C-BAND DEFLECTING CAVITY FOR BUNCH LENGTH MEASUREMENT OF 2.5 MEV ELECTRON BEAM*

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Abstract

The C-band deflecting cavity designed last year is finished. In this paper, the RF measurement of the cavity is introduced. After tuning, it works well at 5.712GHz with a coupling factor degree around 1.05. And we measured the electromagnetic field with bead-pull method. The flatness of the magnetic field is around 0.9, which is not ideal but meet the requirements of the bunch length measurement. And we propose a method of tuning to make sure both frequency and field flatness.

INTRODUCTION

The C-band deflecting cavity designed last year for the measurement of ultra-short electron beams is finished. It's a standing wave RF deflecting structure consisting of 3 cells. This cavity is designed to operate at a frequency of 5.712GHz.

In the second section of the paper, the design of the deflector is briefly introduced. RF measurement results are shown in the third part. And a new tuning method is discussed in the fourth part.

RF DEFLECTOR DESIGN

In our case, we choose a 3-cell SW structure to meet the required transverse deflecting voltage V_{def}=1MV. The working mode is TM_{110} mode and π-mode. The 3D-model draw by CST is shown in Figure 1.

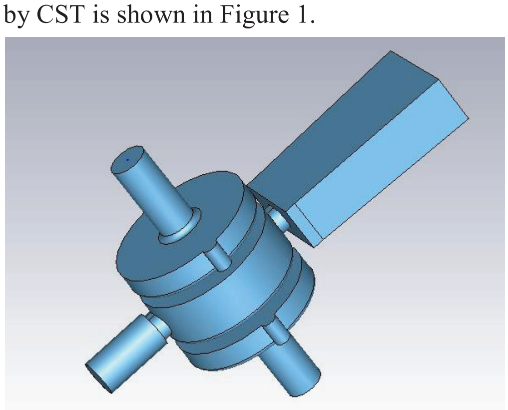

Figure 1: 3D-design of the deflector.

The main part of the model is composed of several cylinders. The radii of the cells are determined by both the frequency and magnet field flatness. And the length of central cell is determined by the working mode while the length of the end cells is determined by the results of particle dynamics[1].

In order to make sure the polarization direction not changed while two cell coupled, two end cells are slotted on the edges which are perpendicular to the direction we put the coupler.

According to the discussion above, the dimensions of the cavity are shown in figure 2 and table 2.

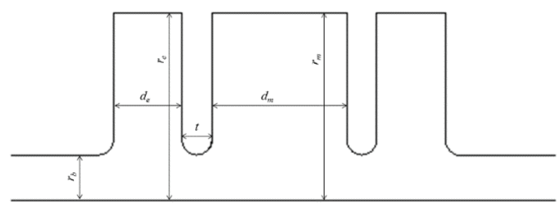

Figure 2: 3D-design of the deflector.

Table 1: Dimensions of the RF Cavity

Dimensions	**Value(mm)**
r_m	30.85
d_m	21.49
r_e	30.61
d_e	10.93
t	4.76
r_b	8
r_{slot} (not shown in figure 2)	3.5

According to the dimensions, it's easy to get the cavity parameters such as the transverse shunt impedance. And table 3 shows the main parameters of the RF cavity. With 1 MW input power, the deflecting voltage can be 1.19 MV.

Table 3: Cavity Parameters

Parameters	**Value**
Q_0	9003
R_T/Q(MΩ)	156
R_T(MΩ)	1.42
P(MW)	1
V_{def}(MV)	1.19

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In table 3, we are more concerned about R_T/Q which has little change after machining. And we can evaluate the real deflecting voltage by measuring the quality factor Q_0 by equation 1

$$R_T = \frac{V_{def}^2}{P} \tag{1}$$

RF MEASUREMENT RESULTS

f and Q_0

Figure 3 and table 4 show the scene and results of cold test. The temperature of the environment is 21.9 °C the last time of tuning. And the working temperature of the cavity is 37°C which means the target frequency with vacuum is 5713.432MHz. By pushing and pulling the tuning holes, frequency of π-mode was finally tuned to 5713.432MHz. The measurement error of temperature is around 0.1 °C so the frequency error is around 10kHz.

