A DIAGNOSTIC SYSTEM FOR BEAM ABORT AT KEKB

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Abstract

A controlled beam abort system has been installed at KEKB for the protection of the hardware components of the accelerator and detector from damage by ampere-class beam currents.

In order to identify the reason for each abort and optimize the abort system to handle each type of problem as well as improve machine operation, a diagnostic system has been developed. Fast signals, such as beam currents, accelerating voltages of the RF cavities and beam loss monitor signals from PIN photo-diodes are recorded and analyzed by a data logger system with a high sampling rate at the moment of each abort.

Beam oscillations, radiation dose at the detector and vacuum pressure are also examined to classify the reasons for beam losses and aborts. Statistics and typical examples of these aborts will be discussed.

INTRODUCTION

KEKB is an energy asymmetric electron positron collider dedicated to B meson physics. An electron ring of 8 GeV (HER) and a positron ring of 3.5 GeV (LER) are installed in a tunnel. The maximum achieved currents of the electron and positron rings are 1.35 A and 2.0 A respectively so far. In order to avoid having a loss of the high current beams which damage the accelerator and the Belle detector components, we have to dump the beam quickly when a large beam loss is expected because of beam instability, trouble in the RF system, and so on. We installed a controlled beam abort system [1] for this purpose and diagnosed the reason for each abort with the abort monitor system.

ABORT MONITOR SETUP

The reason for a beam abort can be determined by recording various information on the beams and the RF status used for the beam abort decision at the moment of beam abort.

Data loggers were set up in three of the local control rooms (LCR) and the signals from other LCRs were also collected to analyze the beam aborts.

The logged time period is 600 ms (HER) and 300 ms (LER). The sampling interval is 5 μs and 1 μs for HER and LER respectively.

The signal flow of the data logger is shown in Figure 1. Beam intensity, pin photo-diodes (PD) loss monitor signals at movable masks, signals from the RF cavities, beam phase showing deviation of synchronous phase and injection trigger timing signals are logged. These fast signals are useful to diagnose the cause of the beam abort since they have a strong relation with the beam condition. The recorded data are sent to the KEKB central control room (CCR) via the KEK internal network and are monitored by the operation shift crew. The information is ready for inspection within a few minutes after the abort.

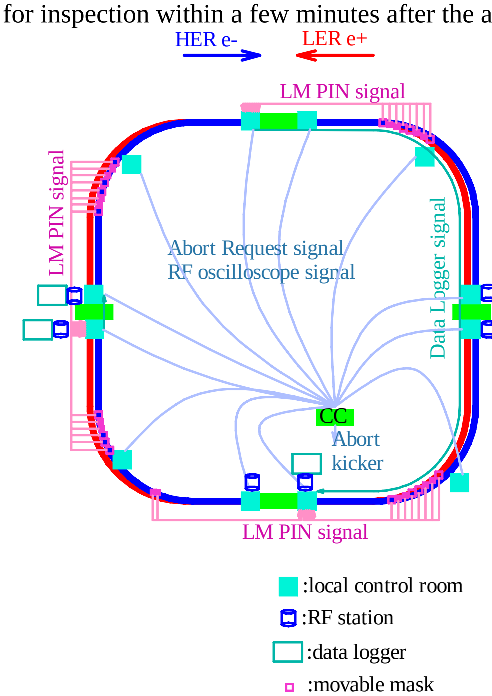

Figure 1: Abort signal chart.

TYPICAL ABORT EXAMPLES

Manual Abort: An example of an abort is shown in Figure 2 (a) when the HER beam is manually aborted. The beam current is measured by a direct-current current transformer (DCCT) [2]. The DCCT signal shows a delay of 40 μs and decay slope of 90 μs in spite of the beam being aborted in 10 μs (1turn). This is a normal behavior of the DCCT signal when the beam is normally aborted in one turn. If the decay time and the slope are different from this example, we consider the abort is abnormal and analyze the data logger information to determine the reason of the beam abort.

Beam Loss Abort: The major reason of the abort is the beam loss, which is identified when the loss of the beam current was recorded and no aberration of the RF signal was observed. In most cases the signal of the PD which is attached to a movable mask was also detected.

The PD signal recorded by the data logger is useful to identify the location of the beam loss when the beam loss happens at the movable mask. We analyzed the PD information together with the data from the beam

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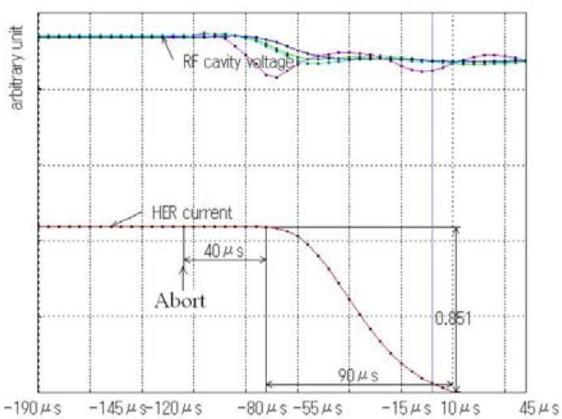
oscillation recorder (BOR) to identify the reason of the beam loss. The BOR records the bunch-by-bunch beam position over 4000 turns just before the beam abort so as to detect vertical and horizontal beam oscillations and this frequencies. From this information, we can figure out the reason of the beam loss. It is used to improve the operation parameters of the KEKB accelerator.

