

# A NOVEL RACETRACK MICROTRON ACCELERATING STRUCTURE\*

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## Abstract

We have designed, constructed, and evaluated a **R**ectangular **C**avities **B**iperiodic **S**tructure prototype for our compact 70 MeV pulsed **R**ace**T**rack **M**icrotron [1]. We present here the design details and test measurements.

## 1 INTRODUCTION

Our mobile 70 MeV RTM requires a narrow accelerating structure to allow 1<sup>st</sup> orbit electrons to bypass the structure. We solved this problem by using a rectangular accelerating structure with rectangular vertically extended beam slots. This structure also produces high frequency horizontal focusing, which we use to simplify the RTM construction and operation [1,2].

## 2 STRUCTURE CALCULATION

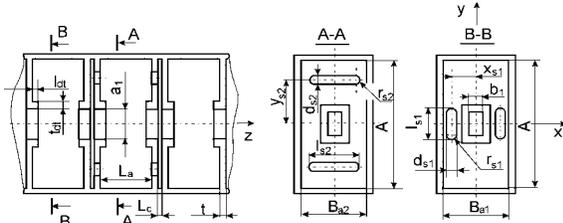


Figure 1: Rectangular cavities biperiodic structure

We found the RCBS structure dimensions with optimal electrodynamic characteristics, seen in Fig. 1, using analytical and numerical calculations as well as computer simulations [3]. We calculated a seven cell section, seen in Fig. 2, whose first cell is for  $\beta=0.67$ . In Table 1 we present the structure dimensions where the first and last end cells are listed separately. In Fig. 3 we show the calculated RCBS dispersion characteristics. Figure 4 contains the calculated on-axis longitudinal electrical field.

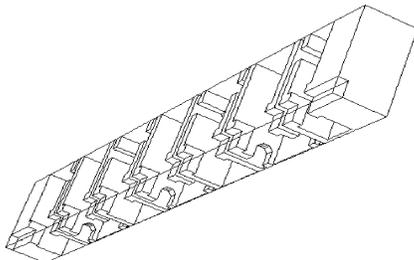


Figure 2: Seven cell RCBS section

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Table 1: RCBS dimensions (in mm)

Main Cells		End Cells	
$D=\lambda_w/2$	52.5		
A	110.0	A[1]/A[7]	110.0/110.0
$B_{a1}$	54.9	$B_{a1}[1]/B_{a1}[7]$	52.98/55.76
$B_{a2}$	55.3		
$B_c$	52.5		
$L_a$	38.0	L. [1]	20.68
$L_c$	3.5		
T	5.5		
$A_1$	20.0		
$B_1$	10.0		
$l_{dt}$	4.4		
$t_{dt}$	5.0		
$x_{s1}$	20.0		
$l_{s1}$	32.1	$l_{s1}[1]/l_{s1}[7]$	51.70/37.36
$d_{s1}$	8.0		
$y_{s2}$	45.0		
$l_{s2}$	38.2		
$d_{s2}$	8.0		

