DESIGN OF A BUNCHING SYSTEM FOR A HIGH-CURRENT ELECTRON LINAC

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Abstract

The high-current electron linac for the positron generation operates in two modes: a single bunch mode of 1 nsec and a multibunch mode of 10-40 nsec. In order to generate 10 mA positron beam, the high-current electron linac is designed to provide 10 A electron beam onto the target. The high-current electron linac bunching system consists of a high-current gun, a following subharmonic buncher, two single cavity S-band prebunchers, and a S-band buncher. The gun is able to deliver 18 A beam at 200 kV. The subharmonic buncher is a quarter-wave reentrant resonant cavity with 1/12th the linac frequency 238 MHz. The prebunchers and the buncher are standing-wave structure with the linac frequency 2856 MHz.

Introduction

The injection system for the 8 GeV synchrotron radiation facility consists of a 1 GeV linac and a 8 GeV synchrotron [1,2,3]. The linac accelerates both the electron and positron beams up to 1 GeV.

The ultimate qualities of the electron and positron beams emerging from a linac depend on the design of the bunching system. It consists of two parts; the electron linac(EL) bunching system for the 120 MeV electron linac section and the high-current electron linac(HL) bunching system for the 300 MeV high-current electron linac section.

The principal differences between the two bunching systems are the specifications for the gun and the existence of a subharmonic buncher in the HL bunching system.

The electron beam experiences strong space-charge forces which affect longitudinal and transverse beam dynamics. Expected performance is analyzed with computer simulations.

We discuss the bunching system for the HL. The characteristics of the high-current linac are given in Table 1.

TABLE 1
Design Parameters of the High-current Electron Linac

Energy	300 MeV
Current	10 A
Pulse width	
short	1 nsec
long	10 nsec
Repetition rate	60 pps
Momentum spread	5 %
Emittance	12 π mm-mrad

Design of the HL Injector

A schematic diagram of the high-current electron linac(HL) bunching system is shown in Fig.1. It consists of a 200 kV electron gun, a 12th subharmonic buncher, two fundamental frequency prebunchers and a standing-wave buncher. The gun is placed out of radiation shield wall because of easy maintenance. The wall thickness is 100-150 mm. The beam from the gun is focused by magnetic lens so that we can adjust the radius and convergence of the beam at the entrance to Helmholtz coils. Solenoidal focusing by Helmholtz coils are used along the entire length of

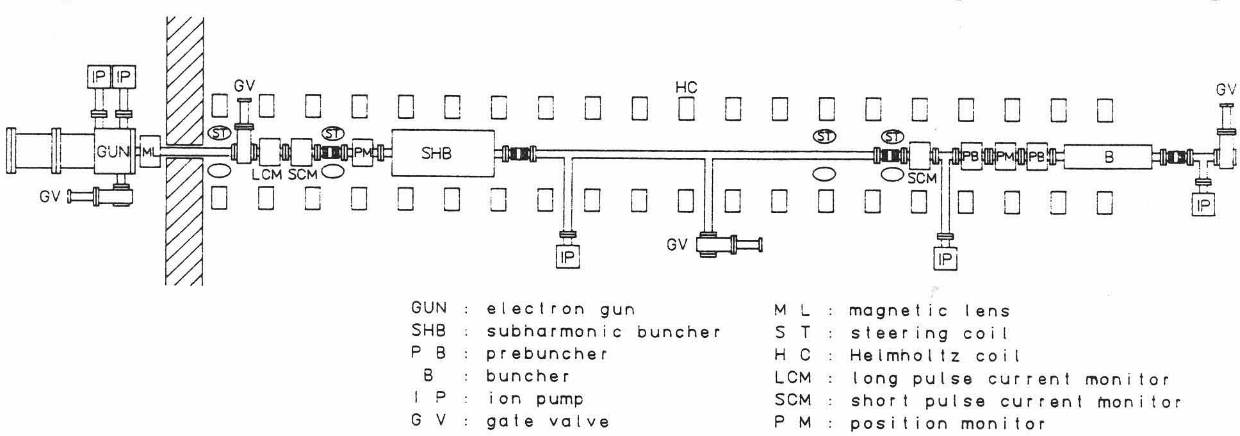

Fig. 1. The high-current electron linac bunching system.

the bunching system to provide radial confinement of the electron beam.

