HIGH-INTENSITY, TWO-BUNCH ACCELERATION FOR DOUBLING POSITRON PRODUCTION AT THE KEKB LINAC

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Abstract

The rapid injection of positrons into the KEKB ring is one of the most critical issues affecting the accumulation of the integrated luminosity. The KEKB linac has until now injected single-bunch positron beams with a charge of about 0.4 nC into the KEKB ring, requiring several minutes of injection time. In order to make this positron injection time as short as possible, we have introduced a high-intensity, two-bunch acceleration scheme in the primary electron beam for positron production, which could eventually double the positron intensity and halve the injection time. The bunch separation has been determined to be 96.29 ns, taking account of the SLED pulse width at the linac as well as the common frequency (10.385 MHz) of both the linac (2856 MHz) and the ring (508.887 MHz). The first beam test results are reported.

1 INTRODUCTION

In high-energy factory machines, like KEKB and PEPII, it is strongly required that the beam-injection time be as short as possible for the effective accumulation of the integrated luminosity [1]. In order to improve the injection time, we must primarily increase either the beam intensity or the bunch number in the injector linac. In the case of the KEKB linac, where a high-intensity single-bunched beam is accelerated to the positron production target, the single-bunch charge amounts to about 10 nano Coulomb [2], which is almost the limit of stable acceleration without introducing any method of special cures. We therefore doubled the bunch number to increase the positron beam intensity per pulse and to halve the injection time (Table 1). The results of the first acceleration and injection tests as well as the two-bunch acceleration scheme are described.

2 TWO-BUNCH ACCELERATION

2.1 Scheme

The generation [3] and acceleration of two-bunch beams is schematically illustrated in Figs. 1. The main constraints for doubling the bunch number are:

- The bunch interval time must be 96.29 ns, which corresponds to the common period of the frequencies of the linac and the ring. This is due to complex frequency relations (Table 2) between the linac and the ring.
- Loading compensation should be carried out within a SLED gain curve (Fig. 3) in order to equalize the two-bunch energies.

Table 1: Injection time for KEKB (Example)

	Present	Full Injection
LER	0.4 ->0.7 A	2.1 ->2.6 A
HER	0.43 ->0.58 A	1.0 ->1.1 A
Physics Run	90 min	20 min
Injection/day	14 times	53 times
LER		
Single Bunch	3.8 min (1.3 mA/s)	6.4 min (1.3 mA/s)
[Two Bunch]	[2 min] (2.5 mA/s)	[3.3 min] (2.5 mA/s)
HER	1 min (2.5 mA/s)	0.7 min (2.5 mA/s)
Beam Switching / Others	3 - 4 min	3 - 4 min
Total	8 - 9 min [6 - 8]	10 - 12 min [7 - 9]

Table 2: Various frequency relations.

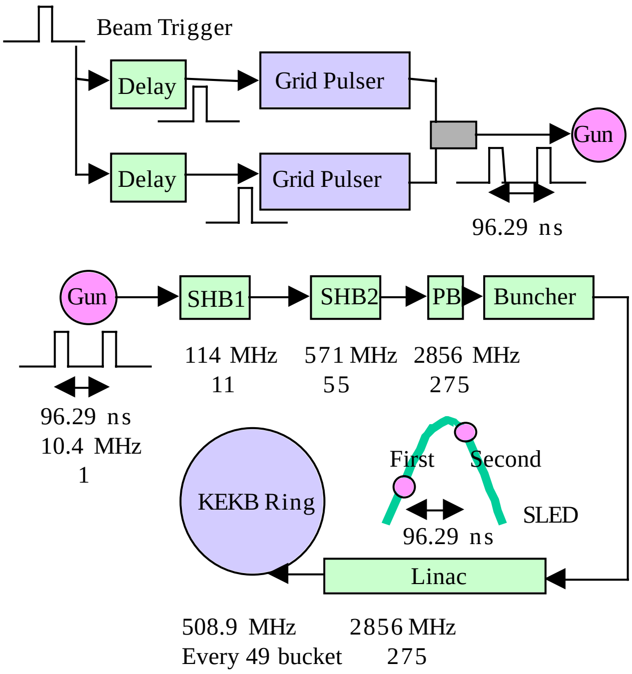

Figure. 1: Two-bunch generation and acceleration.

