Higher Order Modes of the Single Cell Cavity for the SPring-8

H. Ego, M. Hara, Y. Kawashima, Y. Ohashi, T.Ohshima, H. Suzuki, I. Takeshita and H. Yonehara
JAERI-RIKEN SPring-8 Project Team
2-28-2 Honkomagome, Bunkyo-ku, Tokyo 113 Japan

Abstract

Field distributions of resonant dipole modes of a bell shaped cavity were measured with a bead perturbation technique and coupling impedances over the Q-factor for coupled bunch instabilities were obtained. Frequencies of higher order modes are affected by positions of plungers set on the cavity and one of the suppressing methods for coupled bunch instabilities is shown.

I. INTRODUCTION

For a storage ring of the SPring-8, it is most important to accumulate an intense electron beam having low emittance in order to obtain highly brilliant photon beams. The beam quality is strongly dependent on beam instabilities. The coupled bunch instabilities grow up and induce beam blow-up on condition that a frequency of a parasitic higher order mode (HOM) of cavities is multiples of a beam revolution frequency[1]. As the growth rate of a coupled bunch instability is proportional to the coupling impedance of a HOM, a cavity for a storage ring was designed to have lower impedances of dipole HOMs without significant decrease of an accelerating shunt impedance. A bell shaped single cell cavity is favorable since transverse and its longitudinal HOM impedances are about 50% smaller than those of a normal re-entrant cavity[2].

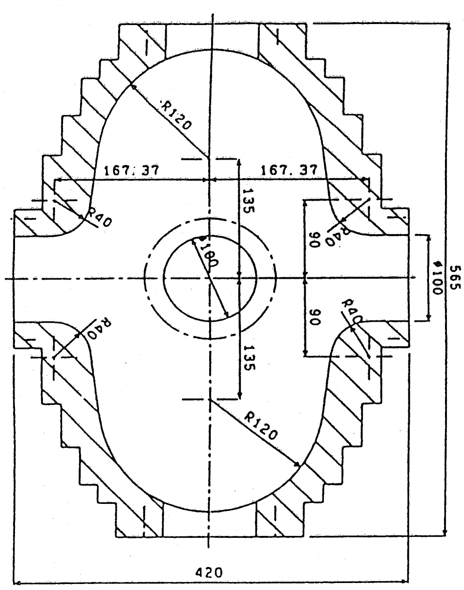


Figure 1. Cross section of a bell shaped single cell cavity.

Dipole HOMs below 1.3GHz must be studied in detail since their coupling impedances are high and they cause strong beam blow-up. The field components of resonant modes were measured with a technique developed by Maier and Slater[3]. Then RF field distributions and the coupling impedances of HOMs in the cavity were obtained.

It is an effective method of suppressing the instabilities to shift the HOM frequencies from the conditions of coupled bunch instabilities[4]. Shifting only HOM frequencies without changing the accelerating frequency is difficult, but HOM frequencies are shifted with the accelerating mode tuned if there are two movable plungers. One is used to change HOM frequencies and the other is used to tune the cavity to the accelerating frequency. Amounts of the frequency shift are reported here in relation to the field measurement results.

II. EXPERIMENTAL SET-UP

The bead perturbation measurements have been executed to specify HOMs in the cold model cavity made of aluminum shown in figure 1. The cavity was set in a constant-temperature room kept on 26.5 ℃. A network analyzer and a stepping motor drive unit are controlled by a computer with the GPIB interface and measurements were carried out automatically. Four types of objects, an aluminum sphere, a ceramic sphere, a brass ellipsoidal needle and a brass disk, were used as perturbating beads. Then directions and distributions of the electric and magnetic fields on the symmetric axis (called the z-direction) were calculated with these beads data. The measured fields are normalized so that the integral of E^2 or H^2 over the cavity is unity. With these normalized fields, the longitudinal shunt impedance of TM010 mode and the transverse shunt impedances of dipole modes are expressed as

$$\frac{R_{sh}}{Q_a} = \frac{2Z_0\left[\int E_z e^{ikz} dz\right]^2}{k}$$

and

$$\frac{R_\perp}{Q_a} = Z_0 V_\perp^2$$

with a parameter,

$$V_\perp = j\int E_\perp e^{jkz} dz - \int H_\perp e^{jkz} dz \quad ,$$

where Qa, $k=2\pi f/c$ and Z_0 are the Q-factor, the wave number of the resonance and the intrinsic impedance of vacuum, respectively[5]. A rectangle copper plate was also introduced into the cavity on the beam axis and the direction of electro-magnetic field was confirmed by frequency shift data. Figure 2 shows a diagram of shifting HOM frequencies with multi-movable plungers. One shifts HOM frequencies and one of the other plungers tunes the 508.58MHz accelerating frequency.

