KEK Preprint 96-119
September 1996
A

Bunching System of the KEKB Linac

J.-Y. CHOI, S. OHSAWA, T. KAMITANI, Y. OGAWA,
A. ENOMOTO and I. SATO

Contributed to the XVIII International Linac Conference, Linac96,
Geneva, Switzerland, 26 - 30 August, 1996.

National Laboratory for High Energy Physics, 1996

KEK Reports are available from:

Technical Information & Library
National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi
Ibaraki-ken, 305
JAPAN

Phone: 0298-64-5136
Telex: 3652-534 (Domestic)
(0)3652-534 (International)
Fax: 0298-64-4604
Cable: KEK OHO
E-mail: Library@kekvax.kek.jp (Internet Address)
Internet: http://www.kek.jp

BUNCHING SYSTEM OF THE KEKB LINAC

Jae-Young Choi, Satoshi Ohsawa, Takuya Kamitani, Yujiro Ogawa, Atsushi Enomoto, and Isamu Sato
National Laboratory for High Energy Physics (KEK),
1-1, Oho, Tsukuba, Ibaraki, 305 Japan

Abstract

At present, the KEK 2.5-GeV Linac is being upgraded as the injector of the KEK B-factory(KEKB). One of the most important changes is to increase the intensities of the positron beams injected into a KEKB ring; it is, therefore, required to accelerate high-intensity single-bunch electron beams to high energy, 3.7 GeV, where they are converted to positron beams. For this purpose, the primary electron bunch should have more than 10 nC. Furthermore, the bunch lengths must be limited to be as short as 10 ps in order to achieve narrow energy spreads of primary electron beams, and to also produce positron beams having short bunch lengths. A bunching system has been designed to meet these requirements by introducing subharmonic bunchers(SHB).

This paper describes the upgrade of the bunching system as well as the results of bunching simulations using PARMELA. The design and RF test of the SHB cavities are also described.

Introduction

The KEK PF 2.5-GeV Linac is now being upgraded for the KEKB project[1]. The pre-injector of the KEKB Linac must provide beams with various charge contents for the KEKB rings and PF ring: single-bunch electron beams of 10 nC for positron-beam production, and 1 nC for direct injection into the KEKB electron ring. The demands on the bunching section lie in the primary electron beams for positron production; the pre-injector must produce single-bunch electron beams of more than 10 nC; furthermore, there exist optimum bunch lengths according to the charges of the bunches in order to minimize the energy spreads during subsequent acceleration, determined by the bunch lengths and longitudinal wake fields. According to the calculation results[2], bunch lengths of about 10 ps at FWHM are desirable for the case of single bunches of 10 nC.

To meet these requirements, the pre-injector system has been designed to introduce two subharmonic bunchers (SHB).

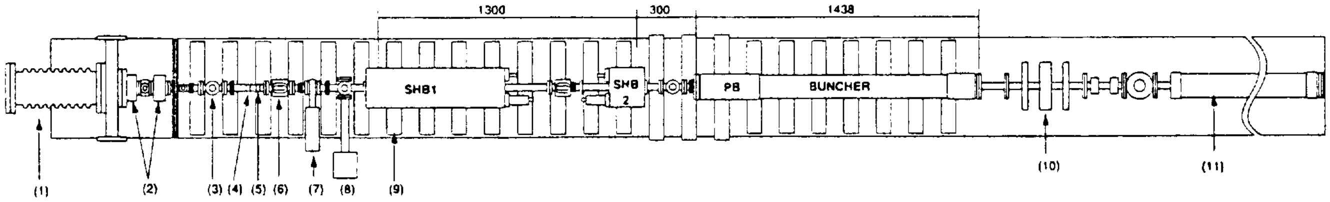
We describe here the design of the entire bunching system as well as the bunching characteristics, together with the design, fabrication, and RF test results of the subharmonic bunchers.

Design of the Bunching System

Acceleration studies on high-intensity single-bunch electron beams for the KEKB Linac have been carried out at the KEK PF 2.5-GeV Linac for a couple of years[3, 4] using one subharmonic buncher(476MHz). It has been made clear from those studies that one more subharmonic buncher is necessary in order to produce single bunches with no satellite bunches if the charge becomes about 10 nC or more[4]. The frequencies of two subharmonic bunchers were chosen to be 114.24 MHz and 571.2 MHz[3], and the cavities are of the standing-wave type.

