Construction of the CEBAF RF Separator*

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Abstract

The CEBAF accelerator is designed in a multipass racetrack configuration, with two 1497 MHz linear accelerator sections joined by independent magnetic transport arcs. Room temperature subharmonic rf separator cavities will be used on each independent arc to extract a portion of the recirculating beam, and one additional cavity will be used to divide the final full-energy beam between CEBAF's three experimental end stations. A single-cell prototype cavity has already been built and tested at low power levels. The next stage of the design process is the construction of a cavity capable of operation at full power, i.e. at a gradient sufficient to provide the required 100 μrad bend to a 6 GeV beam. The paper will discuss both the electrical and mechanical design of the cavity, construction techniques employed, and preliminary test results.

I. INTRODUCTION

The CEBAF accelerator is designed in a multipass racetrack configuration, with two 1497 MHz linear accelerator sections joined by independent magnetic transport arcs. A room temperature subharmonic rf separator cavity will be placed on each independent arc to extract a portion of the beam, and one additional cavity will be used to divide the final full-energy beam between the three experimental end stations.

II. CAVITY DESIGN

The rf separators used at CEBAF are quarter-wavelength cavities with four opposed rods placed parallel to the beam axis (Figure 1)[1]. This creates a field pattern close to that of a TEM dipole mode, resonant at 499 MHz, the third subharmonic of the fundamental accelerator frequency. The rods serve to compress the field into the center of the cavity, increasing the transverse shunt impedance $R_\perp$ to on the order of 250 MΩ. The Q_0 of the cavity is measured to be 5000, from which the power required to deflect the different beams the required 100 μrad can be derived according to

$$P = \frac{(E \times 100 \ \mu\text{rad}/\sin 60°)^2}{\left(236 \,{}^{M\Omega}\!/\!_{m}\right)(.30 \ \text{m})}$$

The above result is for a single-cell structure. Multiple-cell geometry will be used on the higher-energy passes of the accelerator, as is summarized in Table 1.

Table 1
Separator Requirements for CEBAF Accelerator

Beam Pass	Energy (GeV)	No. of Cavities	Power Req'd (W)
1	1.2	1	270
2	2.4	1	1000
3	3.6	2	1200
4	4.8	2	2200
5	6.0	3	2250

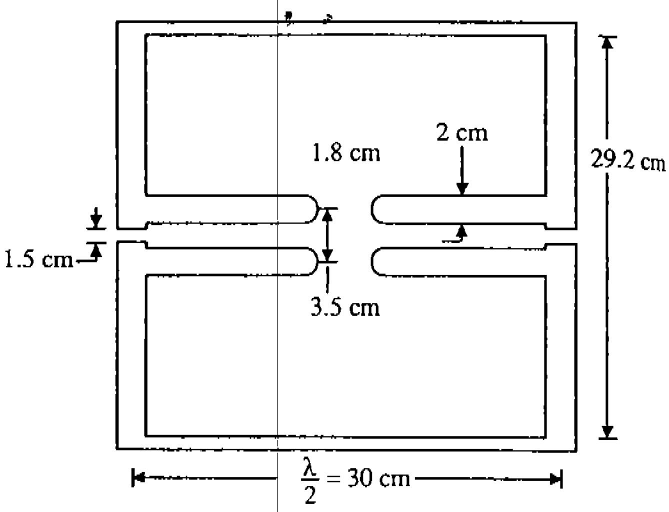

Figure 1. Single Cell Cavity Geometry

III. CAVITY FABRICATION

In order to standardize parts while maintaining the flexibility necessary to support the multiple cell geometry needed for beam separation, it was decided to fabricate the cavity in modular elements. Thus the spool piece, end flanges and center flanges (of multiple cell structures) are discrete elements.

The spool piece, which is the cylindrical body of the cavity, is made from stainless pipe, with a 14 inch knife-edge flange welded on either end. Additional ports on the circumference of the spool are provided for pumpdown and tuner control. The entire assembly, with the exception of the knife edges, is acid copper plated to lessen surface resistivity.

Due to the field concentration caused by the rods, most of the surface current flows from the base of one rod to the next. The control of resistance in this area is critical to maintaining the Q of the cavity. As machining such a complex geometry is feasible, but prohibitively expensive, it was decided to use a gold-copper braze alloy to join the individual OFE rods to an OFE copper insert. This maintains good conductivity while providing reliable seal of the water passages which cool the

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rods. At the same time that the rods are brazed to the insert, a stainless steel ring is brazed around the insert.

