PERFORMANCE OF SuperKEKB HIGH ENERGY RING BEAM ABORT SYSTEM

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Abstract
The new beam abort system is installed in the SuperKEKB High Energy Ring (HER) for Phase I operation. [1] The new abort system enlarges the extracted beam horizontal size to protect the extraction Ti window and the beam abort gap is shortened from 500 nsec to 200 nsec for the stable operation of cavities.

INTRODUCTION

The SuperKEKB accelerator is an asymmetric electron-positron collider. The accelerator complex is composed of 7 GeV electron ring (HER) and 4 GeV positron ring (LER). The new abort system was installed in HER and operated under Phase I operation. It leads the stored beam into the beam dump. The HER design beam current is 2.6A and the design horizontal emittance is 4.6 nm. As shown in Table 1.

Table 1: Emittance, beam current and the beam size at the extraction window in the SuperKEKB complex.

	HER
Beam Energy	7 GeV
Beam Current	2.6 A
Horizontal. Emittance	4.6nm
σ x@window	1.1mm

SUPERKEKB BEAM ABORT SYSTEM

Requirements to The Beam Abort System

Compared with KEKB, the design beam current is increased and its emittance is expected to be much smaller. The horizontal spot size at the extraction window must be enlarged to protect the Ti extraction window. The other requirement comes from the luminosity degradation due to beam-loading effects as well as the requirement for the stable operation of RF cavities. The beam abort gap is required to be less than 200nsec.

Abort System Overview

The beam abort system consists of the abort kicker magnets, the sextupole magnet, the Lambertson septum magnet, the Ti extraction window and the beam dump. [2] Water-cooled ceramic chambers are used for the kicker magnets. [3] The sextupole magnets is installed to enlarge the horizontal beam size. [4] Fig.1 shows HER beam abort system configuration. There are four horizontal and a vertical kicker magnets. The horizontal kicker magnets extract the circulating beam and the vertical kicker tapered the beam trajectory at the extraction window eventually to across the window during one revolution time, i.e. 10 µsec.(Fig. 2) It makes the beam cross-section effectively enlarged at the extraction window. Table 2 shows the parameters of kicker magnets. After being extracted from the window, the Lambertoson DC septum magnet leads the beam to the beam dump. In addition to the vertical sweep, horizontal beam spot size is also enlarged with the sextupole magnet. Horizontal abort kicker deflects the beam to pass the off axis of the sextupole magnet. And it enlarges the horizontal beam size at the window. Another sextupole magnet is installed outside of abort system with a phase advance of 180 degree apart to cancel the nonlinearity of the sextupole magnet of abort system. The beam abort system is designed so that the current density should be same as that of KEKB at the extraction window.

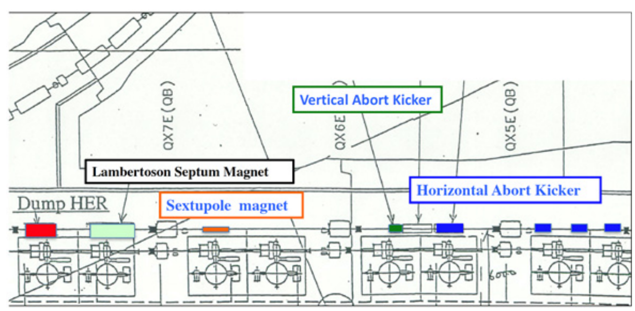

Figure 1: HER beam abort system configuration.

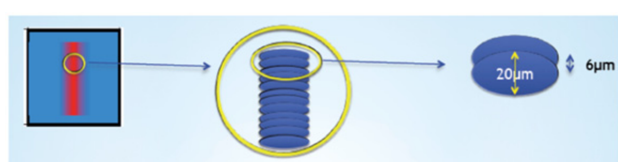

Figure 2: Vertical sweep of the beam spot at the extraction window.

