STUDY OF VERTICAL BEAM BLOWUP IN KEKB LOW ENERGY RING

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Abstract

Vertical beam blowup has been observed in the KEKB low energy positron ring (LER) since early operation. The main characteristics of the blowup are explained by single-beam head-tail instability caused by an electron cloud. About 4600 solenoids were installed in the LER in order to remove the electrons. This paper describes the experimental study of the vertical beam blowup emphasizing the effect of the solenoids.

1 INTRODUCTION

A blowup of the vertical beam size in both single beam and multibunch operation is observed in the KEKB LER[1]. This blowup is one of the most serious problems limiting the luminosity of KEKB. Observations[1,3] have shown that the main characteristics of the blowup are consistent with the model of single-beam head-tail instability caused by an electron cloud which was proposed by F. Zimmermann and K. Ohmi[2]. Many small permanent magnets, called “C-yokes”, were attached to the vacuum ducts to sweep out the electrons. Measurements of a single beam with a short train, i.e. 60 bunches in a train, showed that the C-yokes were effective in suppressing the blowup for large bunch spacings such as 12 rf buckets, but they were not very effective for the shorter bunch spacing of 4 rf buckets which is the spacing used for physics runs. Expecting that the electrons would be removed by solenoids more efficiently than by the C-yokes, a large number of solenoids were installed in the LER.

2 SOLENOID SYSTEM

Solenoids were installed in two stages. In the first stage in September 2000, about 2800 solenoids were installed mainly in the arc sections. The total length of the solenoids was about 800 m. The calculated field strength was 45 Gauss at the center of the solenoid when a current of 5 A was applied. In the second stage of installation in January 2001, about 1850 solenoids were installed in the bellows-NEG pump sections in the arcs. A set of three solenoids covered a bellows-NEG pump section. The total length of the regions where the field strength was greater than 20 Gauss was about 430 m. Thus about 40 % of the ring circumference was covered by solenoid field as a result of the two installations. A photograph of the solenoids is shown in Figure 1.

Figure 1: Solenoids in the LER tunnel. The three solenoids on the right side are those installed in bellows-NEG pump sections. The long solenoid on the left side was installed in the first installation.

3 EFFECT OF SOLENOIDS

3.1 First installation of the solenoids

The effect of the solenoids on the blowup was measured in single beam measurements. The results are summarized as follows.

1) The threshold current of the blowup in a short train was increased when the solenoids were excited, as shown in Figure 2. The data in Fig. 2 is the average vertical beam size over all bunches as measured by synchrotron radiation interferometer. The beam size is transformed from the source point of the synchrotron radiation to the collision point (IP).

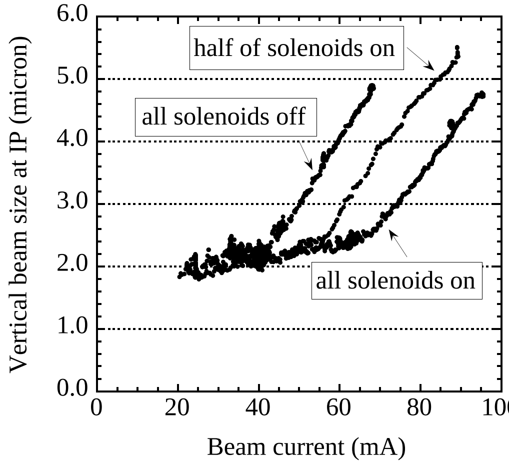

Figure 2: Vertical beam size as a function of the beam current. In the measurement two trains were injected on opposite sides in the ring. Each train contained 60 bunches. Bunch spacing was 4 rf buckets.

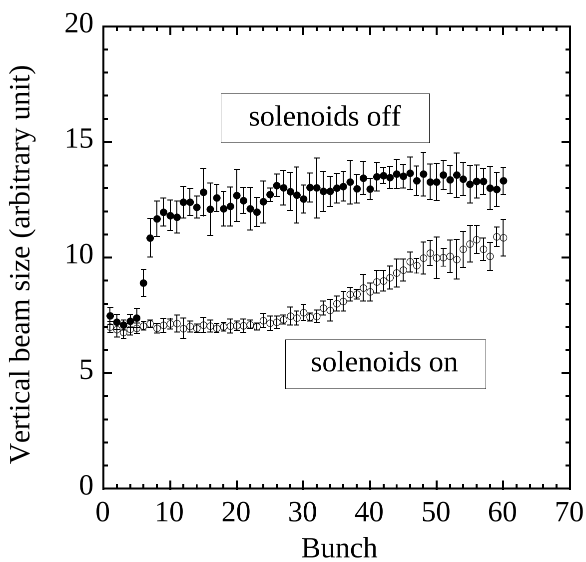

Figure 3: Vertical beam size along a train taken by the gated camera with and without solenoids. The train consisted of 60 bunches. Bunch spacing was 4 rf buckets. Bunch current was 0.67 mA.

