200 MEV RF Linac for Brookhaven National Laboratory

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I. INTRODUCTION

A 200 MeV RF linac was designed and built for Brookhaven National Laboratory. Factory tests have now been completed and it is in final assembly for use at Brookhaven. Table 1 gives the overall requirements of the linac. The system consists of four 3 m sections of S-Band accelerator waveguide powered by three 45 MW Thomson klystrons. The injector is comprised of a triode gun, prebuncher, and a four cavity buncher. The system provides over 1 amp of beam at 1 ns to 10 ns at 10 pps.

Table 1: Brookhaven Linac Requirements

RF Frequency	2856 MHz
Beam Energy	Variable from 40 MeV - 200 MeV
Beam PW	1-10ns
PRF	1-10Hz
Energy Spread at 200 MeV	±1%
Peak Beam Current	1A @ 1-10ns
Beam Emmittance	$<1E^{-6}$mR, geometric
Synchronization, (RF Phase Locked)	35.25 MHz
Vacuum	10^{-8} Torr
RF PW	1.2μs Flat top
Modulator Pulse Flatness	±0.25%
Klystron Peak Power	45MW x 3 Tubes

II. GENERAL SYSTEM DESCRIPTION

A. Beamline

The conceptual design of the Brookhaven National Laboratory 200 MeV linac is patterned after the original SLAC injector, which ran for 20 years delivering beams from a few nanoamps to 2 amps. The BNL linac injector consists of the following components:

1. A 120 kV thermionic triode (with a mesh grid) gun with a 2 sq cm dispenser cathode capable of currents up to 10 amps.

2. A single resonant cavity prebuncher, which bunches about $^3/_4$ of the electrons into a 90° bunch in the 20 cm prebuncher drift.

3. A 10 cm long travelling wave buncher with phase velocity equal to 0.75c, which bunches the beam by about a factor of 3 to about 30° and accelerates the electrons up to about 320 kV.

4. A 3 meter long constant gradient, velocity of light accelerator section, which completes bunching the beam to about 5° FWHM and accelerates the beam to about 45 MeV. According to the program PARMELA, which was used to design the injector, 84% of the beam from the gun should be captured and accelerated, and 84% of the captured beam should be within a 1% full width spectrum. The RMS normalized emittance is calculated to be 30 pi mm-mr at the end of this section.

5. A magnetic focussing system consisting of one iron core magnetic thin lens which matches into a solenoid consisting of 10 large aperture coils placed within the Helmholtz spacing. The beam from the injector is focussed by quadrupole triplets placed between accelerator sections.

Figure 1 shows a portion of the beamline.

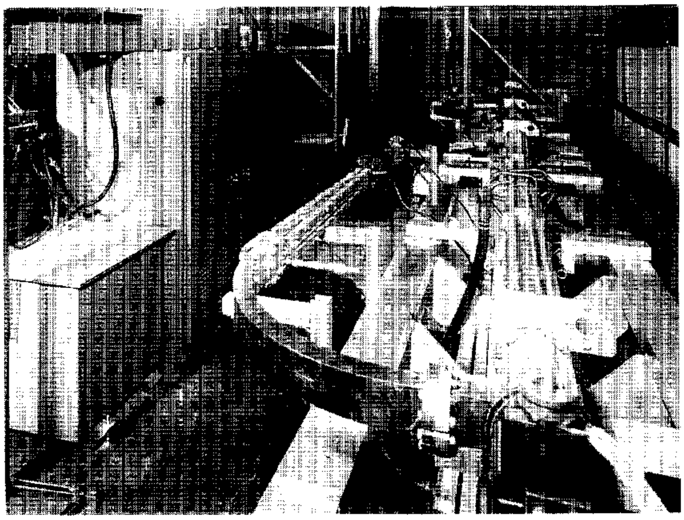

Figure 1

The E-gun pulser is required to generate a low jitter, fast risetime pulse to the gun cathode (grounded grid configuration). A fast avalanche transistor based pulser was developed at Titan Beta to meet these requirements. Amplitude control of the pulser is via a PIN diode attenuator stack that was developed for this purpose. The E-gun output has been shown to be at least 2 amps with rise and fall times of less than 800 picoseconds.

Control and trigger of the E-gun pulser is via fiber optic links providing pulse width, amplitude, and fault detection through serial communication. The E-Gun pulse width is remotely settable between 1 and 10 ns in 1 ns increments using an on-board digital pulse width generator.

The E-gun floating deck is connected to a 150 kV DC power supply which provides the acceleration potential for the injector.