	Multiple	Frequency [MHz]	Period [ns]
Common Frequency	1	10.385454	96.289
SHB1	11	114.240	8.754
SHB2	5*11	571.200	1.751
Linac	5*5*11	2856.000	0.350
Ring	7*7	508.887	1.965

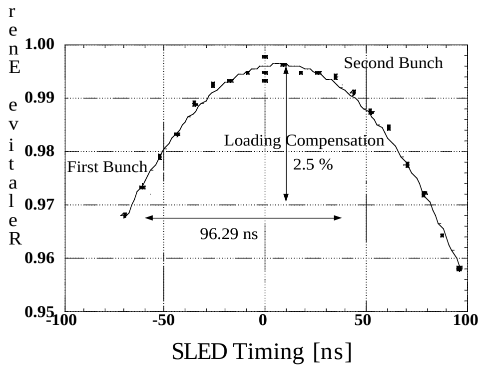

Figure 2: SLED gain curve.

2.2 Bunch Profiles

For stable acceleration of the two-bunch beam it is fairly important to have the same bunch profiles for each bunch at the exit of the bunching section. Figure 3 shows the results of streak-camera measurements by utilizing the optical transition radiation (OTR) generated from a thin piece of metal inserted into the beam line at the exit of the bunching section, indicating that two bunches have almost the same bunch profiles.

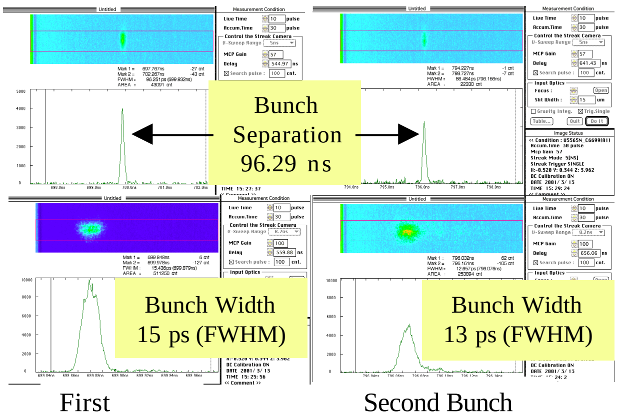

Figure 3: Two-bunch profiles.

2.3 Orbit and Charge in Acceleration

A two-bunched beam with almost the same bunch profiles was successfully accelerated without any conspicuous beam losses to the positron production target, yielding almost the same number of positrons for each bunch, which was accelerated to the end of the linac. Figure 4 shows the orbit and charge of the two bunches accelerated along the linac. We have so far achieved successful acceleration of two-bunched positrons with charges of 0.4 – 0.5 nano Coulomb at the end of the linac. Fine-tuning is under way.

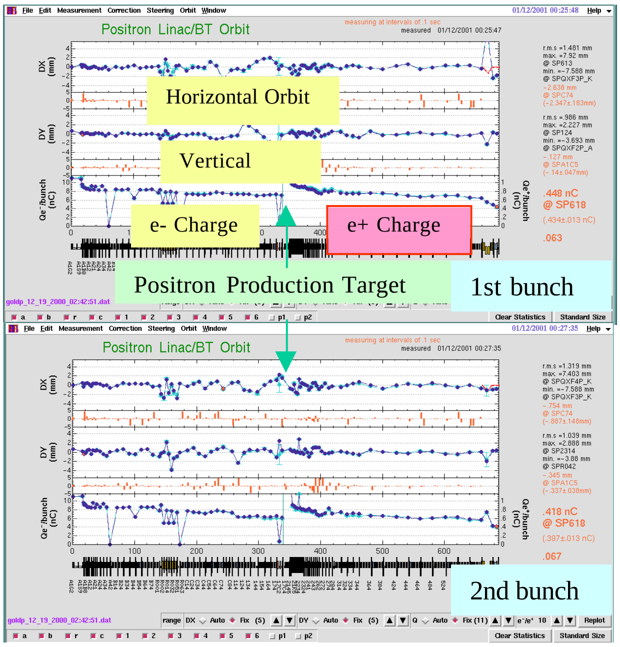

Figure 4: Beam orbit and charge.

2.4 Twiss Parameters for Positron Beam

The twiss parameters of two-bunched positron beams were measured at the end of the linac using wire scanner monitors, which were installed at adjacent positions with appropriate betatron phase advances. The results confirm that each bunch has the same twiss parameters, assuring proper matching to the beam-transport (BT) line to the ring. Figure 5 shows an example of the wire-scanner measurements.