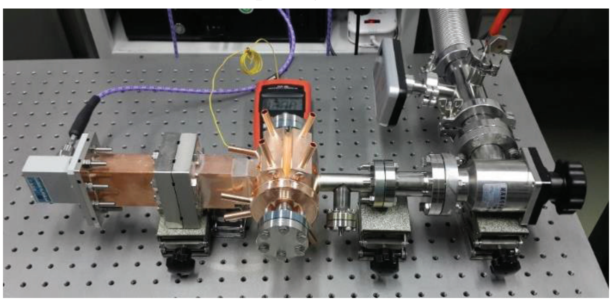

Figure 3: Cold test of the deflecting cavity

Table 4: Results of cold test and tuning

	Before brazing	After brazing	After tuning
temperature(°C)	23.5	21.3	21.9
air or vacuum	air	air	vacuum
frequency(MHz)	5709	5707.88	5713.432
target frequency(MHz)	5711.595	5711.804	5713.4318
Q_0	3624	9050	9448

Figure 4 shows S11 parameter measured in 21.8°C and 0.98mbar vacuum after tuning. From this figure, we can calculate the quality factor is 9448, which is a little bigger than simulation results. With R_T/Q=156 from simulation results and 1MW power input, we can get the deflecting voltage:

$$V_{def} = \sqrt{R_T / Q \times Q_0 \times P} \approx 1.21(MV) \tag{2}$$

Meanwhile, the cavity is over coupled with a coupling factor of 1.065.

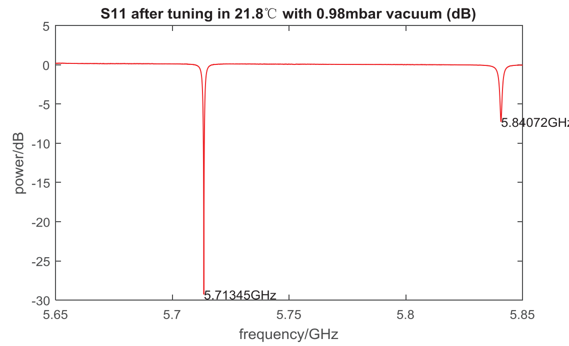

Figure 4: S11 parameter of the cavity

Electromagnetic Field

Figure 5 shows normalized electromagnetic field distribution against the perturbation position along the central axes of the cavity measured by bead-pull method. The flatness ratio of magnetic field is 0.99/1/1.02. Figure 6 shows the results of particle dynamics influenced by field flatness. From this figure, the vertical deflection of the particles changes only 0.15 mm while the flatness changes 0.1. It's believed that the cavity is going to work well.

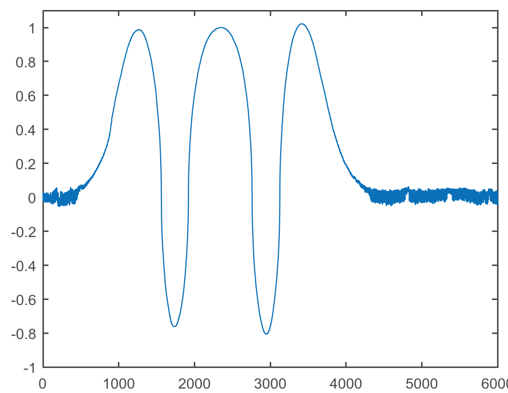

Figure 5: Normalized electromagnetic field distribution

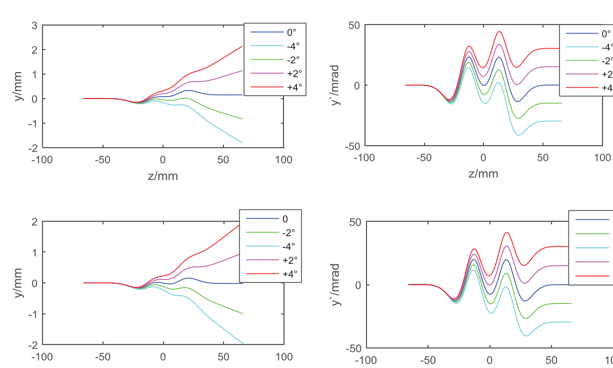

Figure 6: Vertical deflection and vertical angle of particles getting through the deflecting cavity with flatness of 0.995 above and 0.9 below

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TUNING METHOD

Field distribution and frequency of the cavity is tuned by pushing of pulling the tuning hole, which is complexed to make sure both of them. Here we presented a method to calculate the frequency change that each cell need to be tuned while the original frequency and field distribution are known.

