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DESIGN OF THE BUNCHING SYSTEM OF THE KEKB LINAC

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ABSTRACT

As the pre-injector for the KEK B-factory, the injector of the PF-2.5 GeV Linac is being upgraded so as to include subharmonic bunchers. Its main purpose is to produce single bunches of high intensity of more than 10 nC. The design of the bunching system was performed using PARMELA. The design results have shown that the newly designed bunching system can produce single bunches of more than 15 nC within 10 ps with satisfactorily low emittance growth.

INTRODUCTION

The injector linac for the KEK B-factory(KEKB) is required to accelerate a single bunch electron beam of more than 10 nC to the positron target to obtain required positron intensity[1]. Considering a possible charge loss due to wake field at regular accelerating sections, we make it the goal to produce a single bunch of more than 15 nC in the bunching system.

Thus far, the bunching system including electron gun has been constantly upgraded for KEKB project[2, 4]. Preliminary studies have been made of the bunching and acceleration of high intensity single bunch electron beams[3, 4]. From simulation studies and extensive acceleration studies performed using one subharmonic buncher of 476 MHz, it has been clear that for charges more than 10 nC, single bunch beams are difficult to obtain without satellite bunches.

Double subharmonic buncher system was adopted with one additional subharmonic buncher with lower RF frequency. The frequencies of the subharmonic bunchers(SHB1, SHB2) have been selected in connection with the frequencies of the linac and the KEKB ring, 114.24 MHz, and 571.2 MHz[3], 25th and 5th subharmonics of S-band, respectively. In this paper, the results of the design of the bunching system including subharmonic bunchers with PARMELA are described.

BUNCHING SYSTEM AND BUNCHING BEHAVIOR

In this section, the optimum simulation result with PARMELA will be described with a brief account of the entire bunching system. The calculations with PARMELA were made from SHB1 for simplicity. The debunching by space charge force in drift space from the gun to the subharmonic bunchers is negligibly small in our gun energy, 200 keV, and as will be seen in the next section, emittance growth in this region can be nearly prevented by a suitable focusing magnetic field.

The new bunching system including subharmonic bunchers is shown in Fig. 1. The components following the first prebuncher (PB1) has been already upgraded[2, 4].

The prebunchers are of traveling wave type ($2\pi/3$mode, $\beta = 0.7$), and consist of seven and five cavities, including RF couplers, respectively. The buncher consists of the capture section of six cavities, where the phase velocity varies from 0.7c to the velocity of light, followed by 29 cavities with the velocity of light. Concerning buncher, the electric field will be strengthened from 15 MV/m to 20 MV/m, to improve bunching efficiency and to mitigate wake field effects in the buncher.

As mentioned above, it is our goal in the bunching section to produce a single bunch electron beam more than 15 nC at the exit of the buncher. Taking account of the loss in the bunching process, the total charge of the pulse from the electron gun was chosen to be 20 nC. It is important to provide the beam with a linear energy modulation at SHB1, since this will make easy the bunching at SHB2. The initial electron beam pulse used in the simulations is 2 ns, 10 A. Our gun can produce more than 10 A.

The maximum energy modulation by SHB1 is chosen to be 40 kV. The modulation voltage is selected so as to keep the peak power low for two reasons. The first one comes from power source; the adoption of a solid state power amplifier for 114.24 MHz is desirable for simplicity of manufacturing and operation. For this purpose, the lower peak power is favorable. The other one is directly related to the bunching efficiency. For the electron gun for high intensity elec-

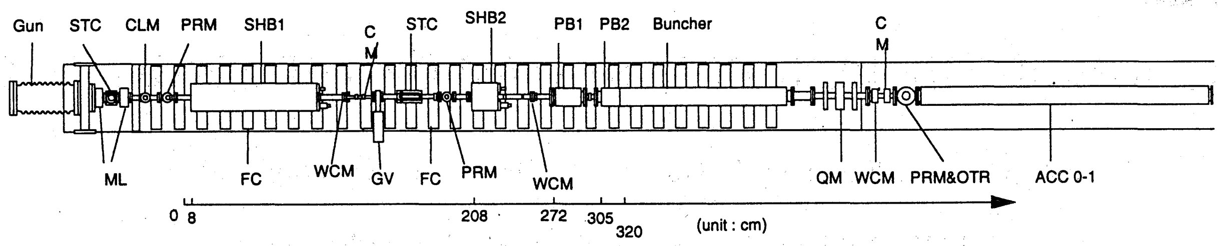

Figure 1: Bunching system of KEKB linac. The positions of SHB1, SHB2, PB1, and PB2 are shown with respect to the starting point of calculation. ML:Magnetic lens, WCM:Wall current monitor, FC:Focusing coil CM:Core Monitor, PRM:Profile monitor, STC:Steering coil

