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SUPERKEKB BEAM ABORT SYSTEM

T.Mimashi, N.Iida, M.Kikuchi, T.Mori KEK, Tsukuba, Ibaraki Japan
K.Abe, Hitachi Power Semiconductor Device, Ltd., Hitachi, Ibaraki Japan
A.Sasagawa, Kyocera Co. Ltd., Higashiomi, Shiga Japan
A. Tokuchi, Pulsed Power Japan Laboratory Ltd., Kusatsu, Shiga Japan

Abstract

The beam abort system of the SuperKEKB is described. The beam abort system consists of the abort kicker magnets, a Lambertson septum magnet, the Ti extracted window and the beam damp. Compared with KEKB, the beam currents will be increased and their emittance is expected to be much smaller. The horizontal spot size at the extraction window will be enlarged with pulsed quadrupole magnet in LER and the sextupole magnet in HER to protect the Ti extraction window. Water-cooled ceramic chambers are used for the kicker and pulsed quadrupole magnets. The beam abort gap is required to be less than 200 nsec. The abort system is designed to fit the betatron injection optics in LER and both betatron/synchrotron injection optics in HER.

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 design beam currents are 2.6A in HER and 3.6A in LER. The design horizontal emittance is 4.6 nm in HER and 3.2 nm in LER. To protect the accelerator components, Belle II detector, as well as the radiation safety reasons, each ring has a beam abort system. They deliver the stored beam into a beam dump and prevent spewing beam everywhere in the ring.

Table 1: Emittance, Beam Current and the Beam Size at the Extraction Window in the SuperKEKB Accelerator Complex

	HER	LER
Beam Energy	7 GeV	4 GeV
Beam Current	2.6 A	3.6 A
Horizontal. Emittance	4.6nm	3.2 nm
σ x@window	1.1mm	1.22 mm

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Abort System Overview

The kicker magnets are installed in the both ring. The abort kicker magnets are composed of horizontal and vertical kicker magnets. The horizontal kicker magnet is used to extract the circulating beam. After extracted from the window, the beam enters the magnetic field region of the Lambertoson DC septum magnet and is deflected about 100mrad and lead to the beam dump.

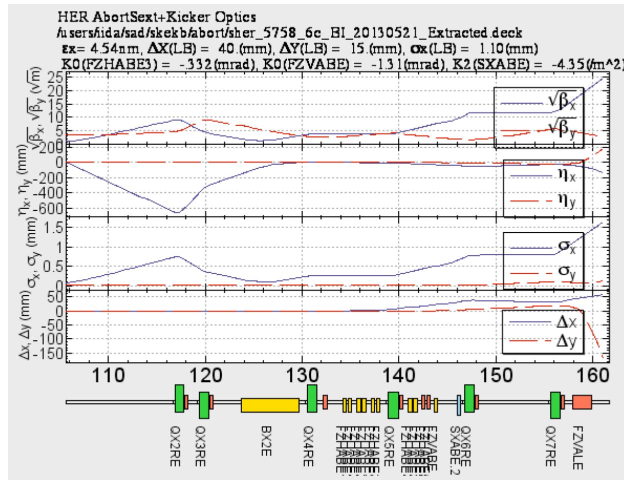

Figure 1: Betatron function, dispersion; beam size and transverse beam position at the HER abort system.

The beam abort gap is designed to be less than 200 nsec. The requirement comes from the luminosity degradation due to beam-loading effects as well as the requirement for the stable operation of RF cavities. The vertical kicker magnet is used to protect the extraction window. The dumped beam has a length of one revolution time, i.e. 10 μsec. The vertical beam kicker is tapered so that the beam trajectory at the extraction window is eventually across the window during 10 μsec making the beam cross-section effectively enlarged at the extraction window. Since the SuperKEKB beam emittance is much smaller than that of KEKB, in addition to the vertical sweep, horizontal beam spot size have to be enlarged. The pulsed quadrupole magnets will be used for this purpose in LER. They horizontally defocus the beam directory at the extraction window. In HER abort system a sextupole magnet is used as the same purpose. 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 out side 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. To protect the semiconductor components for the abort kicker modulators, the lead and Polyethylene shield will be placed around saturable inductance circuit.

