STATUS OF THE CEBAF INJECTOR*

W. T. Diamond and R. Pico
Continuous Electron Beam Accelerator Facility
12000 Jefferson Avenue, Newport News, Virginia 23606

Abstract

The injector for the CEBAF cw superconducting linac consists of a 100 keV electron gun, two choppers and a buncher. A short, room temperature, graded-β, sidecoupled accelerator is used to increase the electron beam energy to about 500 keV to produce a good match into the first superconducting accelerator cavity. Eighteen five-cell superconducting cavities are used to produce an energy of 45 MeV before injection into the first linac. All of the room temperature centerline hardware has been installed on a strongback. Testing of the 100 keV electron gun and transport system is in progress. The rf system for the choppers and buncher is nearly complete and the first rf tests are in progress.

Introduction

The general details of the injector are shown schematically in Figure 1. It uses a 100 keV electron gun, two choppers to produce a 60 degree chopped beam and a buncher to produce a beam of about 12 degrees before acceleration. A room temperature capture section is used to increase the electron beam energy to about 500 keV to produce a good match into the first superconducting rf (SRF) cavity. The room temperature components are mounted on a high precision 16 foot long girder that maintains alignment. The room temperature injector is mounted as closely as practical to the first SRF cavity in a cryostat (called a cryounit in Figure 1) to reduce debunching of the 500 keV electron beam as it drifts from the capture section to the first SRF cavity. Two SRF cavities in the cryounit are used as a preaccelerator to increase the beam energy to 5 MeV. This energy is sufficiently relativistic to allow the beam to drift the 13 m from the preaccelerator to the two cryomodules without debunching. This drift space is used as a beam diagnostic region and contains a bending magnet with an off-line tune up beam dump. The two cryomodules produce an electron beam energy of 45 MeV. The injector is on the same center-line as the first linac. The electron beam is then bent off-line with a chicane of magnets to bypass the recombiner magnet, and recombined with the recirculating beams[1] before entering the first linac.

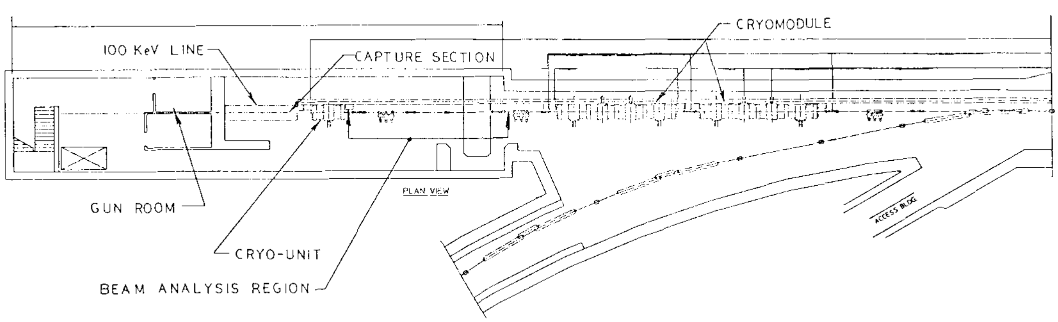

Figure 1 General layout of the CEBAF injector. Either of two guns can be used to provide a 100 keV beam that is chopped, bunched and accelerated to 500 keV in the room temperature section. The cryounit increases the energy to over 5 MeV and the 2 cryomodules produce a 45 MeV beam for injection into the rest of the linac.

The design of the injector for the CEBAF linac is described in a previous publication[2]. This paper is a status report on the construction of the injector. Table 1 gives the specifications of the electron beam from the CEBAF linac.

Table 1 Design Beam Parameters

Energy	0.5 to 4 GeV
Total average beam current	1 to 200 μamp
Number of simultaneous extracted beams	3
Minimum current in individual beam	>1% of total
Beam emittance ($\pi\epsilon$) (at 1 GeV)	2×10^{-9} π m-rad
Beam energy spread (4σ)	$\Delta E/E < 10^{-4}$

In order to achieve this beam quality, the injector must provide a beam with a transverse emittance that is better than the specification, to allow for potential degradation in the linac and arcs[3]. Therefore, the electron gun and 100 keV beam line are designed for 1 mm-mrad transverse emittance at 100 keV. A bunch length of about 1 degree is also required to achieve the high energy resolution.

Electron Gun

The electron gun is similar in design to the gun used for the NBS-LANL cw racetrack microtron[4]. It uses a 2 mm diameter aperture to control the electron beam current. The gun will generally be operated in a dc mode. However, a highly flexible pulser is being developed to control the gun output from 10^{-5} to unity duty factor, with control of either pulse width or repetition rate. This will be a valuable tool during tune-up and pre-operation checkout of the rest of the linac. A temporary CAMAC-controlled pulser has been developed and used for most of the results reported in this paper. Low average beam power (few % duty factor) at from 100 to 500 μamps peak

* This work was supported by the U.S. Department of Energy under contract DE-AC05-84ER40150.

beam current has been typically used. This gives good visual images on the view screens that are used for data collection.

