200 MeV RF LINAC FOR SYNCHROTRON INJECTION

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Introduction

Construction for factory test has been completed on an electron linear accelerator for Brookhaven National Laboratory. This accelerator will be used for injection of a 200 MeV electron beam into a synchrotron for lithography experiments at Brookhaven National Laboratory.

Table 1 gives the system requirements.

TABLE 1

Brookhaven National Laboratories

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	2A @ 1ns, 1A @ 2-10ns
Beam Emmittance	<1E^{-6}mR, geom
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

Description:

The Titan Beta model TB-200/400M-4S Linac system, is a 200 MeV electron accelerating system consisting of high power RF klystrons, modulators and beam line sections. Three klystrons power the beam line sections which include an injector compromised of a triode gun, a pre-buncher, four cavity buncher, lenses and four S-Band constant gradient SLAC type wave guides.

These high powered modulators drive the three 45 MW klystron amplifiers with 2.0 μs FWHM pulses at up to 10 pps. See Figure 1.

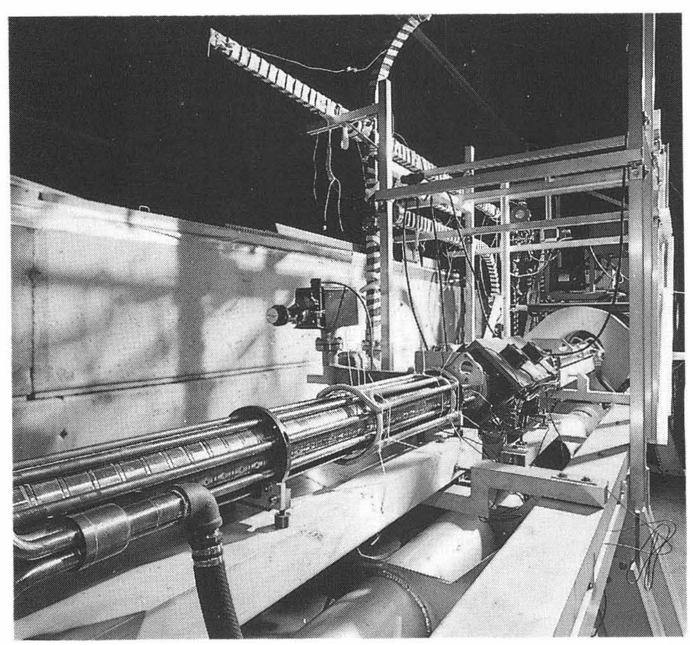


Figure 1

Conceptual Design

The conceptual design of the BNL 200 MeV Linac is patterned after the original SLAC injector {1}, 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 thermionic triode gun with a 2 sqcm cathode.

2. A single resonant cavity prebuncher.

3. A 10 cm long travelling wave buncher with phase velocity equal to 0.75c.

4. Four three-meter long constant gradient accelerator sections with phase velocity equal to the velocity of light.

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 at roughly the Helmholtz spacing over the first accelerator waveguide. The beam is transported from through the rest of the accelerator by small quadrupole triplets in the drift regions between sections.

This injector differs from the original SLAC injector by having a much newer design higher voltage electron gun (120 kV instead of 80 kV) with a 2 sqcm dispenser cathode capable of currents in excess of 10A. In addition this injector has a large aperture solenoid starting before the prebuncher.

The beam of 120 keV electrons form the gun is velocity modulated by the prebuncher. In the 20 cm prebuncher drift, about 75% of the electrons bunch into about 90 degrees of phase. The traveling wave buncher compresses this bunch by about a factor of 3 to about 30 degrees and accelerates the bunch up to several hundred keV. The bunch enters the 3-meter accelerator section at the phase stable electric field null and is further compressed by a factor of five to 6 degrees FWHM in the few wavelengths of the guide. Thus this design has three bunchers: 1) The prebuncher; 2) The 0.75c travelling wave buncher ; 3) The capture region of the first accelerator section. The result of this is to produce a very short bunch with very little charge in the tail. Since the phase and field strength of the prebuncher and the 0.75c buncher are independently adjustable, it is possible to optimize the bunching for any desired current from zero up to perhaps 4 or 5 amps. The concepts behind the design are discussed in detail in Ref 1.

The electron gun design was developed using Herrmannsfeldt's program EGUN. At the nominal full current of 4 amps the normalized "90%" emmittance is 10 pi mm-mr. The beam has a radius of 3 mm at the gun flange and is slightly convergent with a convergence angle of 5 mr. The EGUN output is shown in Figure 2.