HARDWARE

Kicker Magnets and Power Supply

The kicker magnets are conventional window frame magnets made by ferrite core. A coil of the horizontal kicker magnet delivers the magnetic field to two 385mm long ferrite cores. (Fig. 3) Table 2 shows the parameters of abort kicker system. All kicker magnets are operated by a common switching thyratron to prevent either kicker

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from improper firing. The power supply is composed of two parts. The charger and thyratron housing are implemented at the klystron gallery. The main capacitor, saturable inductance and power crowbar diodes are placed just below the magnet. Figure 4 shows supplied current of horizontal kicker magnet. The saturable inductance switch is used to get fast rise time (less than 200 nsec), and the power crowbar circuit keeps large current longer than 10 µsec. (Fig. 4A)

As shown in Fig. 4B, current is constant during one revolution time i.e. 10 µsec. Rise time of horizontal kicker magnetic field is around 160nsec (Fig. 4C).

Table 2: Kicker magnet parameters

	Horizontal Kicker	Vertical Kicker
θ (mrad)	2.72	1.38
B (T)	0.02	0.092
I (kA)	1.12 (4 kickers)	2.1 (3 Turn)
Length of Ferrite (mm)	385 x 8	350 x 1
# of coils	4	1
Length of ceramic (mm)	500 x 8	500 x 1

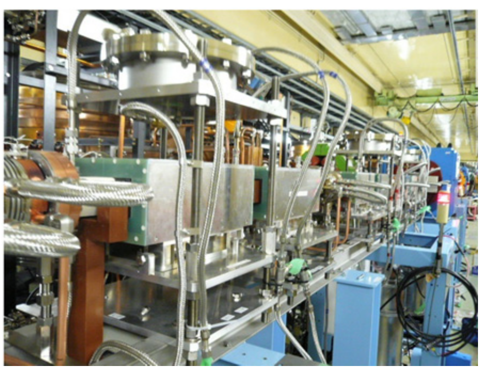


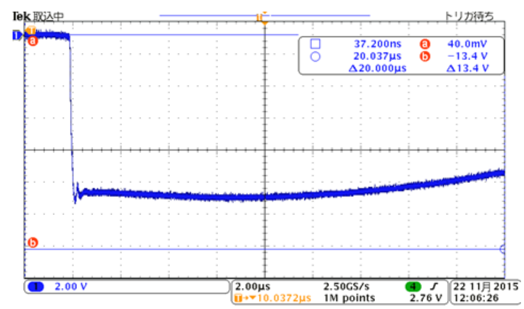
Figure 3: Horizontal abort kickers.

Ceramic Chamber

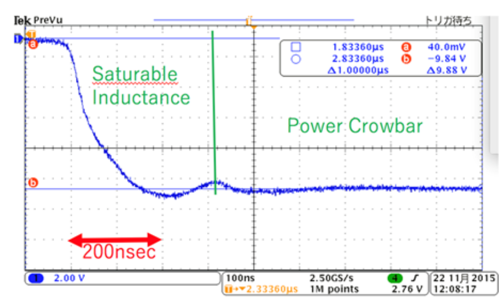
The water-cooled ceramic chambers are inserted into the kicker magnets. A thin Ti conducting layer is deposited on the inner wall of the ceramic. Instead of Mo-Mn braze metallization, Ti with activated metalize method has been chosen which can be used with cooling water. Alumina ceramic was chosen as vacuum chamber because of its greater mechanical strength and best braze metallization.

The chamber has racetrack type chamber. The inner diameter of the chamber is 60mm in horizontal and 40 mm in vertical. The 500mm long hollow type ceramic, which includes cooling water path inside, is fabricated. It makes the structure of ceramic chamber simple and compact. As the result, the gap of horizontal kicker magnet is reduced from 90mm(KEKB) to 70mm(SuperKEKB). The new copper electroforming is applied to deposit the 100 µm thickness Cu conducting layer on the inner wall of Kovar. The Cu conducting layer reduce the heat generated by beam image current on the Kovar braze ring. From the phase I operation, ohmic loss of the beam image current at the 500mm ceramic is measured. It is extrapolated to total beam current 2.6 A on 2500bunches operation. The Cooling water temperature rise will be almost 9 degree for 3 L/minutes water flow. The temperature of Kovar sleeve also measured, and extrapolated to design current operation. The temperature rise of Kovar surface will be 20 degree which is acceptable.

(A) Two components of the coil current



(B) During One revolution time kicker current is almost constant.



(C) Rise Time is 150nsec

Figure 4: Aspects of the output current of horizontal kicker power supply.