2) The vertical beam size along a train was measured by a gated camera. The data shown in Fig. 3 clearly showed that the solenoids were effective to suppress the blowup especially in the forward part of the train.

3) The vertical tune of each bunch in a train was measured by a gated tune meter. The tune increased along the train then saturated. The change of the tune can be interpreted as the focusing effect by the electron cloud. The tune shift at saturation was enhanced about 30% when the solenoids were turned off[4].

4) The threshold beam current at which the blowup started was measured by the interferometer as a function of the solenoid current as shown in Fig. 4. It shows that the threshold beam current is nearly saturated at 3 A, i.e. at about a 30 Gauss solenoid field.

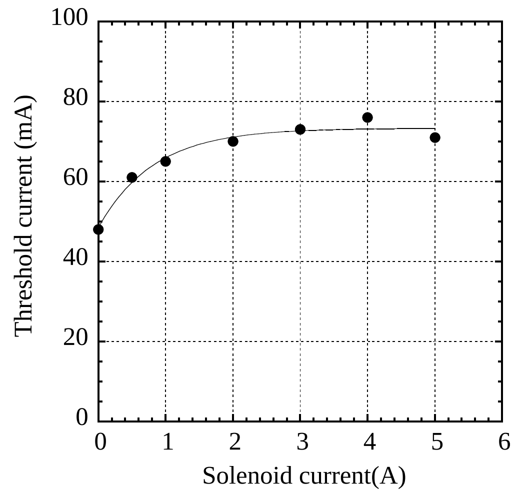

Figure 4: Threshold current of the blowup as a function of the excitation current of the solenoids.

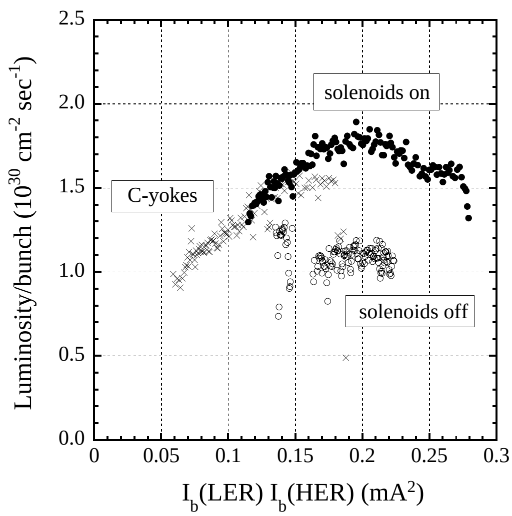

Figure 5: Luminosity per bunch with and without solenoids. The horizontal axis is a product of the bunch current of LER and HER (High Energy Ring). The data with C-yokes is also shown. The fill pattern was that used during physics running. The number of bunches and the bunch spacing were 1153 and 4 rf buckets respectively.

The effect of the solenoids was also confirmed by the measurement of the luminosity. As shown in Fig. 5 the luminosity per bunch increased by a factor of 1.6 when the solenoids were excited. The luminosity per bunch with C-yokes is also shown in Fig. 5. The data with solenoids and with C-yokes almost coincided below 0.15 mA^2. It is seen that the saturation of the luminosity with solenoids starts at higher current than it does with C-yokes. Whether this improvement comes from the replacement of the C-yokes with the solenoids or not is not clear because the beam-beam effect, which depends on machine parameters and beam tuning, also affects the luminosity.