Beam diagnostic devices are arranged as shown in Fig.1 to control and measure the beam qualities. Two kinds of current monitors are used; core monitors (current transformers) are used for long pulses, and wall-current monitors are used for short pulses. We also make research and development on a short pulse monitor using amorphous metal. Beam profile monitors are fluorescent screen monitors using ceramic.

Electron Gun

The gun of the HL section require to have high intensity because of a low conversion(e+/e-) efficiency. The high-current thermionic gun is based on a dispenser cathode assembly (model Y796) developed by EIMAC. The gun is a triode type with a 2.0 cm^2 cathode. It will be able to deliver 18 A pulsed beam at 200 kV. The emission current can be pulsed for duration of 10 nsec and 2-3 nsec FWHM(full width at half maximum) by varying the grid voltage in the triode.

We have simulated the beam optics using the electron trajectory program[4]. Therefore the emittance is calculated with suitable weighting for the current of each ray. The magnetic lens is arranged just after the gun in order to converge the beam, because the gun is separated from the Helmholtz coils by the radiation shield wall. The Helmholtz coils are about 400 mm away from the cathode of the gun. Since the drift distance is long, we have designed to minimize the radial beam size and the transverse emittance. Beam optics to 150 mm for this gun are shown in Fig.2. The calculation predicts an output current of 18 A at 200 kV. We assume that the emission ability of the cathode is 10 A/cm^2 . The calculated overall emittance area is 181 π mm-mrad with the radial beam size of ϕ12 mm at the position of 150 mm from the cathode of the gun. Beam optics to 400 mm are shown in Fig.3. The magnetic lens is arranged at the position of 150 mm. The calculated overall emittance is 362π mm-mrad with the radial beam size of ϕ19 mm at the position of 400 mm from the cathode of the gun.

Subharmonic Buncher

The subharmonic buncher is a quarter-wave reentrant resonant cavity. The subharmonic frequency is the 12th subharmonic (238 MHz) of the linac frequency(2856 MHz). The electron beam from the gun is bunched to within about half a cycle of the subharmonic. This allows the beam pulse from the gun to 2-3 nsec long. The subharmonic buncher will deliver the electron beam having a pulse width of approximately 1 nsec at 200 kV to the following 2856 MHz prebuncher. For the long pulse mode (10 nsec), the subharmonic buncher is not used.

We have simulated the bunching characteristic using the modified disk-model trajectory program[5]. In the simulation, we have assumed that the beam pulse from the gun is the 18A peak Gaussian shaped beam with 2 nsec FWHM. And further we have assumed the beam bore size of ϕ16 mm and the drift tube size of ϕ32 mm. We have modeled a beam as 51 infinitely thin disks of charge. Fig.4 represents the evolution of phase focusing, or bunching. The gap voltage of the subharmonic buncher cavity is 30 kV. The simulation results that 2 nsec (170 degrees) of the Gaussian shaped beam bunches to 0.75 nsec (65 degrees) at the position of 2500 mm from the entrance of the gap. It corresponds to 76% of the 18 A peak Gaussian shaped beam. The equivalent peak micropulse current is 37 A. The first prebuncher position (PB) is indicated in Fig.4.

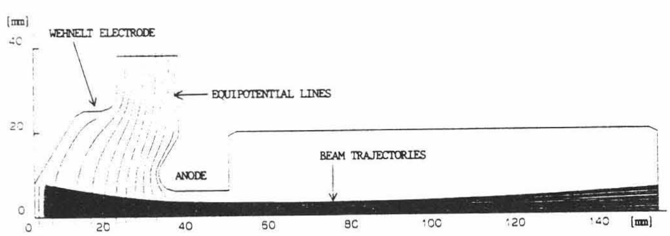

Fig. 2. Beam optics to 150 mm.

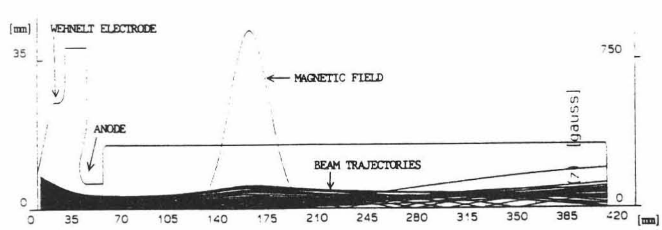

Fig. 3. Beam optics to 400 mm with magnetic field. The scale of vertical axis and horizontal axis is different.