We analyzed the reason for each beam loss abort. Most of the beam loss aborts were caused by the beam oscillation. For example because of a beam abort of the LER, an instability of the HER beam is generated and the horizontal oscillation is observed. Finally the HER beam is also aborted. It depends on beam condition and feedback parameters at that moment.

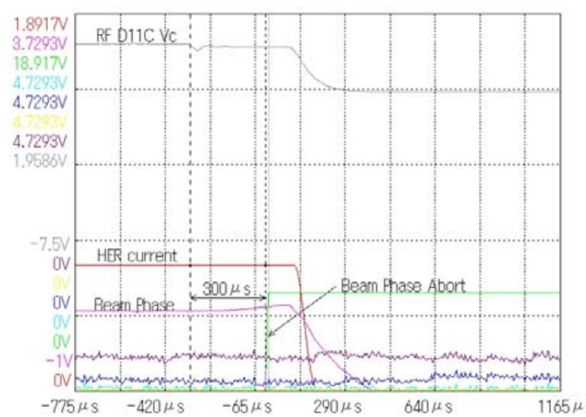
When we find no oscillation despite of a large beam loss, we often find the tune is shifted.

Figure 2 (c) shows an example of beam loss abort. In this case, there is no beam oscillation and the tunes are stable. We found the beam phase (BP) started a swing before the beam is lost and the loss monitor PD signals and the Belle PD signal are generated. This type of abort was found in Feb. 2005. As a result of first investigation on the reason of the beam loss, the vacuum group found some bellows with problems. The pressure and temperature near the bellows were higher than usual. By fixing the vacuum problem, this abort went away. This type of abort happened again, as shown in Figure 3 and the vacuum problems were found each time.

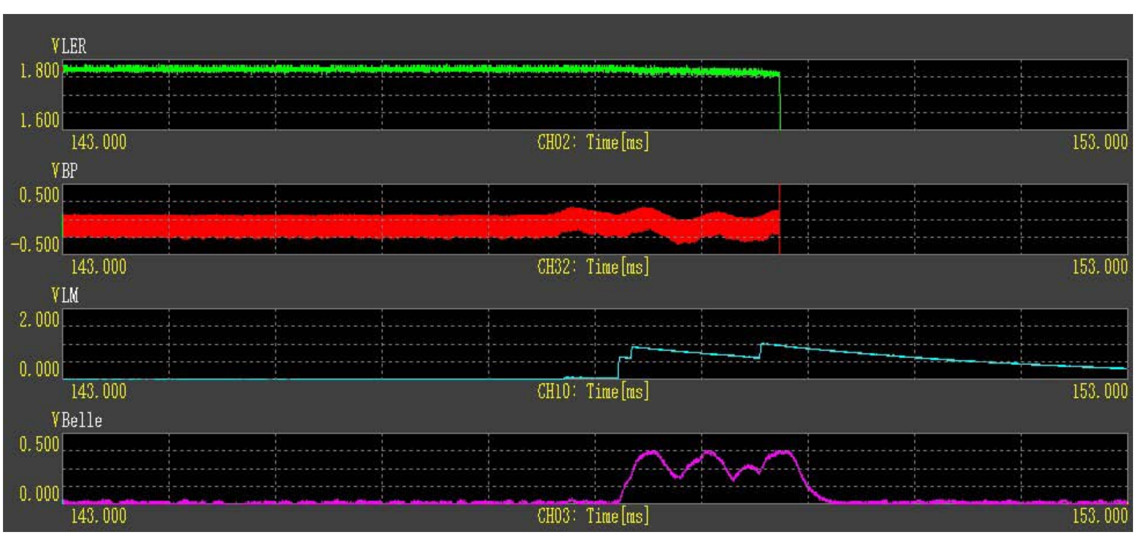
RF Abort: Figure 2 (b) shows an example of logged signals at a moment of beam phase abort caused by a RF trip. The BP signal starts to rise in response to the RF trip. On the other hand, when the beam loss is earlier than the RF trip, the BP starts to swing downward because the RF can not compensate the loss of the beam induced field. In both cases, the synchrotron oscillation causes a large beam loss and damages the hardware components. In order to avoid this, we use the BP as an important abort trigger [3]. We also installed the RF cavity voltage monitor in each RF station as a backup trigger of the BP abort.



(a)



(b)



(c)

Figure 2: Examples of logged signals at a moment of (a) manual beam abort, (b) beam phase abort caused by RF voltage down and (c) beam loss abort caused by vacuum problem. Signals in (c) are LER beam current, beam phase, loss monitor PD and Belle PD in turn from top to bottom.