This sst ring serves as an intermediate between the copper insert and the remainder of the end flange, which is machined from a 14" knife-edge blank. The insert assembly is subsequently electron beam welded to the flange with a full penetration weld. It was felt a copper-steel weld would not provide a reliable water to vacuum seal, while at the same time it is not recommended practice to subject a knife edge seal to braze temperatures. Beam tube, rf input, and cavity field probe flanges are also present on the end flange.

The center flange assembly contains a double-sided rod insert, as it carries rod assemblies for two quarter-wave cells. Two symmetric magnetic coupling irises are present to admit rf to the attached cell(s). RF power is coupled into the cell structure using a coupling loop originally designed as the output coupler on a 5 kW klystron. The loop is cooled by conduction to the outside.

In order to maintain the cavity at the correct resonant frequency, a capacitive tuner was included. The tuner consists of a copper flap, grounded to the wall of the cavity on one end, that can be bent by means of an externally adjusted linear motion feedthrough to close proximity of the rods. A tuning range of 5 MHz is obtained. No dynamic tuning capability was included in the tuner design, as the frequency shift with respect to temperature of the cavity is 2 kHz/deg C. The cooling of the separators limits the temperature increase in any part of the cavity to 1—2 deg C in the rods, while maintaining the remainder of the cavity at 95 deg C. Therefore, it can be seen that any temperature-induced frequency changes are well within the cavity bandwidth.

IV. SYSTEM CONSIDERATIONS

The rf separators are used in two configurations. The four that are placed on the lower energy recirculating arcs deflect the beam in the horizontal direction. The phasing of the rf in these cavities (see Figure 2) and the downstream magnet configuration are such as to allow a portion of the beam to be steered to only one of the experimental halls, while the remainder is recirculated back into the linacs. The remaining separator on the high-energy leg is phased to divide the beam in three for the end stations.

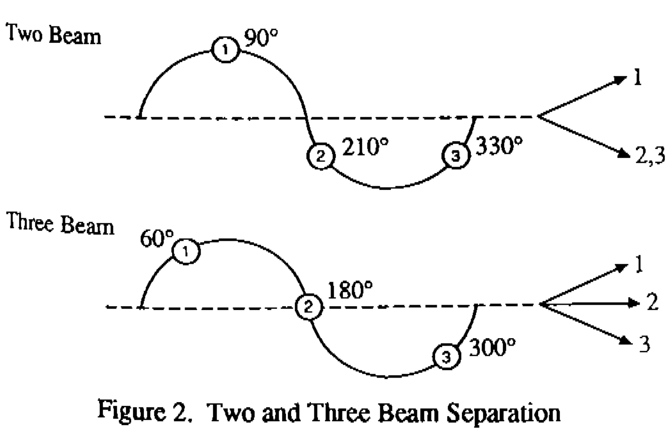

Figure 2. Two and Three Beam Separation

As can be seen from Table 1, the cavities require on the order of kilowatts to achieve separation. Fortunately, the frequency used for the separators is close to the UHF amateur and television bands (420—450 MHz), so amplifiers of the gain and output required for driving the cavities can be obtained commercially with only a slight shift in bandwidth. Currently, only one amplifier has been obtained. Manufactured by Henry Radio, it is capable of producing 1.5 kW at 499 MHz with a gain of 40 dB.

Phase and amplitude stability of the rf in the separator cavities is achieved by using the same modules as the rest of the CEBAF rf control system [2], modified to operate at 499 MHz. The rf system for the separators is locked to the accelerator frequency through the frequency reference system [3].

The major concern in operation of the separators is phase slippage of the cavities with respect to the injector. The experimental halls require differing currents, with Hall B being limited to nanoamperes, while the other two are set to receive microamperes of beam. The injector, through use of a subharmonic chopper and current-limiting apertures, defines the beam current for each bunch. Should the phase of the separators change with respect to the injector, it could result in the beam being sent to the wrong hall. To prevent this, a direct measurement of the injector-separator phase is being implemented. A sample of the field in the chopper cavity is compared to one from the high-energy cavity; if the phase difference between the two has changed, the beam is shut off.

V. CONCLUSION

A separator cavity capable of operating at full gradient has been constructed and is awaiting high-power rf test. All five of the separators will be installed by June 1994. Beam will be provided to the first cavity by March 1994.

VI. REFERENCES

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

[2] S. Simrock, "RF Control System for CEBAF," 1991 Particle Accelerator Conference, May 1991.

[3] A. Krycuk, J. Fugitt, and S. Simrock, "Construction of the CEBAF Frequency Distribution System," presented at this conference.