A PROPOSED HIGH-CURRENT INJECTOR
FOR THE OSAKA UNIVERSITY SINGLE BUNCH ELECTRON LINEAR ACCELERATOR

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Abstract

A single bunch charge has been increased from 14 nC to 30.6 nC by deflecting satellite bunches with a 12th subharmonic single bunch chopper. A new high-current injector has been proposed in order to increase the single bunch charge up to 50 - 60 nC. The injector consists of two 12th subharmonic prebunchers and a 6th subharmonic prebuncher. The electron beam is confined by Helmholtz coils so that the beam may travel through the drift tube at constant radius. A modified disk model has been used to calculate the bunching of the beam and to decide the system arrangement.

1. Introduction

For the purpose of accelerating a single bunch, the pulse width of the beam injected into a prebuncher should be less than the acceptance angle of the prebuncher. Assuming that the acceptance angle is 240°, the pulse width of the beam should be less than 510 ps in L-band, and 230 ps in S-band linear accelerators. At present, it is difficult to generate a high-current beam with the short pulse width. The beam bunching by means of the velocity modulation with a subharmonic prebuncher (SHPB) is useful. Besides, it posseses an advantage in that the initial pulse width of the beam required to produce a single bunch can be made longer. The electrons injected into the prebuncher are accumulated and the single bunch charge is increased. The maximum pulse width of the beam to obtain the single bunch is determined by the subharmonic frequency. For the Osaka University L-band Linac with a 6th SHPB, the pulsed beam of 2 - 3 ns should be generated by the electron gun. Exciting the SHPB by lower subharmonic frequency, the single bunch of higher current can be obtained. On the other hand, longer drift distance is required to bunch the beam electrons and the space-charge defocusing of high-current beam drifting in a free space should be taken into consideration. Therefore it is desirable to bunch the beam with a couple of SHPBs rather than a single SHPB alone. The proposed high-current injector consists of three SHPBs, and the rf-phase of each SHPB is independently controlled to bunch the beam effectively. It is because the space-charge defocusing depends on many beam parameters such as current, energy, radius and current waveform.
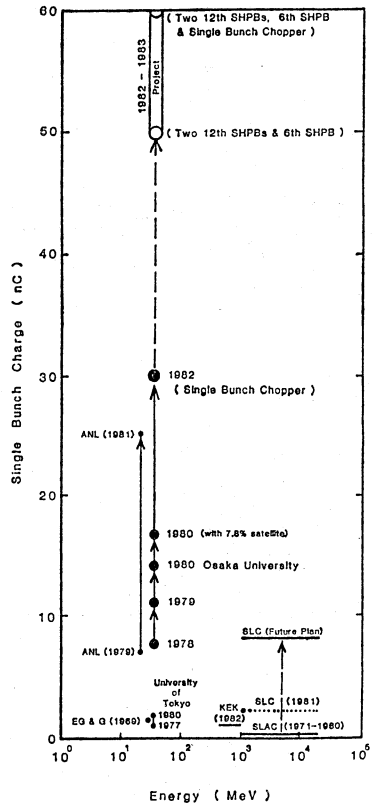

Fig.1. Project to increase a single bunch charge.

2. Calculation of Bunching by Modified Disk Model

The longitudinal space-charge defocusing forces present in a high current beam of uniform radial charge density inside a cylindrical conducting tube can be calculated by the disk model. The force acting on the ith disk due to the jth disk is basically calculated by the distance between two disks. As the energy of electron beam is about 120keV, the relativistic correction of the distance is required. In the conventional disk model, however, the force on a disk is corrected by the total energy of electron in the disk, and then the force on the ith disk due to the jth disk differs from the force on the jth disk due to the ith disk. In the modified disk model, the forces are corrected by the average $\gamma\nu$ of the two disks to conserve the total energy of disks during the space-charge defocusing.

In the conventional disk model, it is assumed that the beam is rectangular pulse equal to the subharmonic wavelength. In the present calculation, it is assumed that the initial beam pulse from the Model-12 gun is a Gaussian shaped beam with σ = 4.5 nsec, of 15 amp peak. The beam is divided by 73 infinitely thin disks of equal charge. The program calculates both the longitudinal positions and the energies of the disks by the following equations:

$$\frac{d\gamma_i}{dz} = \frac{2\,e\,Q_i}{\varepsilon_0\,m_0\,c^2\,\pi\,r^2}\sum_{\substack{j=1\\ j\neq i}}^{N}\sum_{n=1}^{\infty}\frac{\left[J_1\!\left(j_{on}\frac{r}{a}\right)\right]^2}{\left[j_{on}J_1(j_{on})\right]^2}\,e^{-\left|\frac{j_{on}}{a}\frac{(\gamma_i+\gamma_j)}{.2}\beta_0(\theta_i-\theta_j)\frac{\lambda}{2\pi}\right|} \qquad --(1)$$

$$\frac{d\theta_i}{dz} = \frac{2\pi}{\lambda}\left(\frac{1}{\beta_0}-\frac{1}{\beta_i}\right) \qquad --(2)$$