As mentioned above, the charge of the primary electron beam used to produce a sufficient positron intesity for KEKB is 10 nC. However, we have designed the bunching system with PARMELA so that it can produce single bunches of up to15 nC. The layout of the newly designed bunching section is shown in Fig. 1. (For a bunching system with one subharmonic buncher, see reference[3]). We describe below the new bunching system as well as the bunching behavior for the case of 15 nC. To obtain 15 nC single bunches at the pre-injector end, we made the calculation using a beam of 20 nC and 2 ns from the electron gun while considering the charge losses in the bunching process. For such a high charge content, the space-charge force is so large that it is necessary to shorten the drift space after the beam becomes tightly bunched so as to minimize debunching. In this design, the old first prebuncher (PB1) was removed, since debunching occured in the drift space between the prebunchers. The prebuncher (old PB2) and buncher have been mechanically joined toghether so as to minimize the drift space, whereas they are separated electromagnetically.

In our bunching system, SHB1's frequency is so low that a tremendous power is required to provide a large modulation for the beam. We set the effective modulation voltage for the beam at 50 kV, the peak voltage being about 77 kV. Since the space-charge forces cancel the beam-modulation energies as the



(1)Electron Gun, (2) Magnetic Lens, (3) Profile Monitor, (4) Wall Current Monitor, (5) Core Monitor, (6) Steering Coil, (7) Gate Valve, (8) Ion Pump, (9) Focusing Coil, (10) Q-Magnet, (12) Accelerators (2 m x 2)

Fig. 1. Pre-injector of the KEKB Linac

bunching progresses, there exists a minimum possible beam pulse length just before the debunching starts. In the drift space downstream of SHB1, this length is about 1000 degrees or so in the S-band, which corresponds to about half the wavelength of the RF of SHB2. To compress the above-mentioned beam pulse length to shorter than one wavelength of the S-band prebuncher, further bunching is required at SHB2 with a peak electric field of 100 kV. One more important change in the pre-injector is to strengthen the electric field of the buncher from the present 15 MV/m to 20 MV/m by doubling the klystron power. More efficient bunching was confirmed from the results of simulations in the case of high-intensity beams.

Figure 2 shows the parameters of a bunched beam of 15 nC at the exit of the buncher. The result shows that about 70% of the initial charges are contained in 15 degrees around the peak. It is shown that single bunches of about 10 ps at FWHM could be obtained. Though the energy spread is rather broad, a short bunch length is more important than the energy spread in the bunching section, since the energy spread originating from the bunch length during subsequent acceleration dominates the total energy spread. Two tiny satellite bunches were formed on each side of the main bunch, which contained charges of about 6 percent of total initial charges. For other beams with different charges, shorter bunch lengthes and narrow energy spreads were obtained in simulations; 5 degrees and 1.2 MeV for 1 nC bunch, and 10 degrees and 2.0 MeV for 10 nC, all at FWHM.

Bunching simulations for a beam of 15 nC showed that by optimizing the focusing magnetic fields to a maximum of 1400 G, the full capacity of the present focusing coils, could hold the normalized RMS emittance to below 150 π. mm.mrad[6].

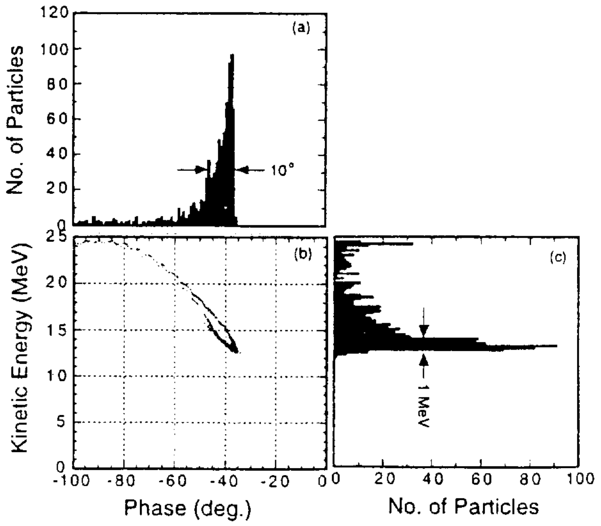


Fig. 2. Characteristics of the bunch for 15 nC at the exit of the buncher. (a)bunch shape; (b) distribution of particles in longitudinal phase space, where the horizontal axis denotes the phase of a particle with respect to the fundamental wave in the buncher; (c) energy spread