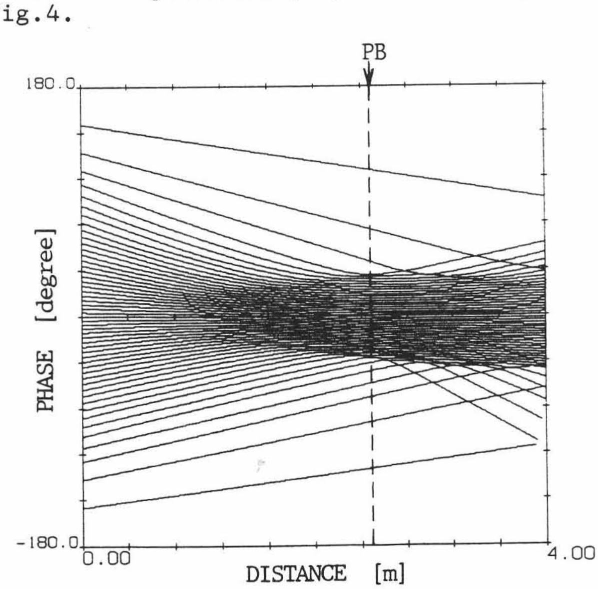

Fig. 4. The evolution of phase bunching in the subharmonic buncher.

Prebuncher

We use two prebunchers to get the high capture efficiency. The prebunchers are reentrant resonant cavity with same linac frequency 2856 MHz.

In the simulation, we have assumed that the beam pulse from the subharmonic buncher is the 37 A peak uniform charge density beam. And further we have assumed the beam bore size of Φ10 mm and the drift tube size of Φ32 mm. We modeled a beam as 51 infinitely thin disks of charge. Fig.5 represents the evolution of bunching. The gap voltage of the first prebuncher cavity is 30 kV, and that of the second prebuncher cavity is 60 kV. The drift distance between the gaps of two prebunchers is 200 mm, and the drift distance between the gap of second prebuncher and following standing-wave buncher is 95 mm. The buncher position (B) is indicated in Fig.5. The velocity modulation by the prebuncher causes 70% of the electrons to be bunched into a 50 degree phase spread at the entrance of the buncher.

The buncher is a standing-wave structure with varying phase velocity. The 50 degree bunches enter the buncher section when the phase field is near null. In the simulation without space charge effect, they become bunched to approximately 5 degrees and asymptotically approach the crest of the wave as they are accelerated in the buncher.

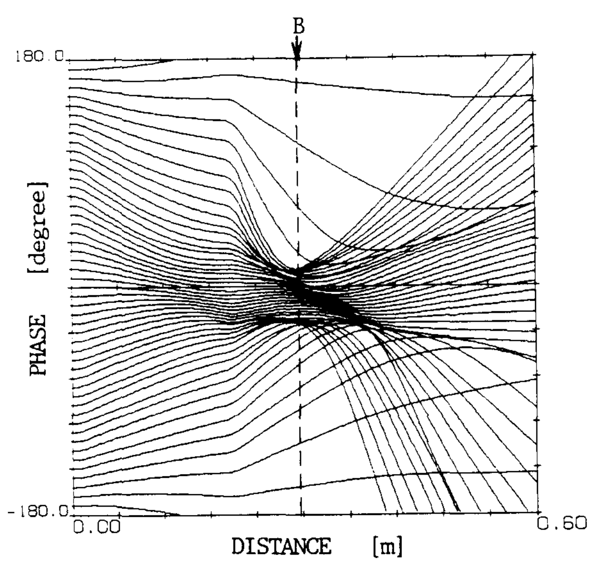

Fig. 5. The evolution of phase bunching in the two prebunchers.

Conclusion

We have designed the bunching system with the subharmonic buncher. Our simulation results that bunching efficiency of the subharmonic buncher is 76%, and that of a pair of bunchers is 70%. Consequently 1 nsec macro pulse width and 26 A peak current beam is obtained.

We are going to simulate the transverse beam dynamics in the bunching system and longitudinal beam dynamics in the buncher in consideration of space charge. We are also going to discuss the 24th subharmonic (119 MHz) buncher in order to accept longer beam pulse emitted from the gun.

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