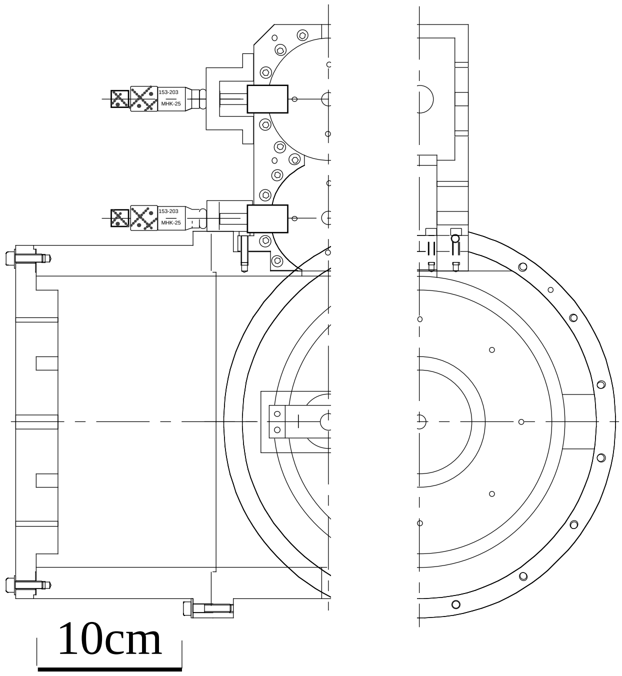

Figure 1: First cold model of ARES without a damper at the c-cavity.

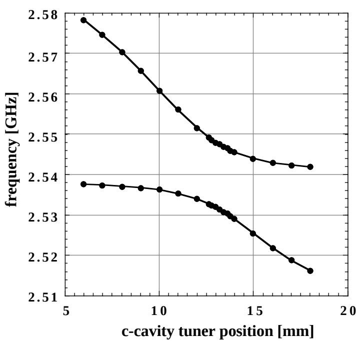

Figure 2: Tuning curve of the c-cavity to the frequency of the s-cavity.

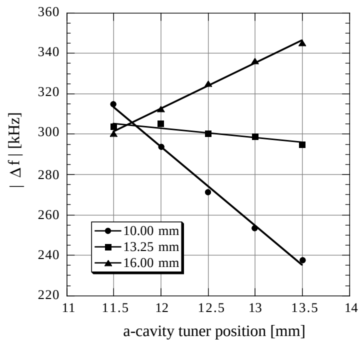

Figure 3: Frequency shift by a metallic bead in the a-cavity as a function of the tuner position of the a-cavity.

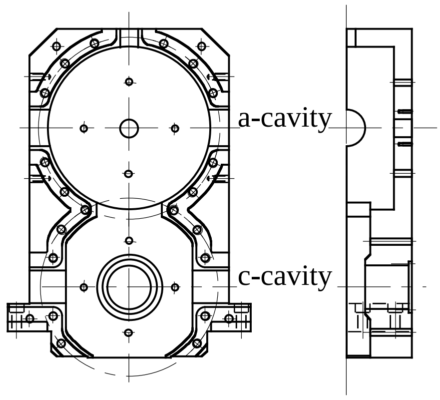

Figure 4: Modified c-cavity for coaxial couplers.

the c-cavity. The tuner of the c-cavity was set to 13.25 mm where the frequency separation between the two coupled modes is minimum.

One of the most prominent features of the π/2-mode operation is the mode stability against the frequency change of an a-cavity. Figure 3 shows the frequency shift by a ϕ6 metallic bead in the a-cavity as a function of the a-cavity tuner position for three different c-cavity tuner positions. The plot is an almost horizontal line with the c-cavity tuner position of 13.25 mm, which is the "tuned" position from Fig. 2. This indicates that the ratio of the stored energy in the a- and s-cavity is almost unchanged by a perturbation to the a-cavity.