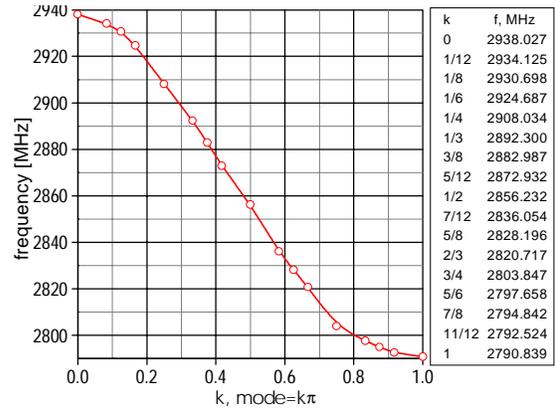


Figure 3: Seven cell RCBS section dispersion characteristics

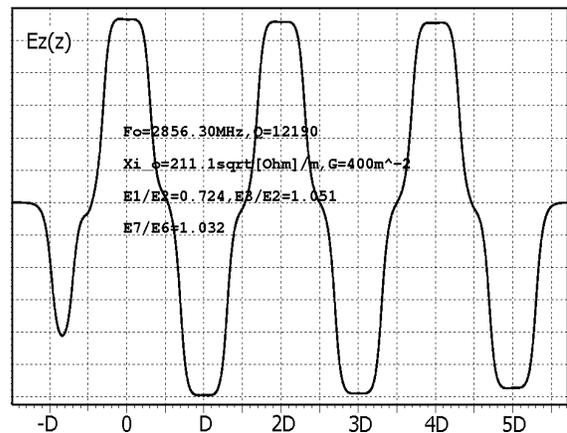


Figure 4: Seven cell RCBS section  $E_z(0,0,z)$

### 3 STRUCTURE TUNING

Our manufactured seven accelerating and six coupling cell section geometry was adjusted to obtain the operating frequency in various resonant setups, each with a different number of RCBS periods. We then tuned the end cells to obtain the required accelerating field distribution at the operating frequency by adjusting the end cell coupling slot lengths and narrow wall dimensions,  $B_{a1}[i]$ ,  $i=1$  and 7. Next we tuned the coupler cell frequency by decreasing its narrow wall dimension by 0.6mm ( $B_{A,CPL}=54.3\text{mm}$ ). We chose the coupling window width for the  $72\times 34\text{mm}^2$  feeding waveguide using its analytical dependence on the normalized impedance, seen in Fig. 5 [4]. To support a 0.7A total beam current from all orbits, we matched the coupler using a coupling coefficient of  $\sim 3.5$  [4]. An approximate analytical formula gave a window width of 31.7mm, which we made 28mm and increased to 28.8mm during tuning.

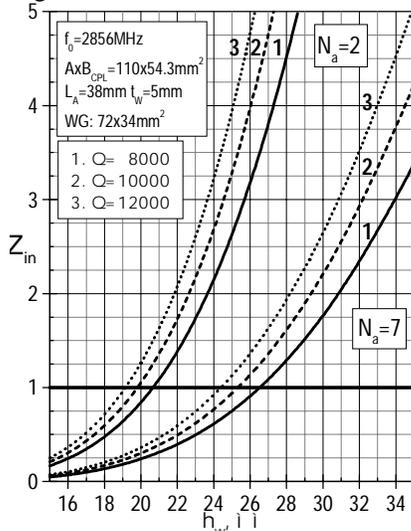


Figure 5: Coupler impedance with window width

### 4 STRUCTURE MEASUREMENTS

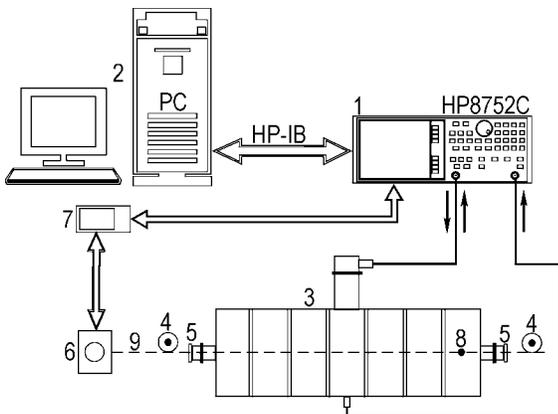


Figure 6: Measurement setup

We measured the section electrodynamics characteristics using the setup shown in Fig. 6, which consisted of (1) a

network analyzer, (2) a personal computer, and a mechanical assembly. This assembly included (3) the structure, (4) a bead pulling system with (5) pulleys, (6) thread directors inserted into drift tubes, and (7) a stepper motor/controller. The stepper motor, used to drive the (8) ceramic bead attached to (9) a nylon thread, was controlled by the computer through the network analyzer.

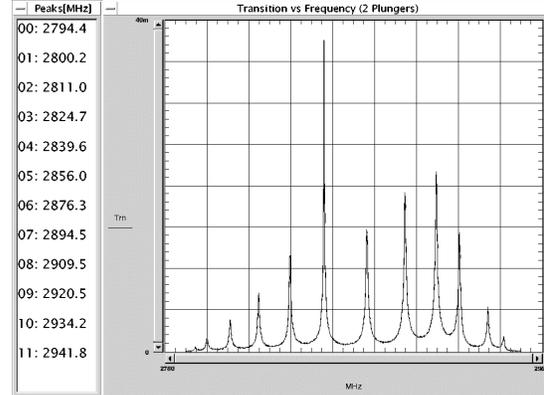


Figure 7: RF modes spectra measurements

After tuning and matching the coupler with the structure, we obtained the  $\pi/2$  mode operating frequency of  $f_0=(2856\pm 0.1)\text{MHz}$  at  $20^\circ\text{C}$  in agreement with the calculated value. We realized the lowest passband  $E_{11}$  resonance frequencies, seen in Fig. 7, using both reflection (standing wave ratio) and transition ( $K_{tr}$ ) coefficient measurements, with two different field exciting and pick-off points, through a waveguide adapter connected to the coupler and through a metal plunger inserted into the drift tube.

After matching the coupler with the rectangular waveguide, the structure coupling coefficient was 3.0. Using a small 5mm diameter metal rod mounted near the narrow rectangular waveguide wall, we obtained the 1.0 standing wave ratio used in field measurements. We also measured the Q-factor.