B. Magnetics

The low energy transport magnetics consist of a bucking coil at the E-gun, focus coil between the E-gun and prebuncher, and ten air core focus coils over the first accelerating section. The field in this open solenoid structure is 1.2 K gauss. Beam focusing is accomplished by using quadrupole triplets between accelerating sections. Steering is provided by X-Y corrector sets at the beam input to each accelerating section. Figure 2 shows one of the quadrupoles on the beamline assembly.

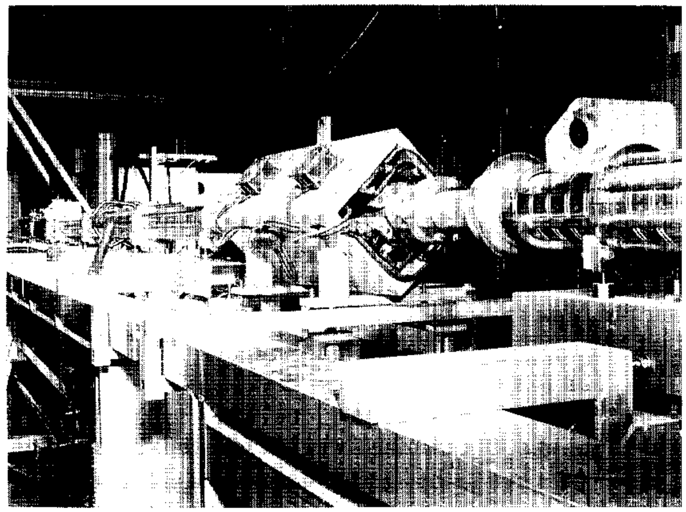

Figure 2

C. Modulators and Klystrons

Each of the three 45 MW klystrons are driven by three identical modulators with 10 stage PFN's capable of delivering 100 MW peak power video pulses with 1.2 microsecond flattop at 10 pps. A high voltage, high frequency switching power supply is used to charge the PFN and to achieve pulse to pulse amplitude stability of $\pm$ 0.1%.

The Thomson TH 2128 klystrons operate at 45 MW to provide the 1.2 microsecond flattop. This allows for the accelerator guides to fill and provides adequate RF flattop for the guides to be used in the stored energy mode.

Evacuated rf waveguide is used throughout the system.

D. Control System

The control system is distributed into various subsystem chassis located in the main control rack. Each chassis has built-in fault detection circuitry to detect any fault condition and display all of the faults and indicate the first fault occurrence. In addition, all faults are summed in the master system controller for subsystem fault identification.

A bussed architecture is used to reduce the number of control cable wires. The fault detection system uses a multiplexed buss to the master system controller instead of individual wires for each fault (16 lines instead of >140 lines).

The entire system can be operated locally, or through CAMAC based computer control. Although Titan Beta was not contracted to provide the operational software, we operated the system at our facility with a 386SX based IBM clone computer running National

Instruments LABWINDOWS control software.

The linac system timing was established by various digital generators built into the system. A sophisticated phase-lock loop timing system was developed to allow linac injection to be synchronized with the synchrotron ring timing. This system allows injection into the ring at 60° increments of the synchrotron frequency with very low jitter.

E. Factory Tests

For factory test, the system was divided in two segments to fit the test cells and space in the Titan Beta facility. The first half was tested with beam from the E-gun through the injector and the first two accelerator sections. These two sections are driven by a single klystron. The RF system for the buncher includes a high power waveguide phase shifter and attenuator. The other two accelerator sections were operated with one klystron powering each to the full 45 MW output of the klystron. The accelerator sections held 45 MW with no problem after conditioning.

Gun tests were performed and the injector output was measured at 1.6 A max for 1 ns, 2 A for 1.25 ns, and 3.1 A max for 10 ns. Rise and fall times were 800 ps. Jitter was measured at less than 100 ps.

With accelerator structures 1 and 2, the energy was measured using beam deflection at 75 MEV and the emittance was measured at less than 150 pi mm mrad. Max current for 10 ns was measured at 1.61 A. A heat run was satisfactorily completed.

F. Conclusions

The performance of a 200 MeV accelerator designed and built at Titan Beta was satisfactory during factory tests. We achieved design parameters and stability required for successfully operation of the linac at BNL. The accelerator was delivered and is being assembled at Brookhaven.

References

1. K. Whitham et al., "200 MeV RF Linac for Synchrotron Injection", *AECL Research 1992 Linear Accelerator Conference Proceedings*, Vol. 2, pp. 615-617.