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Table 2: Parameters of Kicker Magnets and Quadrupole Magnets

	HER (@7Gev Operation)			LER (@ 4GeV Operation)		
	H Kicker	V Kicker	Pulsed Quad	H Kicker	V Kicker	Pulsed Quad
θ (mrad)	2.66	1.31	-	1.32	1.99	-
B (T) or B'(T/m)	0.02	0.087	-	0.023	0.076	1.33 (T/m)
I (kA) of each magnet	1.12kA	2kA(3Turn)	-	1.27kA	1.8kA(3Turn)	0.93kA
Length of Ferrite (mm)	385 x 8	350 x 1	-	385 x 2	350 x 1	350 x 2
# of coils	4	1	-	1	1	2
Length of ceramic (m)	500 x 8	500 x 1	-	500 x 2	500 x 1	500 x 2

HARDWARE

Kicker Magnets

The kicker magnets are conventional window frame type magnets made from ferrite core. They are purely inductive. For horizontal kicker magnets, one magnet coil has two ferrite cores. This is because a water-cooled ceramic chamber limits the core length. Both the horizontal and vertical kicker magnets are operated by a single switching thyratoron to prevent either kicker from improper firing [1]. In addition to the kicker magnets, two pulsed quadrupole magnets are also operated with the same thyratron switch in LER. There will be 4 horizontal kicker magnets in HER and one horizontal magnet in LER. Each magnet has two sets of 385mm long ferrite core. The water-cooled ceramic chambers [2] are inserted into the magnet. A thin Ti conducting layer is deposited on the inner wall of the chamber.

Pulsed Quadrupole Magnet and Sextupole Magnet

The 2 pulsed quadrupole magnets made of the ferrite core are installed in LER, and a DC sextupole magnet will be installed in HER. They enlarge the horizontal beam size at the extraction window to prevent the heating damage of the window.

Power Supply

A single power supply delivers the current to both horizontal and vertical kicker and pulsed quadrupole magnets. The power supply is composed of two parts. The charger and thyratron housing are implemented at the klystron gallery, which is accessible during the accelerator operation. Since the magnet is located approximately 40 m from the charger, the capacitor, saturable inductance and power crowbar diodes are placed just below the magnet. To satisfy fast raise time requirement, the saturable inductance switch is used, and the power crowbar circuit keeps large current longer than 10 μsec. This system makes it possible to satisfy three requirements, 1: Fast rise time (Less than 200nsec), 2:Keep large current constantly during one revolution time (10μsec), 3:Operate horizontal, vertical kicker magnets and pulsed quadrupole magnets by a single switching thyratron. Figure 2 shows current of horizontal kicker magnet. The rise time (2%-90%) is 150nsec, Flattop current is 1.7kA at 39.3kV charging voltage. The current drops 8.8% during 10μsec.

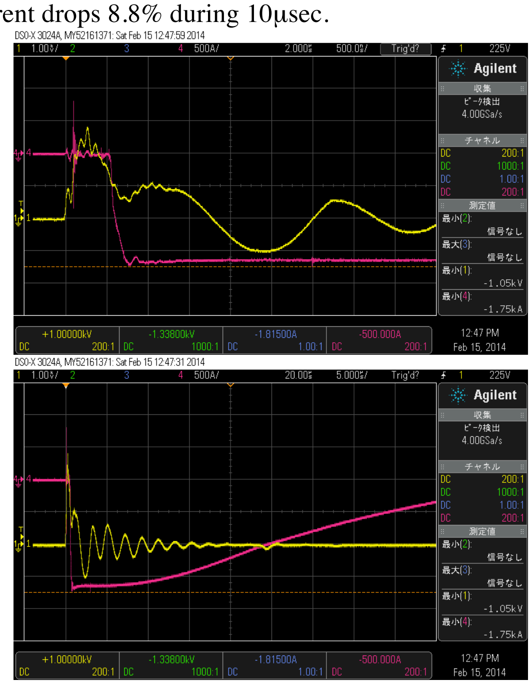

Figure 2: The output current of the power supply. X-axis is 500nsec/division (upper) and 5μsec/division (lower). Pink line shows the horizontal kicker current.

Figure 3: Picture of the storable inductance, which is installed bellow the kicker magnet.

