TWO-BUNCH ORBIT CORRECTION USING THE WAKE FIELD KICK

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Abstract

In the KEKB injector linac, a two-bunch acceleration scheme has been used for doubling the positron injection rate to the KEKB Low-Energy-Ring (LER). In this operation mode, the multi-bunch transverse wake field caused by the first bunch affects the beam orbit of the second bunch. In the KEKB linac, an orbit correction method based on the average minimum of two-bunch orbits has been adopted, and has worked stably. However, a new tow-bunch orbit correction method is strongly required to make the loss of charge less. We propose a new two-bunch orbit correction method based on a local bump method. In this scheme, some local bumps are intentionally constructed in a low-energy area. Adjusting the local bump height can control the wake field strength affecting the second bunch. In this paper, we report on the results of a preliminary beam test to confirm that this new method is useful.

1 INTRODUCTION

The KEKB project started in 1994 to investigate CP-violation in B-meson decays with the double-ring collider [1]. It consists of 8-GeV electron and 3.5-GeV positron storage rings. The beam-injection efficiency from the injector linac to the ring should be boosted as high as possible since the performance of the experiment depends strongly on the integrated luminosity. In order to achieve efficient full-energy injection, the original 2.5-GeV electron linac was upgraded up to 8-GeV, while enforcing the acceleration gradient by a factor of 2.5 and by extending the length of the linac. The layout of the KEKB linac is shown in Fig. 1. Because of the site limit, two linacs with 1.7-GeV and 6.3-GeV were combined using a 180-degree bending magnet system to form a J-shape linac. In the J-arc section, the beam optical parameters are determined so that the achromatic and isochronous conditions are fulfilled [2].

A beam starting from an electron gun passes two subharmonic bunchers (SHB1: 114.24 MHz and SHB2: 571.2 MHz) and an S-band bunching section (2856 MHz) to accomplish a single-bunched beam with a bunch width of about 10 ps (FWHM). After acceleration to the end of sector B (1.5-GeV), it enters into the J-arc section. It is then re-accelerated either to the end of the linac (8.0-GeV) or to the positron production target (3.3-GeV), depending on the operation mode. In order to obtain high-intensity positrons, a large amount of primary electrons should be transported to the positron production target. The primary electron beam was designed to be 10 nC per bunch to produce 3.5-GeV positrons with 0.64 nC. We therefore doubled the bunch number to increase the positron beam intensity per pulse and to halve the injection time [3]. Figure 2 shows the orbit and current status display for two-bunch operation. The bunch interval time must be 96.29 ns, which corresponds to the common period of the frequencies of the linac and the ring.

In the KEKB linac, the orbit correction method, based on the average minimum, has been successfully used for daily operation. The orbit distortion causes beam loss, especially in the J-arc section. Using this method, the orbit correction is carried out so that the average orbit distortion of both bunches can be minimized. Figure 2 shows the orbit and charge status panel in two-bunch operation. This example shows that the charge loss of the second bunch is lager than that of first bunch because of a deterioration of the second bunch orbit. In order to avoid such beam loss due to orbit distortion and to obtain more high-intensity positrons, a new orbit correction method is

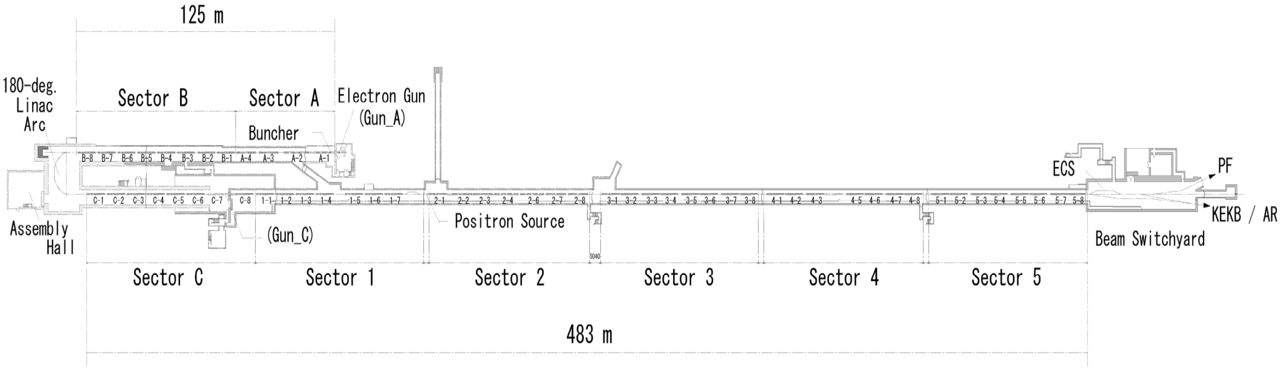

Figure 1: Layout of the KEKB injector linac. The J-arc section combines two straight sections.