Subharmonic Buncher 1 (SHB1)

A 119 MHz subharmonic buncher cavity [7] is available along with the removal of the positron beam line according to the end of the TRISTAN experiments. To examine its usability as the SHB for the KEKB Linac, we measured the main parameters of the cavity and performed a calculation with SUPEFISH. The results of SUPERFISH showed that minor changes in the acceleration gap structure would make the cavity usable as SHB1 of the KEKB Linac, as far as the frequency is concerned. The measured shunt impedance (0.54 MΩ, compared to the calculated value 0.79 MΩ) is so low that it requires a very large peak power for bunching high-intensity beams. For example, for bunching a beam of 20 nC with a pulse width of 2 ns, a peak voltage of 77 kV is required. The shunt-impedance value shows that the cavity should be supplied a peak power as high as 11.2 kW to sustain this peak voltage.

We designed a new SHB1 cavity; since its shunt impedance is about 1 MΩ, we expect to fabricate a cavity with a shunt impedance of more than 0.7 MΩ; if this is the case, the required peak power would become 8.6 kW.

Subharmonic Buncher 2 (SHB2)

Design and low-power RF test. We designed and fabricated a SHB2 cavity. Its structure (Fig.3) is similar to that of the 476 MHz SHB cavity[2] . In the case of the 476-MHz cavity, a ceramic covering was used over the input coupling loop in order to isolate the vacuum from the atmosphere. By doing so, the coupling of the cavity can be changed while maintaining a vacuum. In this case, we did not use a ceramic covering to prevent any electric discharges, which may occur under high-field operations. Since the power input connector is joined to the cavity by a rotatable ICF flange, the coupling can be changed if needed, though this damages the cavity vacuum during the change.

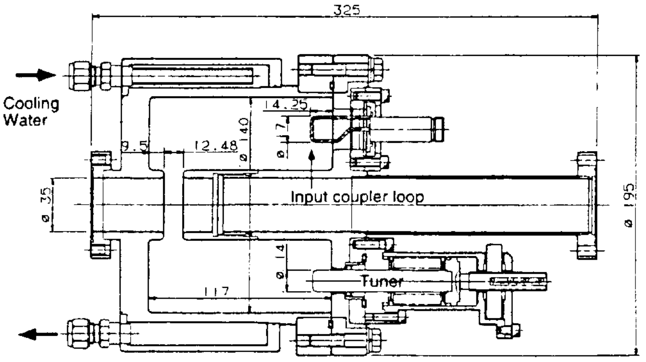


Fig. 3. Structure of the SHB2 cavity.

The main parameters of the SHB2 cavity are given in Table 1. The Q value was measured by both the reflection method and the impedance method[8]. The temperature of the cavity was kept constant at 31± 0.2°C by circulating the cooling water used in the actual beam line, and the vacuum was maintained by a turbomolecular pump to lower than 10^{-2} Pa. The cavity has a Q value of 83% of the calculated one. The shunt impedance given in Table 1 was obtained from the R/Q values measured by Slater's bead perturbation method[8]. The measurements were performed using aluminum spheres of diameter 2, 3, 4 mm as perturbing objects. This is the value obtained by extrapolating these values to the limit of zero volume. This R/Q value is nearly the same as that obtained by SUPERFISH. Figure 4 shows the electric-field distribution on the beam axis near to the acceleration gap. The agreement between the measured values and the calculated ones is good. From this shunt-impedance value it can be seen that a peak power 6.7 kW is necessary to obtain the peak electric field (100 keV) required to be provided by the SHB2 cavity to bunch 20 nC beams. A SHB2 power source capable of a peak power of 10 kW is now being fabricated. It will be a solid state amplifier, and will be completed this fiscal year.