The results of the calculations are shown in Fig.2 for the rectangular beam and Fig.3 for the Gaussian beam. These figures show that the disks tends to exchange energy and to reduce their approach velocity as they close to each other. Figure 2 shows that the rapid approach of a disk to the bunched disks excites the space-charge wave of the beam and generates the beam instability. Consequently, disks existed within ±90° of 12th subharmonic frequency are stably bunched and a smaller bunch than is otherwise predicted by the conventional disk model can be obtained.
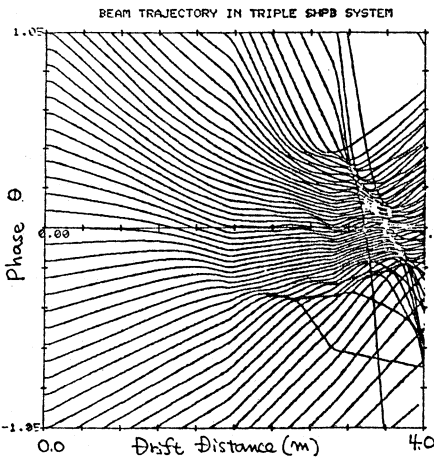

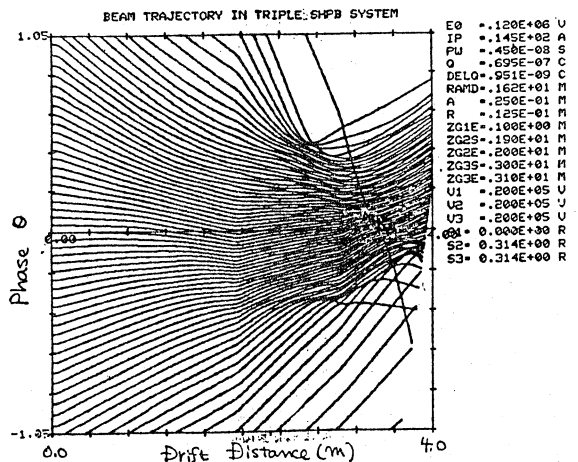Fig.2. Bunching of the rectangular beam.

Fig.3. Bunching of the Gaussian beam.

3. Proposed High-Current Injector

As shown in fig.4, the present injector consists of an injector tank with a gun and a grid pulser, magnetic lenses, a 6th SHPB and Helmholtz coils. The proposed high-current injector consists of the injector tank, 12th SHPB followed by a 1900 mm drift tube, a 12th SHPB followed by a 1100 mm drift tube and a 6th SHPB as shown in fig.5. The beam from the gun is focused by two magnetic lenses in order to controll both the radius and the convergence of the beam at the entrance to a magnetic confined region. The SHPBs and the drift tubes are confined by Helmholtz coils. The axial magnetic field is tapered from 150 Gauss at the entrance to 500 Gauss at the output in order to keep the beam at Brillouin flow condition as the charge density increases due to beam bunching. The electron gun should be placed in a magnetic shield, while the beam should be focused at the place where the field strength is about 60 % of the Brillouin field strength. The adjustment of the locations of lenses with respect to the Helmholtz coils should be required to obtain the optimum point of beam focusing.

Two additional vacuum stations are installed to ensure adequete pumping of the increased surface area. In order to flow the image current of the high-current beam, the drift tube is made of copper and the vacuum stations are connected through slits on the drift tube. The conducting drift tubes of smaller diameter should be required to reduce the forces due to space-charge defocusing. The diameter is desided to be 50 mm while the beam diameter is 25 mm. Design work of the injector system has been started and the construction of the system will be completed in 1983.
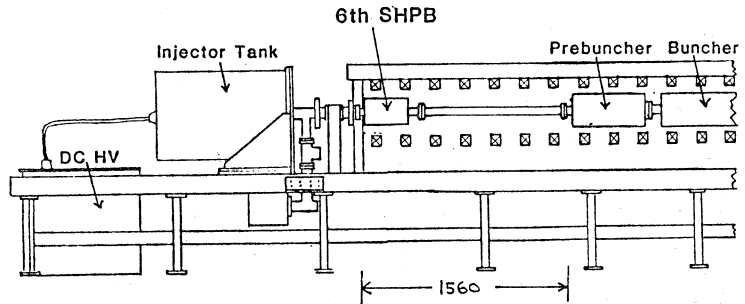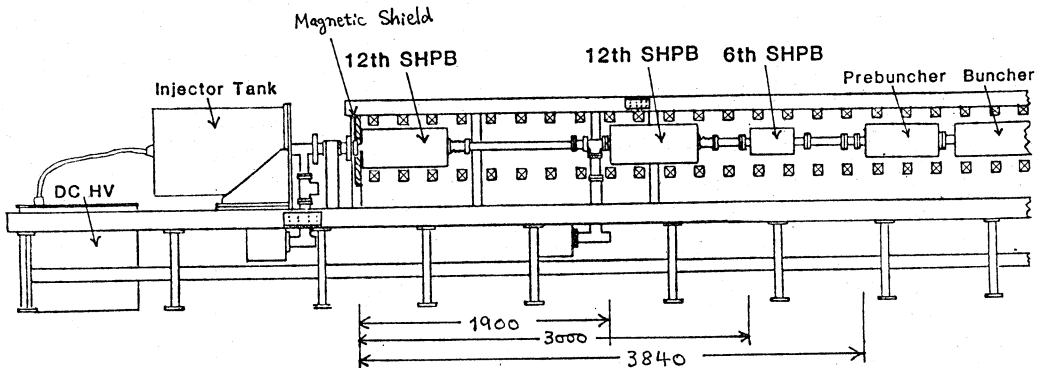

Fig.4. Present injector system.

Fig.5. Proposed high-current injector with three SHPBs.