tron beams, there is a tendency to raise gun voltage to alleviate the space charge effects in the low energy regions like the bunching section. In bunching with these electron guns, a high energy modulation results in a velocity asymmetry among the head and tail parts of the beam pulse because of the relativistic effects. Therefore, we lowered the energy modulation at SHB1 to the limit that the satellite bunches might not occur in the subsequent bunching.

At 200 cm from SHB1 gap, the beam enters SHB2 in a little more broad range than $\pm 110^{\circ}$ of RF wave of SHB2, and the beam at this point has a longitudinal charge distribution of nearly triangular shape. Furthermore, the modulated energies from SHB1 vanishes owing to the repulsive force of space charges as the beam bunches, and at the gap of SHB2, the energies of the particles as a whole converge to 200 keV.

The optimum voltage which SHB2 should provide for the compressed beam was 80 kV. With this modulation, the beam was compressed to about 200 degrees at the entrance of PB1, located at 61 cm downwards from the SHB2 gap of length 3 cm. The electric field in PB1 is 0.35 MV/m for the optimum bunching. The drift space between PB1 and PB2 is 15.9 cm, which had been fixed from the configuration of the RF waveguide and focusing coils. The optimum longitudinal focal point was about 10 cm after PB1, and as a matter of fact, with above distance, debunching has occurred. A compression of a factor of three was achieved by PB1 and PB2. The second prebuncher and buncher are mechanically joined to minimize drift space between them, whereas they are separated in electromagnetically.

At the entrance of the buncher, the bunch length was 70° of S-band. The beam was bunched to 25° in the first six cavities. A further bunching continued in the regular cavities. The various characteristics of the bunch at the exit of the buncher are shown in Fig. 2. The total transmission rate is 99 percent. Eighty two percent of the initial charge is bunched into 10 degrees of the final bunch. Fifty one percent of the initial charge is contained in 4 degrees at FWHM. About four percent of the initial charge was formed into satellite bunches.

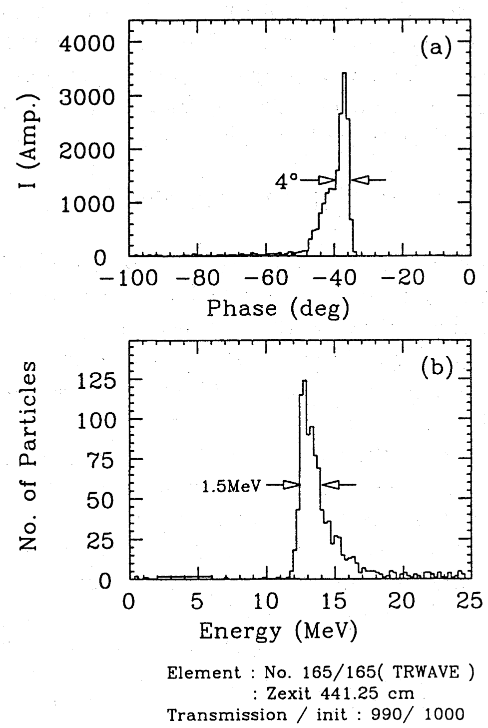

Figure 2: Bunch characteristics at the exit of the buncher. (a) longitudinal bunch shape (b) energy spread

TRANSVERSE DYNAMICS

Emittances of high intensity beams can increase largely in the bunching section by space charge effects. Though the emittance value requirements for the KEKB linac have been specified at the end of the linac (1000 $\pi\cdot$mm$\cdot$ mrad) and none for the bunching system, it is desirable to minimize emittance growth at the bunching section.