3.2 Second installation of the solenoids

Fig. 6 shows the luminosity per bunch before and after the second installation of the solenoids. The data shows

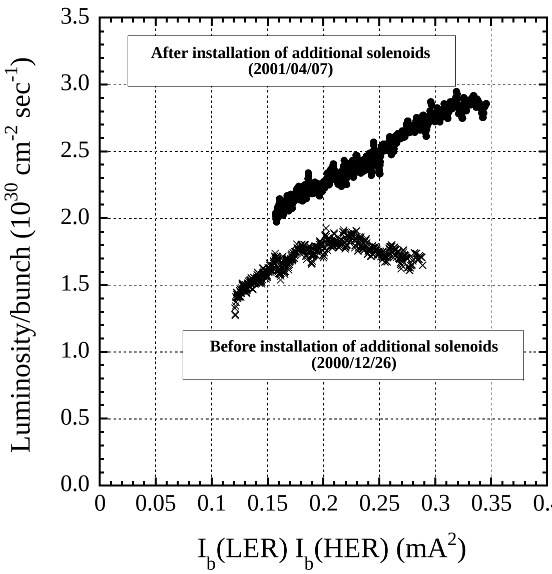

Figure 6: Luminosity per bunch before and after the second installation of solenoids. The data denoted by "x" was taken between the first and second installations of the solenoids. The horizontal axis is the product of the bunch current of LER and HER. The fill pattern was that used in the physics run. The number of bunches was 1153 and bunch spacing was 4 rf buckets.

that the saturation of the luminosity at 0.2 mA^2 disappeared after the second installation. At present we do not know how much the additional solenoids contribute to this improvement because other machine parameters such as tunes and beam tuning also affect the luminosity. The vertical tunes in both rings were changed between the two measurements from just above integer to above half integer. The effect of the change of the tunes on the luminosity has not been clarified yet. We will soon compare the luminosity with and without the additional solenoids to measure their effect more clearly.

The behavior of the luminosity is also given in separate papers [5,6].

4 REMAINING BLOWUP

Though it was confirmed that the solenoids and C-yokes were effective to decrease the blowup, the blowup still remains. As seen in Fig. 3 the beam size starts to increase at the 30th bunch even with the solenoids on. Furthermore there is an indication that the effect of forward bunches on the blowup of rearward bunches does not disappear even at relatively long range. Fig. 7 shows the vertical beam sizes of two trains which were separated by 120 rf buckets from each other. In Fig. 7 the beam size along the second train increases faster than along the first train and the beam size at the tail in the second train is larger than that in the first train.

The remaining blowup may be caused by the electrons which are not removed yet or by unknown mechanisms. We have a plan to install more solenoids both in the long

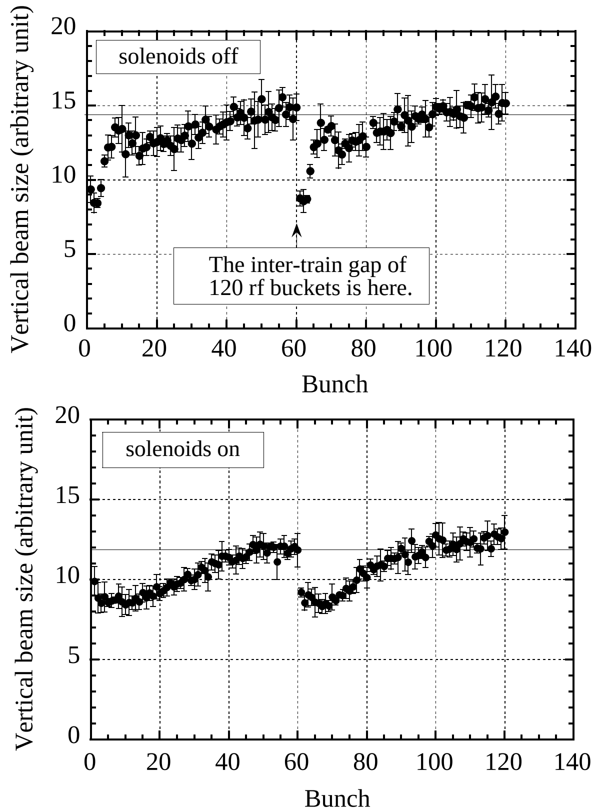

Figure 7: Effect of train spacing on the blowup. Bunch spacing was 4 rf buckets. Bunch current was 0.81mA. Data was taken between first and second installation of solenoids.

straight sections and in the arc sections to see how much the blowup is reduced by further winding of the solenoids.

5 ACKNOWLEDGEMENTS

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