Tuning process can be simulated by adjusting the radius of the 3 cells using CST. Figure 7 shows that the flatness of magnetic field is linearly to frequency of π-mode while radius of the 3 cells changing respectively. Suppose resonant frequency changes Δf

$$\Delta f = \Delta f_1 + \Delta f_2 + \Delta f_3 \tag{3}$$

where Δf_1, Δf_2 and Δf_3 mean the change of the resonant frequency adjusting the radius of the 3 cell respectively. Suppose

$$x_1 = \left|\frac{B_{1,\max}}{B_{2,\max}}\right|, x_3 = \left|\frac{B_{3,\max}}{B_{2,\max}}\right| \tag{4}$$

then, the change of the field flatness is given

$$\begin{aligned} \Delta x_1 &= \frac{\partial x_1}{\partial f_1}\Delta f_1 + \frac{\partial x_1}{\partial f_2}\Delta f_2 + \frac{\partial x_1}{\partial f_3}\Delta f_3 \\ \Delta x_3 &= \frac{\partial x_2}{\partial f_1}\Delta f_1 + \frac{\partial x_3}{\partial f_2}\Delta f_2 + \frac{\partial x_3}{\partial f_3}\Delta f_3 \end{aligned} \tag{5}$$

Considering equation (4) and simulation results, finally we get

$$\begin{pmatrix} \Delta x_1 \\ \Delta x_3 \\ \Delta f \end{pmatrix} = \begin{pmatrix} -61.287 & 25.846 & 29.479 \\ 29.565 & 25.994 & -61.147 \\ 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} \Delta f_1 \\ \Delta f_2 \\ \Delta f_3 \end{pmatrix} \tag{6}$$

or

$$\begin{pmatrix} \Delta f_1 \\ \Delta f_2 \\ \Delta f_3 \end{pmatrix} = \begin{pmatrix} -0.0115 & -0.0005 & 0.3096 \\ 0.0120 & 0.0120 & 0.3794 \\ -0.0005 & -0.0115 & 0.3110 \end{pmatrix} \begin{pmatrix} \Delta x_1 \\ \Delta x_3 \\ \Delta f \end{pmatrix} \tag{7}$$

From equation (7), we can easily calculate how much frequency adjustment needed to be made for each cell knowing the original field distribution and frequency. And it can greatly reduce the complexity of tuning process.

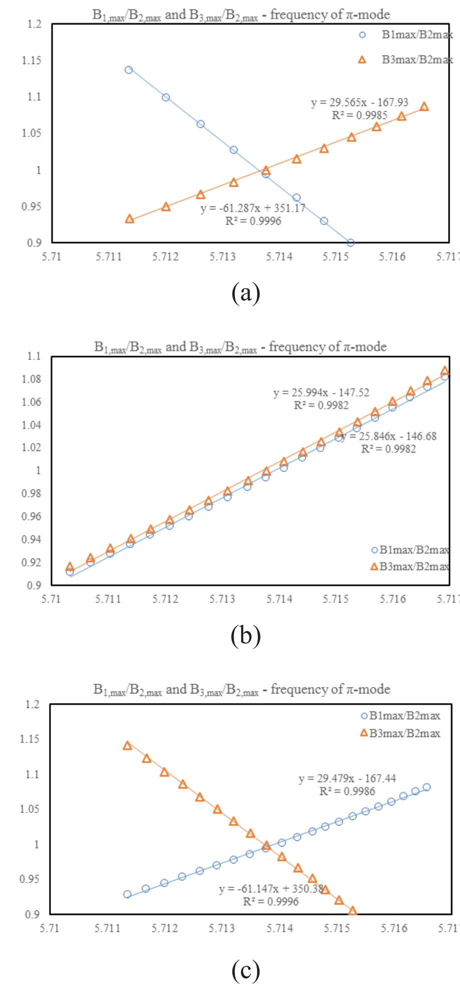

Figure 7: Magnetic field flatness changes against frequency of π-mode while radius of (a)cell 1, (b)cell 2, (c)cell 3 changing

CONCLUSION

We introduced the design and cold test of the RF deflector. After tuning the deflecting cavity performs well at a frequency of 5.712GHz (37℃) and the coupling factor is 1.065. The deflection voltage is up to 1.21MV with 1MW power input. The flatness of magnetic field is adjusted to 0.92, which meets the requirement of bunch diagnosis. To reduce the complexity of tuning process, we proposed a method to calculate frequency adjustment of each cell knowing the original field distribution and frequency, which would be verified in the next deflecting cavity.

REFERENCES

[1] Jiaru Shi, Studies of RF deflecting/crab cavities for beam manipulation and diagnostics, Diss. Tsinghua University, 2009.