The transverse focusing in the bunching system is provided by Helmholtz coils arranged along the bunching section with an interval of 165 mm. For optimum bunching with low emittance, the magnetic field was adjusted. In case the magnetic field is too high in drift space, the beam begins to scallop, that is, its radius changes in a violent and periodic fashion, resulting in particles gaining excessive transverse momentum at the waist of the scallop, and leading to emittance growth in drift space. Therefore, we kept the field low so as to maintain constant radius in the drift space to SHB2. The emittance increased fairly after SHB2, where a strong bunching starts. Figure 3 shows the variation of the normalized rms emittance in this case. The bunching condition is the same as that of the optimum bunching in the previous section. The initial emittance value from the electron gun is about 7 π·mm·mrad, the value calculated with EGUN. It can be seen from the Fig. 3 that emittance grows mainly in the prebunchers and buncher. The maximum focusing field of the present buncheing system is 1000 Gauss. The value is a little too weak at the buncher, and the radius diverged there. The initial radius, 2 mm, increased to 4 mm in the first part of the buncher. The final emittance is about 100 π·mm·mrad, which is satisfactorily low.

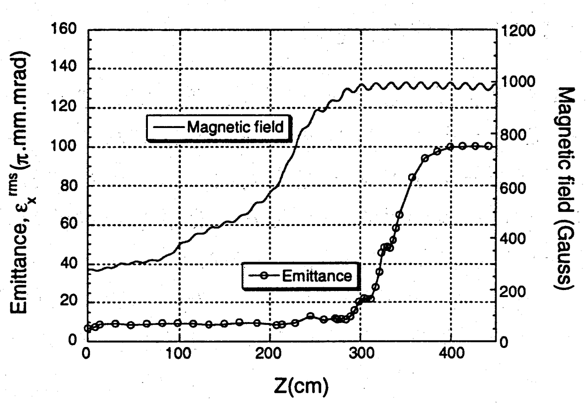

Figure 3: The variation of the emittance and the distribution of magnetic field using the present focusing coil.

To suppress emittance growth further, a stronger focusing field is necessary. By raising the magnetic field by 20% at the buncher, the emittance was lowered below 50 π·mm·mrad, and it is shown in Fig. 4. In this case, the emittance value reduced by half at the cost of the longitudinal bunching efficiency. We could, however, still have a good bunching; 50%, 74%, and 86% of the initial charge was contained in 4°, 10°, and 15° around the peak, respectively. The variation of the horizontal radius in this case is shown in Fig. 5

It follows from the above result that we can get an sufficiently low emittance beam for KEKB at the exit of buncher with a little change of focusing coils.

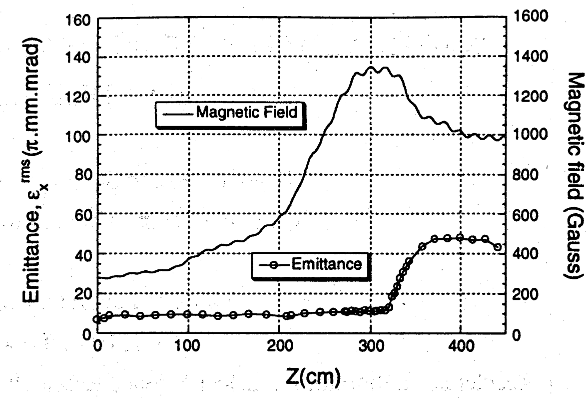

Figure 4: The variation of the emittance and the distribution of magnetic field using stronger focusing coils.

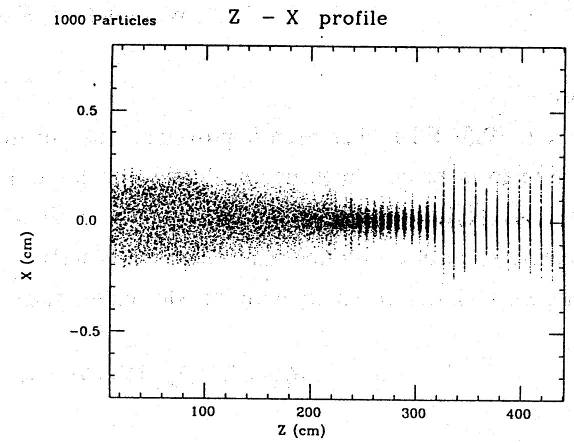

Figure 5: The variation of the radius with bunching in case stronger focusing coils.

SUMMARY

We designed the bunching section for KEKB using the simulation code PARMELA. We conclude that single bunches with the desired qualities for KEKB can be produced by adding two subharmonic bunchers to the present bunching system. The emittance can be kept quite low below requirements.

References

[1] A. Enomoto et al., *Proc. 1994 Int. Linac Conf.* 184

[2] S. Ohsawa et al., *Proc. 1993 Particle Accelerator Conf.* 3087

[3] S. Ohsawa et.al., *Proc. 1994 Int. Linac Conf.* 193

[4] S. Ohsawa et al., *these proceedings*