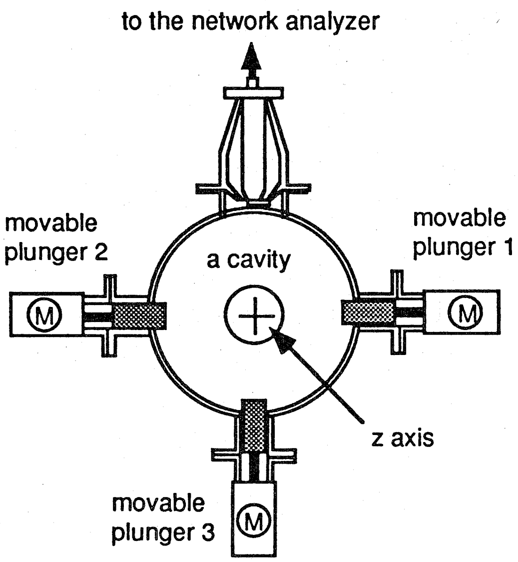


Figure 2. A schematic diagram of the multi-plunger system.

III. RESULTS

The dipole mode frequencies were calculated with the computer codes[2]. In a real cavity, however, the degenerating mode splits into two modes. Figure 3 shows field distributions of the accelerating mode and the dipole HOMs on the beam axis. A 709MHz mode and a 710MHz mode have transverse electric field on the beam axis and their field distributions are similar to each other. Therefore the 709MHz mode and the 710MHz mode were identified as the TE111 mode. The TM110 mode has transverse magnetic field. Figure 3 shows that a 761MHz mode and a 765 MHz mode correspond to the TM110 mode. A 1078MHz mode and a 1079MHz mode were assigned as the TM111 mode.

Figure 4 shows the results of perturbation by the rectangle plate directed (a) horizontally and (b) vertically. If there is magnetic field perpendicular to the face of the plate set on the beam axis, a resonant frequency of HOM shifts higher. In the case of parallel electric field to the direction of the plate, the resonant frequency shifts lower. The result shows that the electric field of the 709MHz mode was directed horizontally and that of the 710MHz mode was directed vertically. The 765MHz mode and the 1079MHz mode were vertical modes and the 761MHz mode and the 1078MHz mode were horizontal modes when an input loop coupler was set up the upper side of the cavity. Then dipole HOMs under consideration were identified with these data. The calculated and measured shunt impedances over the Q-factor are listed in the Table 1.

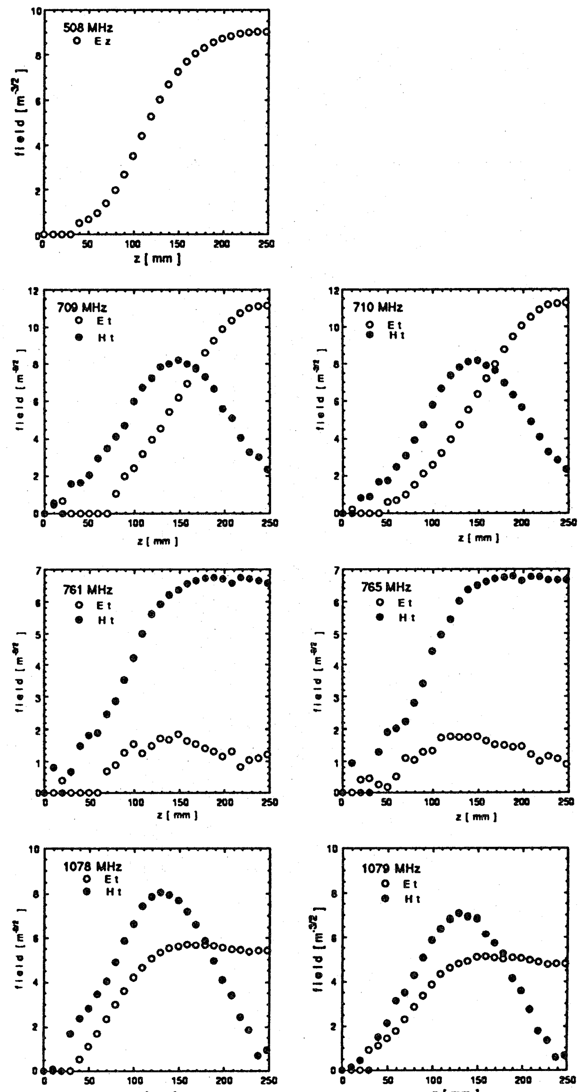
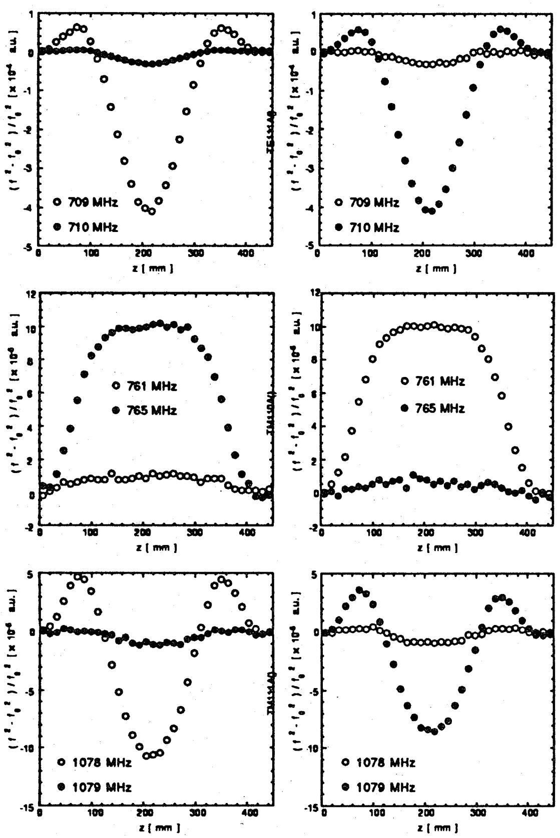


