CEBAF's New RF Separator Structure Test Results*

Reza Kazimi, J. Fugitt, A. Krycuk, C. K. Sinclair, L. Turlington
Continuous Electron Beam Accelerator Facility
12000 Jefferson Avenue, Newport News, VA 23606 USA

Abstract

Prototypes of the rf separator for CEBAF have been made and successfully beam tested. The structure is a new design which has a high transverse shunt impedance together with a small transverse dimension compared to more conventional rf deflecting structures. Five rf separators will be used at CEBAF to allow beam from any one of the five recirculation passes to be delivered to any of the three experimental halls. We have already described the basic design of the structure and theoretical calculations. we have also reported some results from rf measurements and beam tests. In this paper we present more beam test results, our final design parameters, and test results of coupling two 1/2 wavelength cavities together.

I. INTRODUCTION

The CEBAF rf separator is a new design [1]. In our previous paper we have discussed the purpose of rf separators at CEBAF, the basic design of the structure, and characteristics and advantages of the new structure [2]. The following sections present a summary of our previous test results and an update of our progress.

II. TEST CAVITY RF TEST

A test cavity with the dimensions listed in Table 1 was constructed [2]. Since one can not incorporate all the geometrical details into MAFIA to arrive at the exact resonant frequency, the rods were intentionally made slightly longer than needed. This resulted in a lower resonant frequency, about 489 MHz. Then, through several iterations the rods were cut shorter and the resonant frequency was raised to about 1 MHz above the 499 MHz target. The final tuning was done with capacitive tuners which come in at the center of the cavity and are capable of driving the frequency down as much as 20 MHz with little degradation of the Q.

Table 1
RF Separator Test Cavity Parameters

Frequency	499 MHz
Cavity length	30 cm
Cavity diameter (d_{out})	33 cm
Gap between facing rods	2 cm
Rod separation (center to center)	4 cm
Rod diameter (d)	2 cm
$R_\perp/Q$ (MAFIA)	47 kΩ/m

Figure 1 shows the frequency spectrum of the cavity (before tuning) from 320 to 580 MHz. The second mode at 501 MHz is our desired mode [2]. The unloaded Q factor for this mode was measured to be 5400.

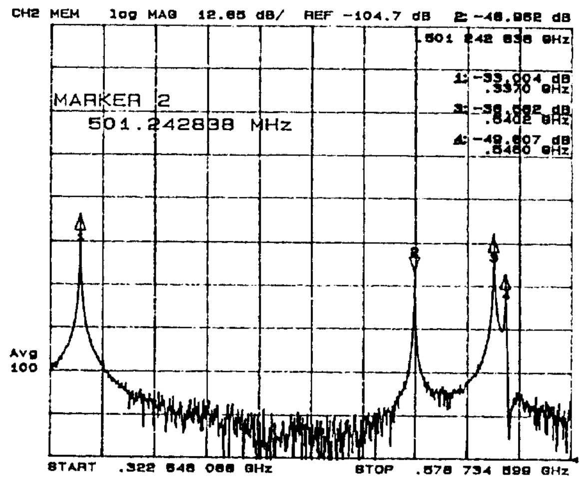

Fig. 1 Cavity modes from 320 MHz to 580 MHz.

III. BEAM TEST RESULTS

For our test, we used the electron beam from the CEBAF injector at 45 MeV. Consequently, only 9.5 W of rf power can produce a separation angle of 0.5 mrad, or 0.5 cm separation at 10 m away. This is a large enough separation to easily measure on a view screen. At approximately 9 m downstream from the separator cavity, the beam can be observed on a view screen and measured by a harp (a wire scanner). As soon as the rf was turned on to the cavity, the one beam spot on the screen was split into three spots (Fig. 2). Changing the rf phase changed the relative positions of the three spots.