The electron gun can produce up to 5 mA, although most operation will be at less than 2 mA. An initial set of measurements has been made that demonstrate that 1.2 mA of beam can be transmitted through two apertures with an acceptance of 1 mm-mrad, with less than 10% beam scraping on the first aperture. This meets the requirement of 200 μA of beam current (chopped to 60°) within the emittance specification of 1 mm-mrad. Further testing is in progress.

The electron gun operates at 100 keV. The filament supply and pulser are mounted on a high voltage deck and controlled with a CAMAC crate also mounted on the deck. Further details of the control system are provided in paper WE3-39 of this conference[5].

100 keV Line

The 100 keV line is designed to transport the electron beam from the gun to the capture section with minimal degradation of the radial emittance. Choppers and a buncher are used to prepare a bunched beam of about 12° in longitudinal phase space. Figure 2 shows the results of PARMELA calculations of the beam radius and the longitudinal phase space

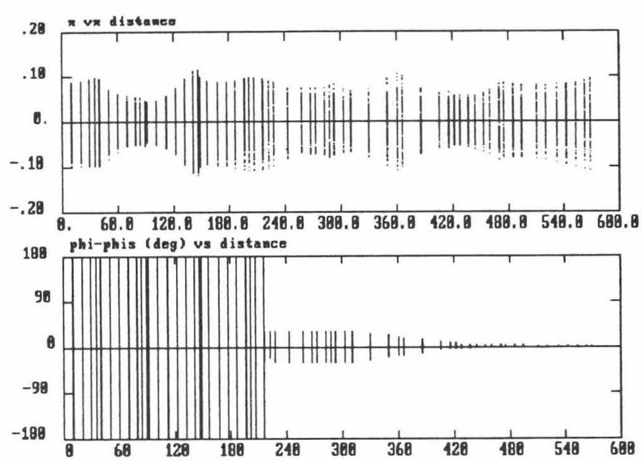

Figure 2 PARMELA calculations of the beam radius and longitudinal phase space for the 100 keV line.

for the 100 keV line. Positions of the lenses, apertures and steerers are also shown on this figure. Figure 3 shows a photograph of the 100 keV line. All of the centerline hardware has been installed on a rigid aluminum strongback that maintains alignment of the elements. Apertures A-1 (1 mm dia) and A-2 (2 mm dia) define an acceptance of 1 mm-mrad. Steerers S-1 and S-2 correct for a small deflection of the electron beam from the gun and start the beam on the centerline. A vertically compensating degaussing coil is used to compensate for the earth's field along the entire 100 keV line. With this compensation, the electron beam is transported along the rest of the line with nearly no local correction from the other steerers. The steering coils are commercially available television scanning coils that have been modified by the vendor to be readily removable from the beamline for baking out the vacuum system. Figure 4 shows details of the focusing coils mounted on a standard 1.5" diameter vacuum union. The focusing coils have two coils counterwound so they can also be used when polarized electrons are accelerated in the linac. These coils are wound with polyimide insulated wire rated at 200°C, on an anodized aluminum spoolpiece. They can be baked in place, permitting the whole vacuum system to be baked to about 200°. All of the vacuum system uses metal seals, including the valves. A base pressure of less than 10^{-8} torr has been obtained on a system that has been routinely opened for changes during this early phase of development, with no bakeout.

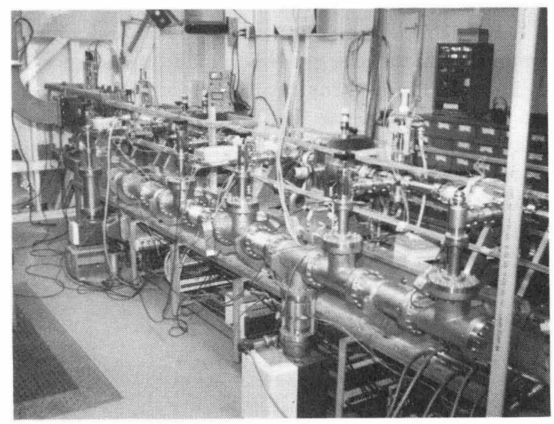

Figure 3 Photograph of the 100 keV line.

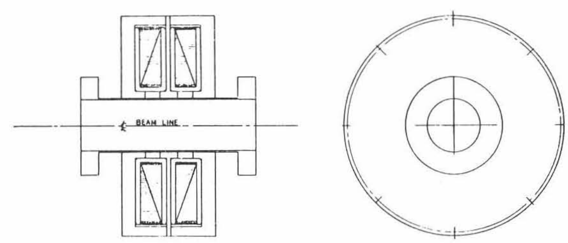

Figure 4 Details of the focusing coils used for the 100 keV line.