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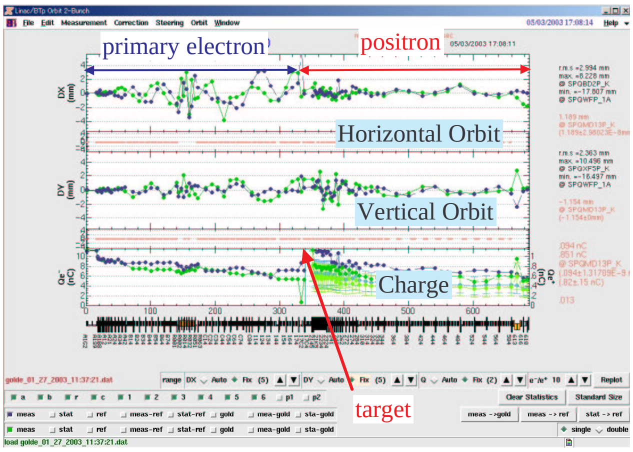


Figure 2: Orbit and charge status panel for the two-bunch operation mode. Top and middle show the horizontal and vertical orbit respectively. Bottom shows charges of each bunch. Blue and light green indicate first and second bunches.

2 TWO-BUNCH ORBIT CORRECTION METHOD

In a new two-bunch orbit correction method, which we have proposed, the beam position of first bunch is corrected by using the wake field kick of first bunch. When the first bunch beam traverses the off-center of an accelerating structure, the long-range transverse wake field caused by first bunch kicks the second bunch. Figure 3 shows a schematic drawing of this correction method. If the bump height is adjusted to a suitable value, the orbit of the second bunch can be controlled arbitrarily. If both the beam positions and angles of each bunch can be corrected to zero in a low-energy section, the beam orbit keeps constant in the following beam line. Accomplishing such a high-quality orbit correction will

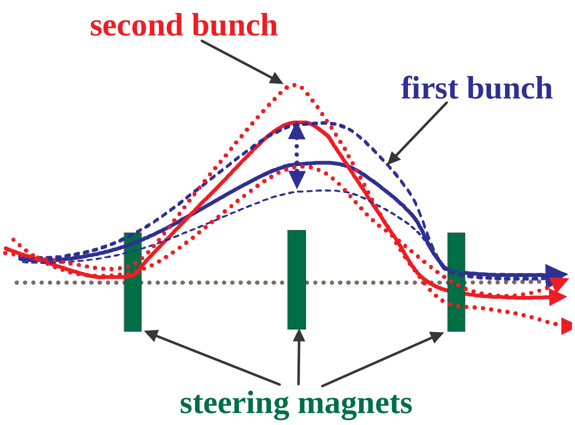


Figure 3: Schematic drawing of a new two-bunch orbit correction method using the transverse wake field kick caused by first bunch.

result in reducing the charge loss in the J-arc section of the KEKB injector linac.

3 RESULTS OF BEAM TEST

In this section, the results of a beam test are presented. Only a horizontal beam-orbit correction was carried out in this experiment. The procedure of this test is as follows:

(a) Construct a first local bump at a beam position monitor (BPM) where the orbit difference between first and second bunch is becoming larger. Adjust its bump height so that the orbit difference is minimized at the downstream side of the bump.

(b) Step (a) will deteriorate the beam orbits of each bunch further at the downstream side. With keeping the first bump, construct a second local bump downstream of the previous bump. Then, iterate the above procedures in order to squeeze out the orbit difference toward the downstream side of the linac, and minimize the beam position and angle of each simultaneously.

If the orbits of each bunch are corrected in Sector A or B without an optics mismatch, it can be expected that the charge loss in the J-arc section will be decreased.

Figure 4 shows the software panel for constructing a local bump. This software can construct a local bump at an arbitrary BPM position in the KEKB linac. In this beam test, three local bumps were successively constructed for an orbit correction. In Fig. 4, local bumps (1), (2) and (3) were constructed by changing the bump heights of the SPA11, SPA32 and SPB14 BPMs, respectively. First of all, the bump height of SPA11 was set to 1 mm, so that the orbit difference would be reduced at SPA32. However, the orbit difference in the downstream area of SPA32 became worse after first bump was constructed. In the next step, in addition to bump (a), a bump height of SPA32 was varied in order to reduce the orbit difference of each bunch downstream of the second bump (b). After the height of the bump (b) was set to 2.5 mm, bump (c) was constructed, while