Figure 3. Field distributions of the accelerating mode (508.58MHz) and dipole higher order modes from the enterance of the cavity to the center. Ez means electric field parallel to the beam axis (the z-direction) and Et and Ht stand for transverse electric and magnetic fields, respectively.

	TM010 [Ω]	TE111 [Ω/m]	TM110 [Ω/m]	TM111 [Ω/m]
calculated R/Q	151	73	229	311
measured R/Q	158±5	82±5	210±10	310±20

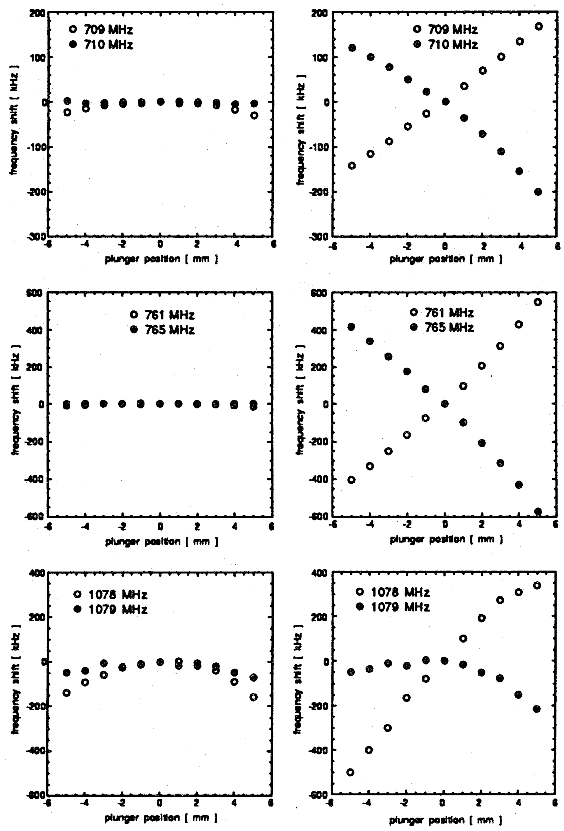
Table 1. Properties of the accelerating mode and dipole higher order modes in the bell shaped cavity. Comparison is made with the calculation of SUPERFISH[6] and URMEL[7].



(a) (b)

Figure 4. Frequency shifts of dipole HOMs by the rectangle copper plate directed (a) horizontally and (b) vertically.

Figure 5 shows frequency shifts of dipole HOMs by two movable plungers. The combination of used plungers was (a) the plungers of both horizontal sides of the cavity, the plunger 1 and the plunger 2 in the Figure 2, and (b) the plungers of the horizontal side and the vertical side, the plunger 1 and the plunger 3. In the case of (b), the plunger 3 was used to shift the HOM frequencies and the plunger 1 was used to tune the cavity to the accelerating frequency. The results show that the frequency shifts for all modes under consideration were small in the case of (a) and large in the case of (b). The perturbation by the plungers to resonant modes depends on the direction of HOMs. The vertical electric mode such as the 710MHz mode and the 1079MHz mode, or the 761MHz horizontal magnetic mode are largely perturbed by the vertical plunger 3. On the other hand, the horizontal plunger 1 and 2 affect both the horizontal electric modes and the vertical magnetic mode. The reason for the small shifts of dipole resonant frequencies in the case of (a) is that the plunger 1 controlling the accelerating frequency compensates the perturbation caused by the plunger 2 shifting the HOM frequencies. The use of the horizontal plunger 1 (or 2) and the vertical plunger 3 makes no compensation for the perturbation to HOMs with the accelerating frequency tuned. As a result, the resonant frequencies were shifted between 30kHz/mm and 100kHz/mm. With the system of multi-plungers, dipole HOM frequencies can be easily adjusted not to satisfy the conditions of the instabilities in machine operation.



(a) (b)

Figure 5. Results of frequency shifts of higher order modes with a diagram of two movable plunger system. (a) two plungers were set on both horizontal sides of the cavity (the plunger 1 and the plunger 2 were used) and (b) one was set on the horizontal side and the other was set on the vertical lower side (the plunger 1 and the plunger 3 were used).

IV. REFERENCES

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