The rectangular cavities are fundamental frequency (1497.0 MHz) chopping cavities, built by Los Alamos National Laboratories using a design similar to the NBS-LANL cw microtron[4]. (Note that this is a change from the subharmonic choppers described previously[2]. A decision was made to develop the multiple beam capabilities later in the project.) Figure 5 shows a schematic of the beam envelope as it passes through the 100 keV line. The first chopper produces a circular scan of the beam at the chopper aperture, A-3, which is also the position view screen 2. Lenses 4a and 4b re-image the beam at the center of chopper 2, and the beam diverges to form a circular scan at view screen 3. Figure 6a shows a photograph of a television image of the circular scan at view screen 3. When the chopping aperture (see insert on Figure 5), A-3, is inserted, only 60° of the circle is transmitted. This is shown in the photograph of Figure 6b. When the second chopper is powered and correctly phased, the rf deflection of the first chopper is compensated, and the beam is once again imaged on the beam centerline as shown in Figure 6c. The buncher will further compress the longitudinal bunch length to about 12° before insertion into the capture section. It has also been operated, but no effective demonstration of its operation is available until the capture section becomes operational.

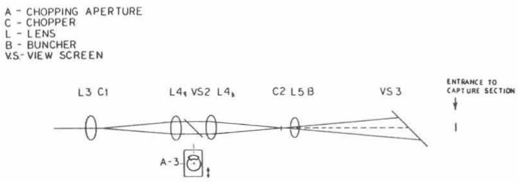

Figure 5 Schematic of the electron beam envelope as it is deflected by the first chopper, imaged at the position of the second chopper and transmitted to the end of the 100 keV line. The broken line shows the path when the second chopper is on and phased correctly.

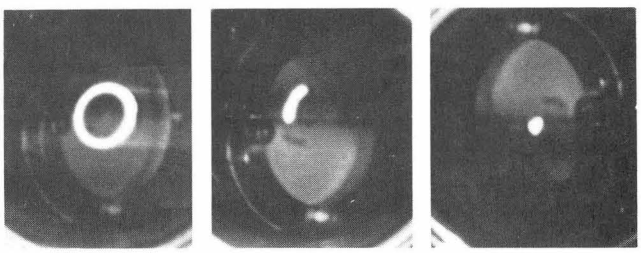

Figure 6 (a) Beam at view screen 3 with first chopper on. (b) When aperture A-3 is inserted, only 60° is transmitted. (c) When chopper 2 is powered and phased correctly, the beam is reimaged to a focus at view screen 3.

Capture Section

The capture section is a 5-cell standing wave accelerator that was also built by LANL. It is graded in β from 0.58 at the input to 0.83 at the output and increases the energy from 100 to 540 keV. It is designed to achieve the required energy gradient with less than 10 kW of rf power. This permits the use of two of the 5 kW klystrons in parallel that are used for the rest of the linac. Figure 7 is a photograph of the capture section mounted on the girder. It is under vacuum and as soon as an rf window is installed, low-power rf testing will begin.

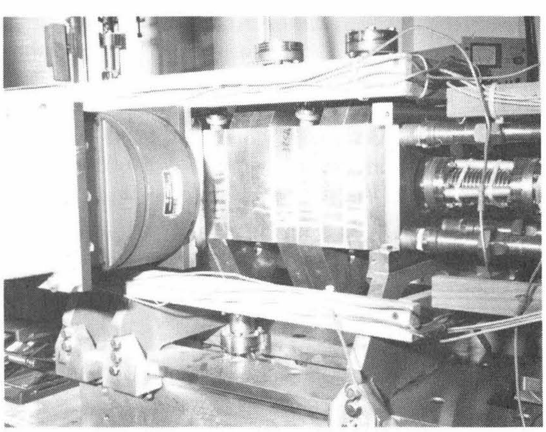

Figure 7 Photograph of capture section mounted on the girder.

Summary

Construction of the room-temperature portion of the CEBAF injector is nearly complete. The electron gun and the 100 keV beamline have been constructed, and the optics and rf system have been operated. A low duty factor electron beam has been chopped and bunched and tranmitted to the end of the 100 keV line. The capture section is installed on the girder and is being prepared for rf tests. Testing is in progress to increase the cw beam current to the design value.

Acknowledgements

The authors would like to acknowledge the professional assistance of Greg Arnold, Mark Augustine, Frank Humphry, T. G. Mason and Bob Vignato during the construction and testing of the injector.

References

1. R. C. York and C. Reece, "RF Steering in the CEBAF CW Superconducting Linac", IEEE 1987 Particle Accelerator Conference, p. 1307.
2. W. Diamond, "The Injector for the CEBAF Superconducting Linac", IEEE 1987 Particle Accelerator Conference, p. 1907.
3. D. R. Douglas and R. C. York, "Perturbation Effects in the CEBAF Beam Transport System", IEEE Particle Accelerator Conference, p. 1292.
4. M. Wilson et al., NBS-LANL RTM Injector Installation, IEEE Trans. Nuc. Sci., NS-30, No. 4, 1983, p. 3021.
5. R. Pico, W. Diamond, J. Fugitt, and R. Bork, Thermionic Gun Control System for the CEBAF Injector.