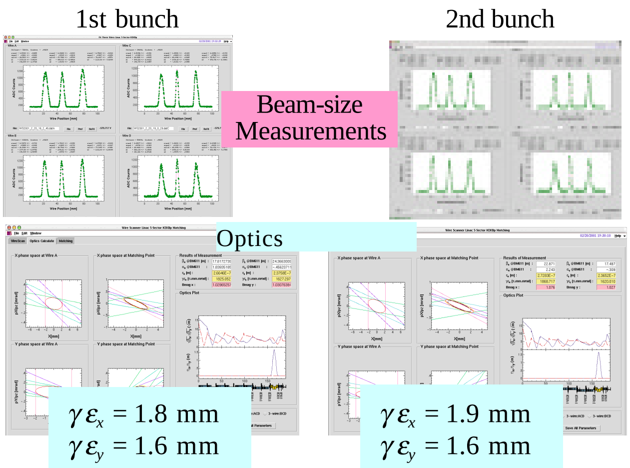

Figure 5: Measurements of the twiss parameters of positron beams at the end of the linac by wire scanners with three wires: horizontal, 45 degree and vertical.

3 INJECTION TEST

After passing an energy compression system (ECS) located at the end of the linac, a two-bunched beam was guided in the BT line to the KEKB positron ring (LER). Since the system of beam-position monitors in the BT line are being reconfigured for two-bunch beam measurements, the beam orbit along the whole BT line is still unchecked, except for the charge intensity of each bunch at the end of the BT line. Regardless of these situations, we dared to try injection into LER to find out if there are any essential problems concerning the two-bunch injection scheme. To begin with, we injected just two bunches into LER, confirming a bunch interval of 49 buckets in the ring. We then tested a special fill pattern of 64/4/4 (234*2), which means 64 trains with 4 bunches in each train and 4 rf-bucket spacing, amounting to a total bunch number of 234*2=468 in the ring. Figure 6 shows the bunch current distribution measured along the ring (total current of 100 mA), which indicates two groups in each train corresponding to two-bunch injection. The intensity difference between two groups may be partly attributed to that of the injected beam at the end of the BT line, which is expected to be improved after correcting the BT orbit.

We will continue the injection tests with more realistic fill patterns for high-luminosity experiments.

4 ISSUES

The remaining main issues for two-bunch operation are the following:

- Fine adjusting of the two-bunch beam orbits at the bunching section, which could assure a well-behaved orbit downstream.
- The development of a new orbit-correction algorithm for two bunches; one example (average minimum algorithm) is shown in Fig.7.
- Simultaneous beam diagnosis for two bunches in both wire scanners and beam-orbit measurements, which is being prepared.
- A more sophisticated feedback system for equalising the energy and orbit of two bunches, which is definitely necessary for stable operation.
- Complicated bucket selection system for two-bunch injection, which is due to the non-simple frequency relations between the linac and the ring (Table 2).

With all of these items resolved, we expect the stable operation of two-bunch injection into LER in FY2001.

5 CONCLUSIONS

Two-bunch acceleration at the KEKB linac has been successfully carried out as well as the first injection tests. Each bunch profile of two-bunched primary electron beams for positron production was investigated at the end of the bunching section, while an intense two-bunched

Figure 6: Bunch current distributions along LER, when two bunches are injected with a special fill pattern of 64/4/4(234*2). Two groups in a train correspond to two-bunch injection.

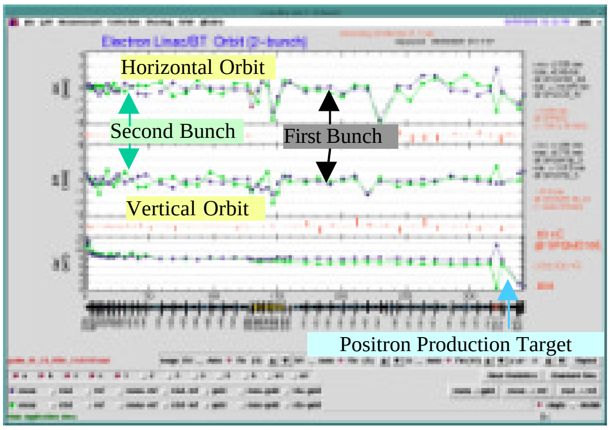

Figure 7: New orbit correction method based on the average minimum of two-bunch orbits applied to the primary electron beam for positron production.

beam with a charge of 7 and 8 nano Coulomb each was accelerated to the positron production target. A two-bunched positron beam with a charge of 0.4 – 0.5 nano Coulomb each was then accelerated to the end of the linac. The first injection test was performed with a special fill pattern, confirming no conspicuous problems for the two-bunch injection scheme. Further fine-tuning with more sophisticated beam diagnostic tools is in progress as well as the development of a new bucket selection system for injection.

REFERENCES

[1] Y. Funakoshi et al., "KEKB Performance", EPAC'00, Vienna, June 2000, p.28.

[2] K. Furukawa, "Towards Reliable Acceleration of High-Energy and High-Intensity Electron Beams", LINAC'00, Monterey, USA, August 2000, p. 630.

[3] S. Ohsawa et al., "Two-Bunch Generation for KEKB", in these Proceedings.