The measured Q value of the π/2-mode is 3.3×10^4, which corresponds to 1.4×10^5 for a full scale copper cavity. The effect of surface finish on the Q value was estimated by measuring the Q value of a pillbox cavity with the same material, surface finish and inner shape as the a-cavity of the cold model, which we call "reference pillbox" here. Taking this effect into account, the measured Q value of the π/2-mode is 0.85 times the value calculated by MAFIA.

The shift in the resonant frequency of the π/2-mode was measured by placing a small metallic bead in the a-cavity to simulate the effect of detuning. The ratio of this frequency shift to the shift obtained by the same measurement for the reference pillbox was 0.069, which is in good agreement with the expected value 0.065. This means that R/Q of the accelerating mode is reduced by a factor of about 1/14. This clearly shows that the detuning of the ARES π/2-mode due to the beam loading is largely reduced.

B. Second Model with Damping

The next cold model has two ports for coaxial lines at the center of the end plates of the c-cavity as shown in Fig. 2. The

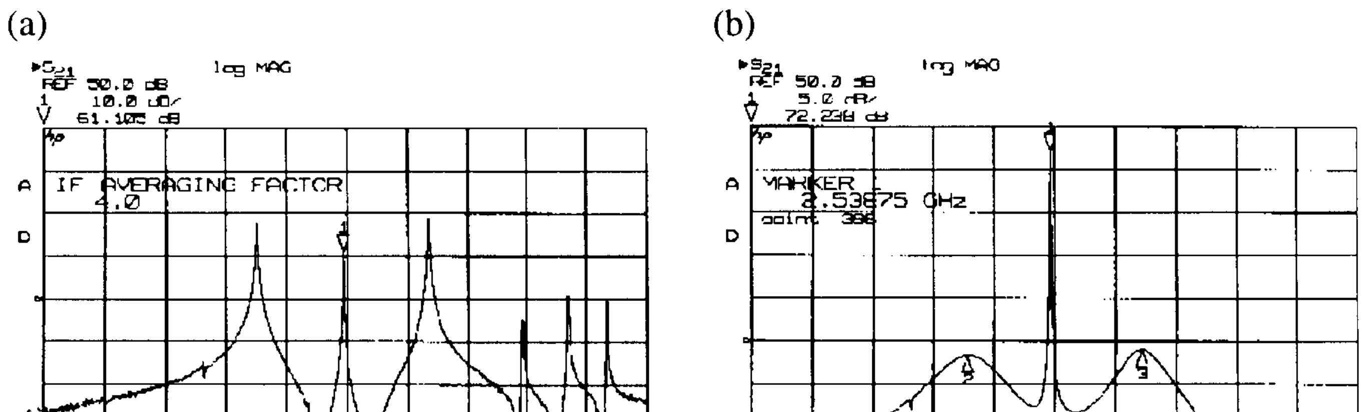

Figure 5: Measured transmission between beam ports at a-cavity: (a) coupling cavity is not damped and (b) is damped.

Table 1: Measured parameters of the 0- and π-modes.

	f [MHz]	Q	R/Q [Ω]*
0-mode	503.4	110	103
π-mode	514.9	150	72

$* R = V^2/P$

coupling cavity was damped by connecting loads to these ports. The cavity surface around the inner conductor of a coaxial line protrudes into the cavity like a nose cone for concentration of the electric field. In order to compensate for the frequency drop, part of the cavity was filled to form a racetrack-shaped cylinder. The measured transmission between a beam port and an end plate of the storage cavity is shown in Fig. 5: (a) the coupling cavity is not damped and (b) is damped.

The measured frequency, Q and R/Q are listed in Table 1. With the parameters in Table 1, the growth time of the longitudinal coupled bunch instability is calculated to be 17 ms for 20 ARESs in LER. We have also investigated the response of the growth time to the skewness of the passband, which is defined as

$$\frac{\left|\left(f_\pi - f_{\pi/2}\right) - \left(f_{\pi/2} - f_0\right)\right|}{\left|f_\pi - f_0\right|}.$$

It was found that the growth time decreases from 35 ms to 10 ms as the skewness increases from 0 to ~10 %.