Table 1.
Main parameters of the SHB2 cavity

	Calculated	Measured
Cavity Length	117 mm	
Gap Length	12.2mm	12.48mm
Resonant Frequency	571.2 MHz	
Tuning Range	570.44 - 572.32 MHz (total stroke of tuner :30mm)	
Q_0 value	10,870	9,010
Coupling Parameter	1.4	
Shunt Impedance	1.83 MΩ	1.50 MΩ

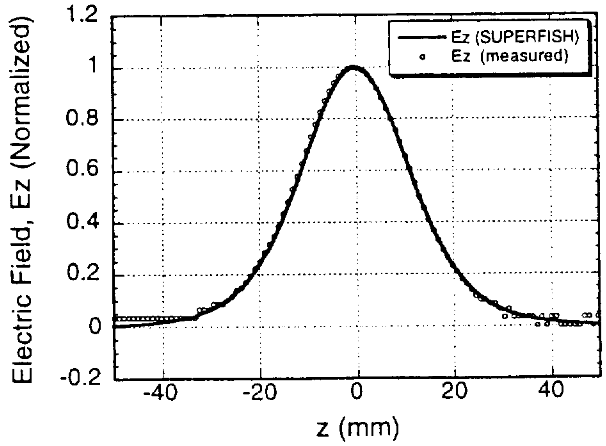


Fig. 4. Electric-field distribution on the axis near to the acceleration gap of SHB2.

High-Power RF Test. Since a high-power source of 571.2 MHz is not available to us at present, we performed a preliminary high-power test of the newly fabricated cavity using the 476 MHz power source which is installed in the present beam line. To adjust the resonant frequency of the cavity to 476 MHz, we lengthened the cavity by inserting a copper spacer having a thickness of 26.7 mm in the cavity.

The test was performed at 31± 0.2°C and 3×10^{-7} Pa. The electric discharges due to multipactoring were observed during the initial RF aging, and we perfomed high-power tests at various levels for two days. We finally set a peak power of 4.2 kW into the cavity, though this was not a sufficient level. We confirmed a stable operation with no continuous electric discharge at this level except for the initial-stage discharges. Figure 5 shows the power pulses observed by an oscilloscope.

When a 571.2 MHz power source becomes available, we will again perform a high-power test through the full range at the resonant frequency.

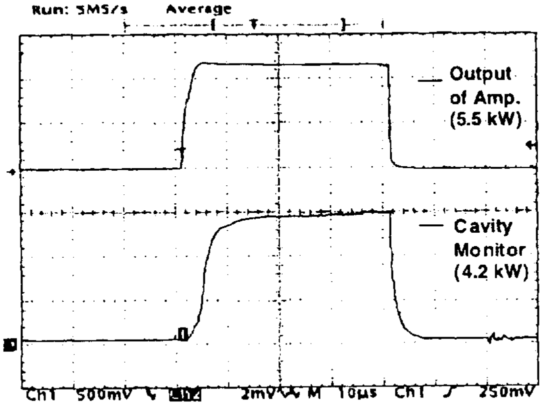


Fig. 5. Power pulse forms in a high-power test observed at the power source (above) and cavity monitor (below)

Conclusion

We designed the bunching system for the KEKB Linac using the simulation code PARMELA. The results showed that the new system can produce the bunched beams required for the KEKB pre-injector. We fabricated a new SHB cavity and confirmed that it has the required properties.

References

[1] A. Enomoto, "Upgrade to the 8-GeV Electron Linac for KEKB", these proceedings.

[2] Y. Ogawa, et al., " Wake-field issues concerning the KEK B-Factory Injector Linac", Proc. 1994 Int. Linac Conf., 535

[3] S. Ohsawa et al., "High-Intensity Single-Bunch Beam of the PF 2.5-GeV Linac", Proc. 1994 Int. Linac Conf., 193

[4] Photon Factory Activity Report 1994, KEK, 1996

[5] S. Ohsawa, et al., "Pre-Injector of the KEK 2.5-GeV Linac and High-Current Single- Bunch Acceleration", these proceedings.

[6] Design Report on PF Injector Linac Upgrade for KEKB (in Japanese), KEK Report 95-18 March 1996

[7] A. Asami, et al., "Injector of the Positron Generator", Proc. 1986 Int. Linac Conf., 496

[8] E. L. Ginzton, *Microwave measurements*, McGraw-Hill, 435, 1957