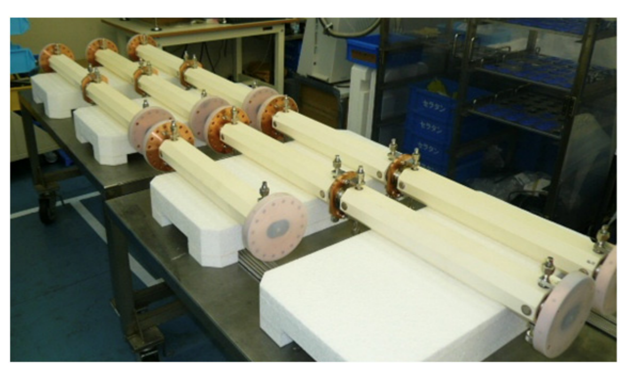


Figure 5: The water-cooled ceramic chambers.

OPERATION

At the phase I operation, two important requirements to the abort system was examined. One is if the horizontal beam spot size at the extraction window is enlarged as the design value. And vertical sweep of beam spot at extraction window works or not. Horizontal beam size of single bunch is measured with a screen monitor located behind the extraction window. An alumina fluorescent screen whose thickness is 0.2 mm is used. Fig. 6 shows the result of horizontal beam size measurement. The horizontal beam size is 1.18 +- 0.16 (mm) which is consistent with the design value of 1.1 mm. Without the sextupole magnet, horizontal beam size of the extracted beam at the window becomes 0.104mm.

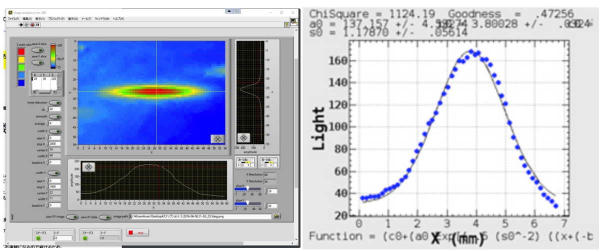


Figure 6: A beam profile behind the extract window.

From the Ti window hardness beam test using KEKB abort beam, the Ti window had a damage between 260mA/mm2 and 400mA/mm2. [5] The maximum Current density at the extraction window will be 80mA/mm^2 at the design current. If the abort system does not enlarge the horizontal beam size, the current density would be 830mA/mm^2. It would give some damage to the Ti window.

Figure 7: Abort beam position monitor in front of the beam dump.

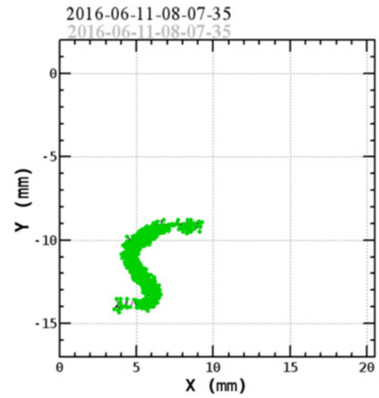


Figure 8: Beam position in front of the beam dump.

Beam position at the extraction window is measured through the beam position monitor which is equipped in front of beam dump. (Fig. 7) [6] Fig 8 shows the beam trajectory in front of the beam dump. The 6.5 mm vertical sweep at the beam position monitor corresponds to 15mm vertical sweep at the extraction window. It is consistent with design value. Since magnetic field strength of the horizontal kickers and the vertical kicker is controlled by single power supply, the current ratio between horizontal and vertical kickers are adjusted by adding inductance to the 4 horizontal kickers and resisters to vertical kicker magnet.

Figure 9: Bunch current monitors.

The other requirement is if the abort gap can be shortened less than 200nsec. The abort gap length is measured. The single backet is filled then abort the beam. Using the alumina fluorescent screen behind the extraction window, it is checked if the aborted beam pass the window. Trigger timing is changed each time. It corresponds the backet position movement. From this measurement, the abort gap can be reduced down to 160 nsec which satisfy the requirement.

SUMMARY

HER abort system went well as planned. Abort gap becomes from 500nsec to 200nsec, horizontal beam size at the extraction window is 1.18mm. The vertical beam sweep at the window is measured to be 15mm. Temperature rise of the water cooled ceramic chamber is acceptable at the design beam current. All of them are close to design value.

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