Dependence of Higher-Order Mode Frequencies on Temperature for a Bell-shaped Single Cell Cavity

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Bell-shaped single cell cavities are expected to be installed in the SPring-8 storage ring. Figure 1 shows the inner structure of a prototype cavity. The cavity was designed so that the accelerating TM010-like mode oscillates at 508.58 MHz. The cavity has other resonant modes except TM010-like mode. The modes are called intrinsic higher-order modes (HOMs). When electromagnetic wakefields generated by an electron beam in the RF cavity resonate at the frequency of a specific HOM with high coupling impedance, strong interaction between the electron beam and the wakefields occurs and coupled-bunch instabilities are likely to be induced[1]. We are in particular attentive to such HOMs as TE111, TM110, TM011 and TM111-like modes since the longitudinal or transverse coupling impedance of each mode is high. Their RF parameters computed with the code of URMEL[2] are listed in Table 1. For the bell-shaped single cell cavity, characteristics of HOMs such as the field distributions in the cavity have been measured[3][4][5].

Table 1: RF parameters for some resonant modes of a bell-shaped single cell cavity. They were computed with the code of URMEL [2], assuming that the cavity is made of pure copper.

mode	frequency [MHz]	unloaded Q-value	R/Q [MΩ] or [MΩ/m]
TM010-like	508.15	44100	6.7
TE111 -like	712.14	56000	4.1
TM110-like	763.13	52800	12.1
TM011-like	904.55	43500	2.8
TM111-like	1077.13	44000	13.7

In order to compensate energy loss of the electron beam due to bending magnets and insertion devices, about 100 kW RF power is fed into the cavity when beam current of 100 mA is stored at 8 GeV in the storage ring. About 50 kW RF power is dissipated on the inner wall of the cavity. Tests feeding RF power up to 100 kW into the prototype cavity has been successfully completed[6]. The cavity is equipped with eight channels in which cooling water is supplied by the amount of 80 liter per minute. The channels are also shown in Fig.1. It was found that the temperature near the inner surface increased by about 12 ℃ in case of the 50 kW wall loss. The frequencies of TM010-like mode and of HOMs change according to the temperature raise. The dependence of the frequencies on the temperature of the cavity was one of the important RF characteristics. Therefore, it has been measured and reported here.

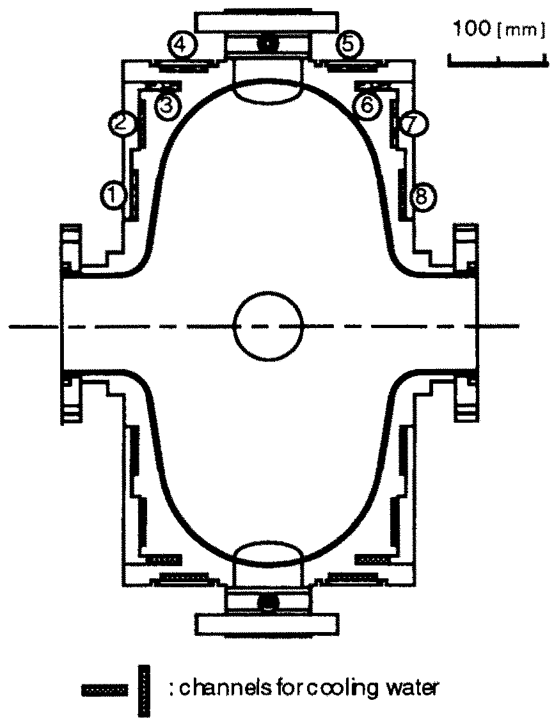

Fig.1:Inner structure of a bell-shaped single cell prototype cavity. Eight channels for cooling water are shown. Each channel is indicated by the circled number.

We have wrapped the prototype cavity in mantle heaters and heated it up, since it is difficult to measure the change of a HOM frequency while feeding high RF power into the cavity. The temperature of the cavity was set to 21, 29, 38, 47 and 57℃ and kept within an error of ± 0.5 ℃. The cavity was evacuated to about 10^{-5} Pa to prevent the inner surface from oxidizing. Then we have measured the frequency changes of TM010, TE111, TM110, TM011 and TM111-like modes with a network analyzer through a coaxial-loop transforming input coupler.

Figure 2 shows the frequency shifts of the modes mentioned above as a function of the temperature. The frequency shift of each mode was proportional to the temperature. There were two resonances for the dipole mode; they were horizontal and vertical modes. They had the same proportionality constant. The proportionality constants are summarized in Table 2. Figure 3 shows the proportionality constant as a function of the resonant frequency. The relation can be approximately expressed by a linear function;

$$A = -0.591 - 0.0159 \times f ,$$

where A and f are the proportionality constant in the unit of kHz/ ℃ and the resonant frequency in the unit of MHz, respectively.

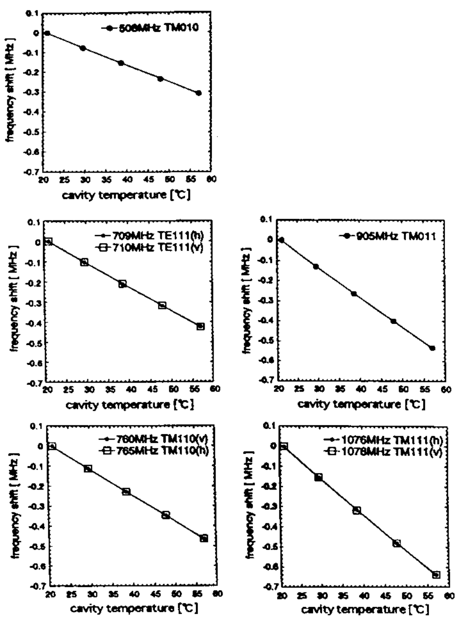

Fig.2: Frequency shifts of TM010-like mode and some HOMs as a function of the temperature of the cavity. The symbols of "(h)" and "(v)" following the mode names in the legends stand for the horizontal and the vertical mode, respectively.

Table 2: Proportionality constant of the frequency shift to the temperature of the cavity.

mode	A [kHz / ℃]
TM010-like	-8.6
TE111 -like	-11.8
TM110-like	-12.9
TM011-like	-14.8
TM111-like	-17.7

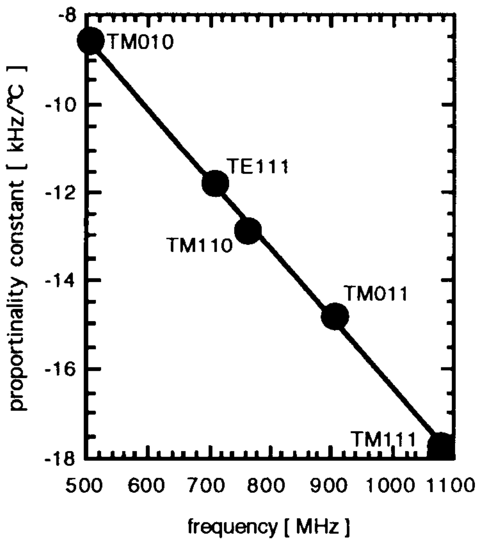

Fig.3: The proportionality constant of the frequency shift as a function of the resonant frequency.

References

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