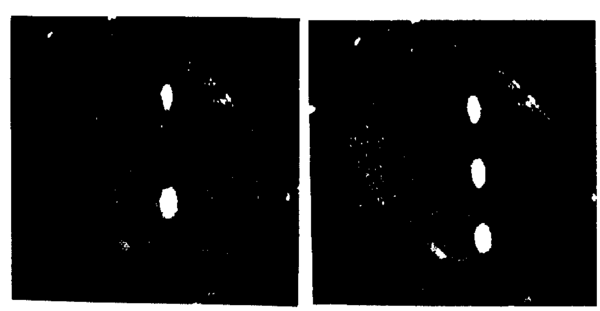

Fig. 2 The separated beam on the view screen. Two and three beam creation.

Since the beam is split in the y direction, the beam was focused in y and defocused in x to give a sharper signal in the y direction. Figure 3 shows the harp traces of the beam for the two different rf phases. The first signal on the harp trace is the x scan and the others to the right of it

*Supported by D.O.E. contract #DE-AC05-84ER40150 are the y scan. Using the amount of the beam separation vs. rf power, the measured $R_\perp/Q$ was determined to be 43.8 $\pm$ 2.4 kΩ/m, which compares well with 47 kΩ/m from MAFIA. ($R_\perp = \frac{V_\perp^2}{P}$; $V_\perp$ is the integrated deflection voltage.) We measured the field uniformity by moving the beam within the cavity aperture and observing the change in the amount of the deflection; however, we did not see a significant change. We also measured the emittance for zero and maximum deflection. We observed, within 10% measurement error, no change of the emittance due to the separator. This is consistent with the very short measured bunch length in the CEBAF injector.

a)

b)

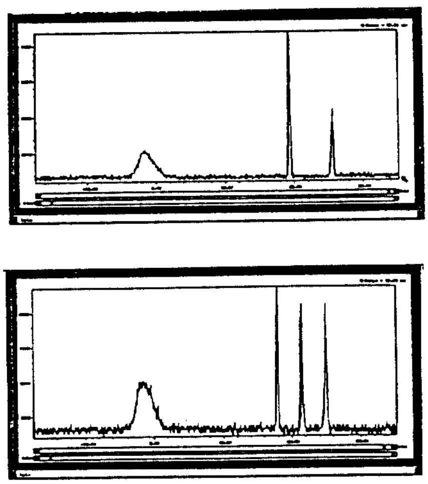

Fig. 3 Harp scan of the beam for a) two and b) three beam creation.

VI. FINAL DESIGN PARAMETERS

The parameters for the CEBAF RF Separators are listed in Table 2.

Table 2
CEBAF RF Separator Parameters

Frequency	499 MHz
Cavity length	30 cm
Cavity diameter (d_{out})	33 cm
Gap between facing rods	1.8 cm
Rod separation (center to center)	3.5 cm
Rod diameter (d)	2 cm
$R_\perp/Q$ (MAFIA)	75 kΩ/m
Max surface E-field	<0.5 Kilpatrick

The $R_\perp/Q$ value is about a factor of 50% larger in Table 2 than in Table 1. This is due to the change of distances between the rods. With $R_\perp/Q$ given by MAFIA, and $Q \approx 5000$, then $R_\perp \approx 375$ MΩ/m. The required rf power for a separation angle of 0.1 mrad at 4 GeV is then:

$$P = \frac{V_\perp{}^2}{R_\perp \ell} = \frac{(4\text{ GeV} \times 0.1\text{ mrad}/\sin 60^\circ)^2}{(375\text{ M}\Omega/\text{m})\ (0.60\text{ m})} = 1.0\text{ kW}$$

The maximum surface E-field listed in Table 2 is an over estimation of the maximum E-field on the tip of the rods. In our calculation, we considered the highest electric field on two conducting spheres separated by the distance equal to the minimum separation between the rods. The radius of the spheres is equal to the minimum radius on the rods, and the voltage on the spheres is the maximum voltage between the tips of the rods.