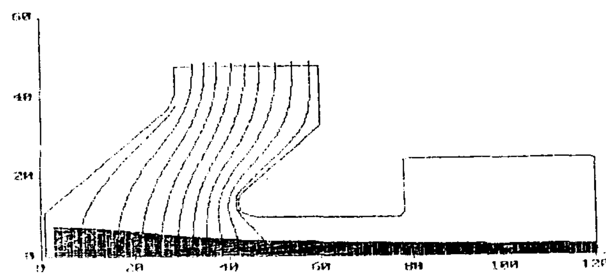
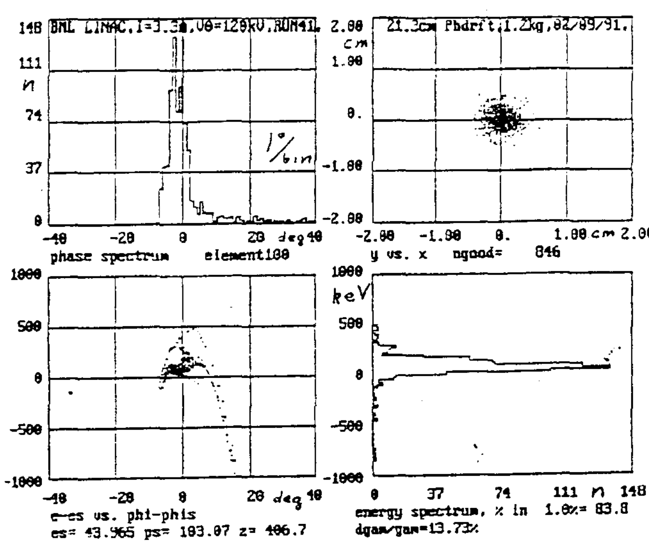


Figure 2

The detailed beam dynamics design from the gun flange to the end of the first accelerator section was simulated using the program PARMELA. The PARMELA output for the beam at the end of the first accelerator section is shown in Figure 3.



$$I_{GUN} = 3.3a \quad 100\% \tag{1}$$

$$I_{CAPT} = 2.8A \quad 84\% \tag{2}$$

$$I_{IN}\ 1\% = 2.3A \quad 71\% \tag{3}$$

$$E_n\ (rms) = 30\pi \text{ mm-mr} \tag{4}$$

Figure 3

The lower lefthand plot shows the distribution of particles in longitudinal phase space, with the horizontal axis being time in degrees of S-Band phase and the verticle axis being energy relative to the reference particle in keV. This distribution in phase space is projected upward onto the upper lefthand plot to give the distribution of charge in the bunch. Similarly the phase space distribution is projected to the right to give the energy spectrum of the beam in the lower righthand plot. The horizontal axis is the number of macroparticles per bin while the vertical axis is the energy. Each bin is 25 keV. The plot is presented in this orientation to enable the designer to see which particles in the phase space distribution go into what parts of the spectrum. The reference particle energy at this point is 44.0 MeV, and from the distribution in phase space we can conclude that the bunch was approximately on the crest of the wave in the section. The transverse distribution of particles is shown in the upper righthand plot. The beam radius is about 3mm at this point.

After the first section, the beam is transported via quadrupoles through the remaining three accelerator sections. The first klystron powers the first two sections plus buncher and prebuncher. The remaining two klystrons power one accelerator section each. Each klystron (TH2128C) is pulsed by identical individual modulators using dc charged PFN's to obtain 2 μs FWHM video pulses at up to 10 pps. The RF flat top is 1.2 μs, giving ample flat top after the guide rise time for the 10 ns beampulses.

E-Gun Pulser

The E-gun pulser was required to generate a low jitter, fast risetime pulse to the E-gun cathode (grounded grid configuration). A fast avalanche transistor based pulser was developed to meet these requirements. Amplitude control of the pulser was via a PIN diode attenuator stack that was developed for this purpose.

Control and trigger of the E-gun pulser is via fiber-optical links providing pulse width, amplitude, and fault detection through serial communication.

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

Control and Timing Systems

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 was used to reduce the number of control cable wires, and 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 BETA was not required 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.

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

References

R. H. Miller, R. F. Koontz, D. D. Miller, "The SLAC Injector", IEEE Trans. NS-12, #3, 804-808, June 1965.