III. ARES for KEKB

The use of the TE013 mode as an operating s-cavity mode is now under serious consideration. An smaller TE013 s-cavity has practical advantages regarding low cost, easy optimization

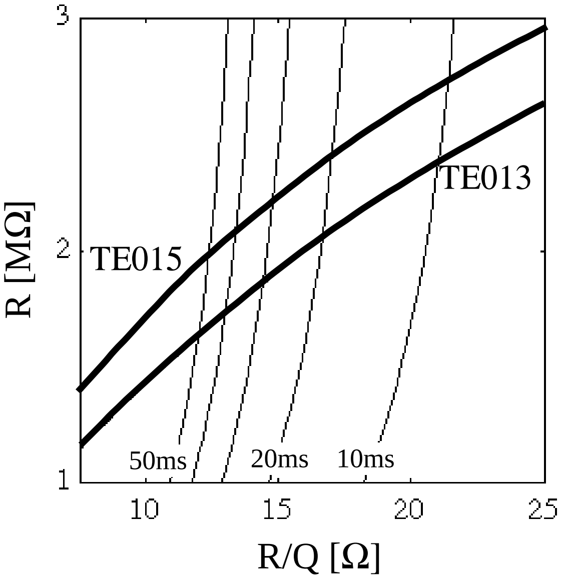

Figure 6: Chart used for comparison between the TE013 and TE015 s-cavity.

and easy installation. Recent study on the coupled bunch instability due to the accelerating mode and expected available power in KEKB suggests that the TE013 s-cavity allows a stable operation even in LER of KEKB. The two thick solid lines in Fig. 6 show the relation between R and R/Q with the ratio of stored energy in the a- and s-cavity as an implicit variable. Thin solid lines are contour lines of the growth time of the longitudinal coupled bunch instability only due to the accelerating mode assuming 20 ARESs in LER. From Fig. 6, R of TE013 is roughly 20 % less than that of TE015 if the growth rate is the same.

A separate TE013 storage cavity is now under construction to test the quality of Cu electroplating on its inner surface. A full-size ARES will be fabricated by late 1996 and installed in AR to be tested under the beam of 500 mA. The coupler for ARES is being designed [8].

IV. CONCLUSION

Basic RF characteristics of the ARES structure, which was proposed for use in high-current and low-emittance rings, was measured. The results demonstrated that it is consistent with theoretical predictions. In addition to that, the two parasitic modes were sufficiently damped for use in KEKB.

V. REFERENCES

[1] T. Shintake, Part. Accel. **44**, 131 (1993).

[2] Y. Yamazaki and T. Kageyama, Part, Accel. **44**, 107 (1994).

[3] K. Akai and Y. Yamazaki, Part, Accel. **46**, 197 (1994).

[4] "An Accelerator Resonantly Coupled with an Energy Storage (ARES) for KEKB", Y. Yamazaki, K. Akai, N. Akasaka, E. Ezura, T. Kageyama, F. Naito, T. Shintake, and Y. Takeuchi, FAE09 in this Conference.

[5] T. Shintake, Jpn. J. Appl. Phys. Lett. 31, L1567 (1992).

[6] "Development of a HOM-Damped Cavity for the KEK B-Factory (KEKB)", T. Kageyama, K. Akai, N. Akasaka, E. Ezura, F. Naito, T. Shintake, Y. Takeuchi, and Y. Yamazaki, WPQ17 in this Conference.

[7] "HOM Absorber for the KEKB Normal Conducting Cavity", Y. Takeuchi, K. Akai, N. Akasaka, E. Ezura, T. Kageyama, F. Naito, T. Shintake, and Y. Yamazaki, WPR05 in this Conference.

[8] "Input Coupler for the KEKB Normal Conducting Cavity", F. Naito, K. Akai, N. Akasaka, E. Ezura, T. Kageyama, T. Shintake, Y. Takeuchi, and Y. Yamazaki, WPR09 in this Conference.