VI. COUPLING TWO $\lambda/2$ CELLS

Two $\lambda/2$ structures can be coupled to each other to obtain a 60 cm long two-cell structure. The longer structure will require half as much rf power for the same deflection. The coupling is done magnetically through two rectangular shape (2″ × 5″) openings in the wall between the cells. This coupling creates symmetric (zero mode) and anti-symmetric (π mode) fields in the structure. The size of the opening is chosen to produce about 2 MHz separation between the modes. We arrived at this frequency separation by iteratively increasing the size of the openings. The desired mode is the π mode in which the deflection from the first and second cells adds. Because of magnetic coupling the π mode has a lower frequency than the zero mode. To confirm which resonant frequency is the zero and which is the π mode experimentally, a cold model was used. The phase of the magnetic field was measured in one of the cells at both frequencies. Then without changing the orientation of the loop, the loop was moved to the other cell and the phase of the magnetic field was measured again at the same frequencies (Fig. 4). At the lower frequency mode, the phase was changed by 180 degrees between the two measurements; however, at the higher frequency mode, the two measurements had the same results. Therefore, the lower mode was the desired π mode.

a)
1: -168°
2: 169°

b)
1: 6°, 180° out
2: 174°, same

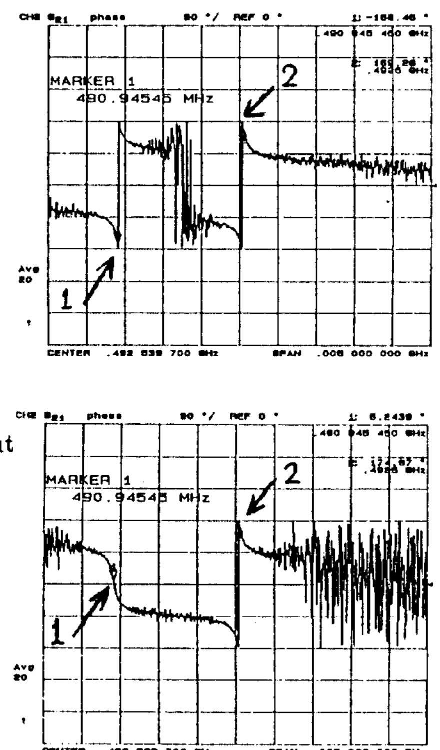

Fig. 4 Phase of the S_{11}. a) RF_{in} and RF_{out} loops in the same cell b) RF_{out} in a different cell.

Two tuners are used in the structure, one in each cell. Two tuners are required to tune the structure to the right frequency and to ensure equal field amplitudes in both cells. The equality of the field amplitudes was studied by a bead-pulling experiment and, also, by comparing the magnitude of S_{11} (reflected wave amplitude) for the zero and π modes. We found equal field amplitudes, when the two reflected wave amplitudes were equal. In this situation, frequency separation between the two modes is the least. In addition to cold models, a full-size two-cell (one λ) structure was constructed to study the structure properties [3]. Figure 5 shows the π and zero modes. We are planning to perform full rf power tests of this structure soon.

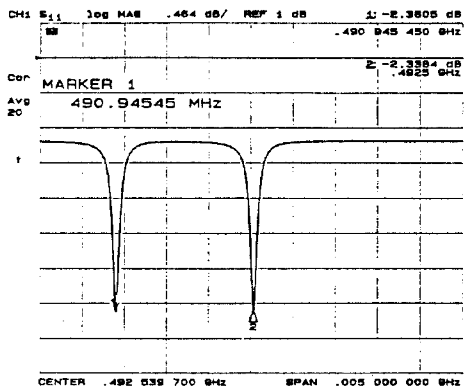

Fig. 5 π and zero modes for two-cell (one λ) structure.

VI. CONCLUSION

A proof of principle experiment has been conducted with successful results [2]. We have verified the high transverse shunt impedance properties of the cavity and we have also seen no degradation of the beam characteristics of the deflected beam. We have established that this new design is well suited to the CEBAF rf separator requirements.

VII. REFERENCES

[1] C. Leemann and G. Yao, "A Highly Effective Deflecting Structure," 1990 Linear Accelerator Conference, Albuquerque, New Mexico.

[2] R. Kazimi, *et al.*, "Test of a new rf separator for CEBAF," 1992 Linear Accelerator Conference, pp. 244–246.

[3] A. Krycuk, *et al.*, "Construction of the CEBAF rf separator," These proceedings.