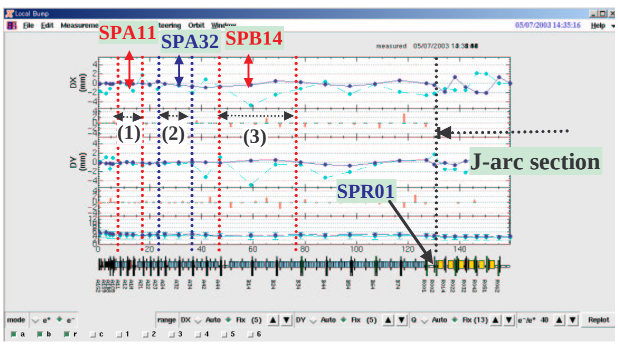
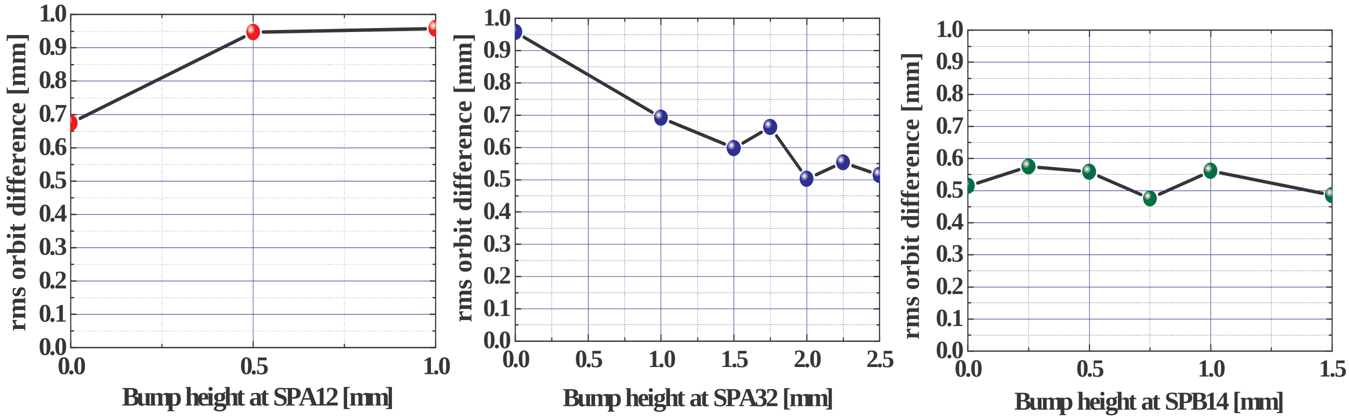


Figure 4: Software panel to construct a local bump. The dotted plot shows the range of local bumps. Three local bumps are successively contracted.



(a) First Local bump (1)   (b) Second Local bump (2)   (c) Third Local bump (3)

Figure 5: Rms orbit difference between first and second bunches versus bump height. The rms orbit difference calculated from the all BPMs between SPA12 (first bump position) to SPR01 (entrance of J-arc section). Three local bumps were contracted successively. In the case of (c), therefore, three local bumps were simultaneously constructed.

bumps (a) and (b) were kept.

Figure 5 shows the results of the rms orbit differences between first and second bunches. The rms orbit difference was calculated from all of the BPMs between SPA12 (first bump position) to SPR01 (entrance of J-arc section). These three local bumps were contracted successively. In the case of (c), therefore, three local bumps were simultaneously constructed. The result of varying the bump height of first bump (1) is plotted in Fig. 5-(1). The rms orbit difference is increased after the bump is constructed because the orbit at the further downstream of SPA32 is deteriorated. Increasing the bump height of the second bump (2) can reduce the orbit difference, as shown in Fig. 5-(b). Figure 5-(c) shows that varying the bump height of bump (3) cannot adjust the rms orbit at the downstream side. The beam energy in Sector B is higher than that in Sector A. For that reason, the long-range wake field of first bunch cannot fully kick the second bunch. In addition, bump (3) was contracted in a relatively long area where three different types of accelerating structures are used for compensating the transverse wake field.

With regard to the beam loss after an orbit correction, the transmission rate decreased to a great degree. To recover the transmission rate, we tried optics matching. However, the emittance could not be measured, since the large emittance growth prevented a wire scanner measurement. If the bump positions are selected by those betatron phases, some suitable bump combinations will be found without any emittance growth.

4 SUMMARY AND FUTURE PLAN

A new orbit correction method was proposed for two-bunch operation in the KEKB injector linac. This method uses the long-range transverse wake field kick caused by the first bunch. To confirm this correction method, a preliminary beam test was carried out in the KEKB injector linac. The results of a beam test shows that this correction method can be useful for a two-bunch orbit correction when the bump positions are suitably selected.

On the other hand, the emittance growth due to a local bump also caused an optics mismatch between the straight and J-arc sections. It became an origin of charge losses. In order to avoid such emittance growth, constructing an additional bump at the 180-degree phase difference is very effective. With all of these conditions fulfilled, the two-bunch beam orbit can be corrected without any emittance growth. Therefore, this new orbit correction method can be used for daily operation. A more detailed beam test and a numerical simulation will be carried out in the near future. We will present its result, elsewhere.

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