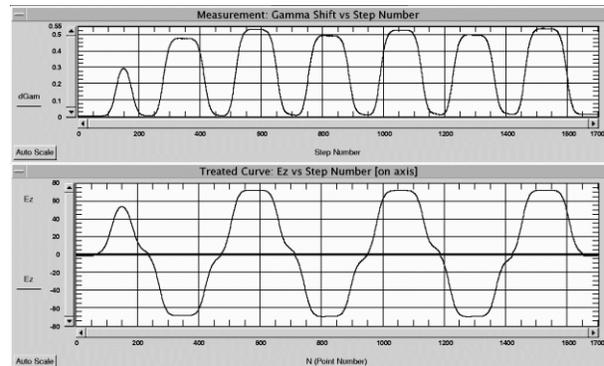


Figure 8: Seven cell  $E_z(0,0,z)$  measured distribution

We measured the field distribution and effective shunt impedance using the bead-pull method with a 6mm long, 0.6mm diameter dielectric cylinder as the perturbing bead. The bead form factor, measured in the  $E_{010}$  cylindrical

resonator mode, was  $8.849 \times 10^{-20} \text{ m}^2 \text{ c} / \Omega \text{ m}$ . We made these field distribution measurements, seen in Fig. 8, in two ways. In the first we obtained the shunt impedance by measuring, with the network analyzer, the induced frequency shift as the bead moved along the structure axis. From  $\xi(\mathbf{z}) = E_z(\mathbf{z}) / \sqrt{PQ} = \sqrt{\Delta f / (2\pi K_r^E f_0^2)}$ , where  $E_z(z)$  is the on-axis longitudinal electric field,  $P$  is RF power, and  $Q$  is the Q-factor,  $\xi_0 = E_{z0} / \sqrt{PQ}$  was obtained by integrating over the regular part of the field distribution curve and its first harmonic amplitude for  $\xi(z)$ .

In the second more accurate method, we measured the reflection coefficient,  $\Gamma$ , at a fixed frequency to obtain the longitudinal electrical field gradient. Here the electric field at the bead position is proportional to  $\sqrt{\Delta\Gamma}$ , and we calculated the focusing gradient,  $G_x = 2(I(\mathbf{x})/I_0 - 1) / x^2$  (or y-axis).  $I_0$  is the integral of  $\sqrt{\Delta\Gamma(\mathbf{z})}$  over the regular part of the on-axis field data and  $I(x)$  is this measurement off-axis by a distance  $x$ . The measured adjacent cell electrical field amplitude ratios were found to be  $E_1/E_2=0.78$ ,  $E_3/E_2=1.06$ , and  $E_7/E_6=1.04$ .

The effective shunt impedance to Q-factor ratio was obtained from  $r_{\text{sheff}}/Q = \xi_0^2 L/2$ , where  $L$  is the regular structure length. The test section is not a regular structure so we used an indirect effective shunt impedance measurement. We found  $\xi_0$  and related it to the effective shunt impedance by  $r_{\text{sheff}}/Q \sim \xi_0^2$ . We then obtained the full section shunt impedance to Q factor,  $R/Q$ , by integrating  $\xi(\mathbf{z})$  over the full section length. The structure electro-dynamics characteristics results are seen in Table 2.

Table 2: Structure Electro-dynamics Characteristics

Characteristic	Measured	Calculated
$f_0$ (MHz)	$2,856 \pm 0.1$	2,856.0
$k_c$ (%)	5.1	5.1
Q	$10,800 \pm 200$	12,400
$\xi_0$ ( $\sqrt{\Omega}$ /m)	$205 \pm 5$	211
$r_{\text{sh,eff}}/Q$ (k $\Omega$ /m)	$3.3 \pm 0.3$	3.65
$r_{\text{sh,eff}}$ (M $\Omega$ /m)	$37 \pm 3$	45
$R/Q$ (k $\Omega$ )	$1.25 \pm 0.02$	1.23
$G_x$ ( $\text{m}^{-2}$ )	$500 \pm 100$	410
$G_y$ ( $\text{m}^{-2}$ )	$-300 \pm 100$	-410

## 5 CONCLUSIONS

The RCBS for our compact 70 MeV pulsed RTM has measured EDC in good agreement with those we calculated. Our RCBS, which operates in the  $\pi/2$  mode at 2,856 MHz with a Q of 11,000, has a  $\sim 40 \text{ M}\Omega/\text{m}$  effective shunt impedance and a  $\sim 400 \text{ m}^{-2}$  focusing gradient.

## 6 REFERENCES

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