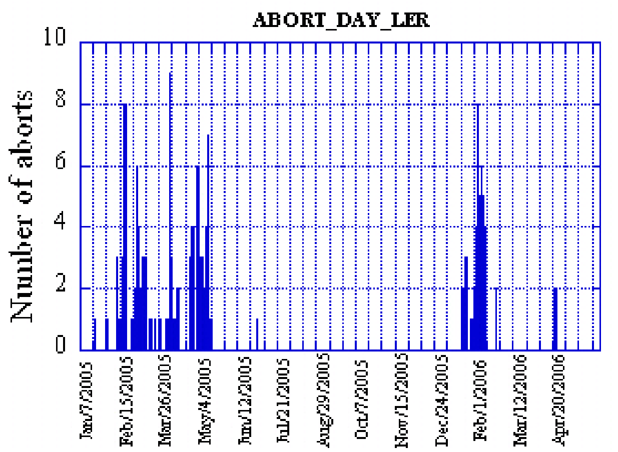


Figure 3: Number of beam loss abort caused by vacuum problems.

STATISTICS

The statistics of the KEKB abort, which are categorized by analyzing the data logger information and other monitors, is shown in Figure 4. It shows the number of aborts per day averaged over one month for the recent five years. The manual aborts issued by the operation shift crew are not included.

From the figure, we see that there are two major reasons for the beam abort; RF trouble and beam loss. Their fraction in all number of aborts is 30% and 60%, respectively. Even though the fraction is not so high, there are many other abort triggers such as earth quake, vacuum pressure, magnet power supply and so on. The number of aborts does not strongly depend on the beam current as shown in Figure 5 and is reduced by optimization of the abort condition. The number of HER aborts is 3/day and that of LER aborts is 2/day these days.

CONCLUSION

A controlled beam abort system was installed at the KEKB accelerator to protect the hardware component from the loss of high current beams. The signals of the PIN photo-diode beam loss monitor and the status signal of the RF are supplied to a data logger system to make a diagnosis of the beam abort.

By analyzing the data, the reason of beam loss and the beam abort have been identified and the best condition of the beam abort has been determined. As a result of the optimized beam abort, we succeeded in eliminating catastrophic beam losses, which had caused serious damage to the hardware. We think the abort causes are identified almost perfectly.

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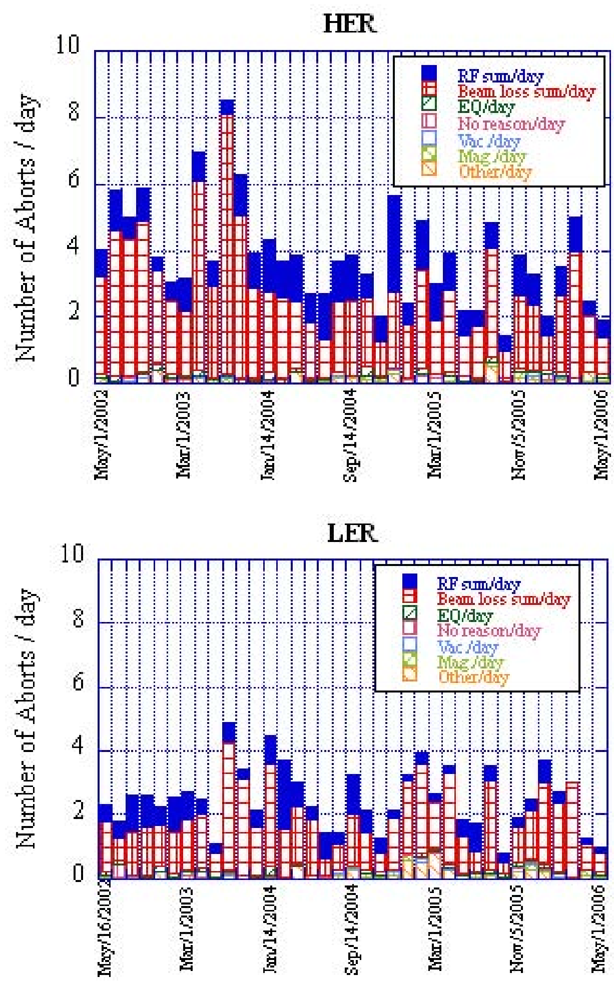

Figure 4: Statistics of beam abort for the last 5 years.

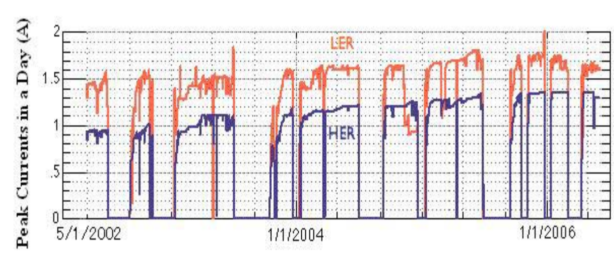

Figure 5: Beam current growth of KEKB for the last 5 years.