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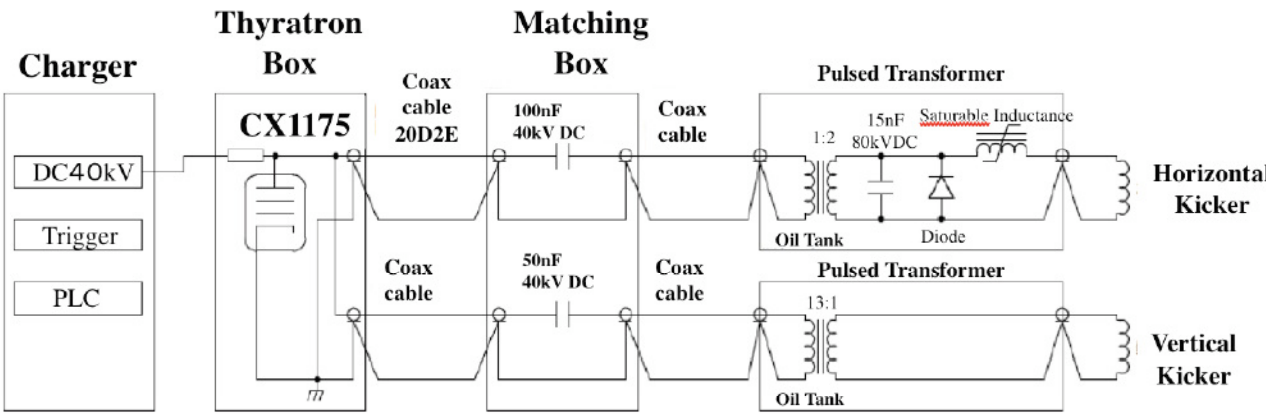

Figure 4: The circuit diagram of the test power supply of abort kicker magnet.

Ceramic Chamber

As same as KEKB, the water-cooled ceramic chambers are chosen. 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.

Since the kicker magnets and pulsed quadrupole magnets are required to have very fast rise time and large current, the gap of kicker magnet and bore radius of pulsed quadrupole magnet must be as small as possible. The development of very thin and compact ceramic chamber plays a very important role in this system. The chamber has racetrack type chamber. The inner diameter of the chamber is 60mm in horizontal and 40 mm in vertical. And the gap of horizontal kicker magnet is 70mm. The thickness of the ceramic chamber is 30 % reduced from that of KEKB. Figure 5 shows structure of two types of ceramic chambers. In order to reduce the thickness of ceramic, two kinds of approach have been chosen. The A type chamber * has been produced with amazing technology. The 500mm long hollow type ceramic, which includes cooling water path inside, is fabricated. It makes the structure of ceramic chamber simple and compact. 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. The B type chamber† has a double tube structure, and cooling water flows between inner and outer ceramic pipes. Cupper was chosen as metal brazes ring. It provides low stress hermetic seal to ceramic and flexible transition between ceramic and massive flange. And it also reduces the heat from beam image current.

* This ceramic chamber was made by Hitachi Power Semiconductor Device, Ltd. and Kikusui Chemical Industries Co.Ltd.

† This ceramic chamber was made by Kyocera Co. Ltd.

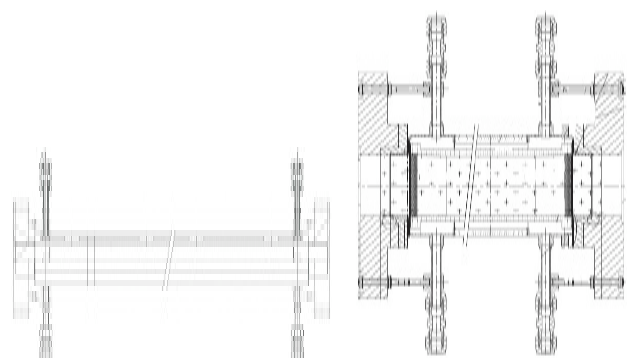

Figure 5: The structure of the ceramic chambers.

CONCLUSION

The new beam abort system for the SuperKEKB is under construction. The key components of the system such as water-cooled ceramic chambers, power supply and pulsed magnets, are developed [3] and fabricated. New abort system in HER will be ready by the phase I commissioning. LER abort system will be constructed in concordance with the beam commissioning of the damping ring.

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