THE DESIGN OF BEAM ABORT SYSTEM FOR THE SUPERKEKB

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Abstract

The beam abort system designed for SuperKEKB consists of kicker magnets, pulsed quadrupole magnets, a Lambertoson septum magnet and a beam dump. Water-cooling ceramic chambers are used for the kicker and pulsed quadrupole magnets. At the KEKB upgrade project, the beam abort gap is required to be less than 200 nsec. Compared with KEKB, the beam currents will be increased and their emittance is supposed to be much smaller. In order to protect the extraction window from heating damage, the pulsed quadrupole magnets will be installed. They enlarge the beam cross section at the extract window. The key components for the SuperKEKB abort system are under development. The compact water-cooling ceramic chambers are developed to reduce the gap of kicker magnets and bore radius of the pulsed quadrupole magnets. The common power supply for the kicker magnet and pulsed quadrupole magnet is also developed to satisfy the 200 nsec rise time requirement and to keep the large current constantly during one revolution time.

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 2.62A in HER and 3.6A in LER. And the design horizontal emittance is 2.4 nm in HER and 3.2 nm in LER. To protect the accelerator components and Belle II detector, and for radiation safety, each ring has a beam abort system. They divert the stored beam into a beam dump and prevent spewing beam everywhere in the ring.

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

	HER	LER
Beam Energy	7 GeV	4 GeV
Beam Current	2.62 A	3.6 A
Horizontal. Emittance	2.4 nm	3.2 mm
σ x@window	0.36 mm	0.74 mm

SUPERKEKB BEAM ABORT SYSTEM

Abort System Overview

The kicker magnets and pulsed quadrupole magnets are installed at the LER and HER ring. The beam is extracted through the extraction window from the vacuum chamber to the air and lead to the beam dump. The abort kicker is composed of horizontal and vertical kickers. The horizontal kicker 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.

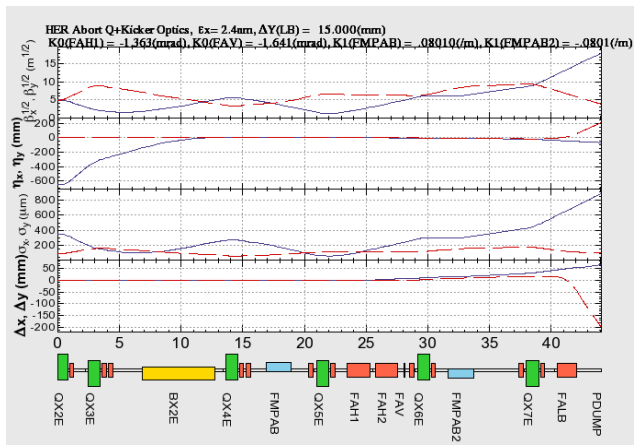


Figure 1: Betatron function, dispersion; beam size and transverse beam position at the HER abort system

The vertical kicker magnet is used to protect the extraction window. The dumped beam continues one revolution time, i.e. 10 μsec. The vertical beam kick is tapered so that the beam cross-section at the extraction window is eventually across the window over the 10 μsec and it makes the beam cross section of the extraction window effectively enlarge. The beam abort gap is designed to be less than 200 nsec. The requirement of abort gap length comes from the requirement of the stable operation of RF cavities. Since the SuperKEKB beam emittance is much smaller than that of KEKB, in addition to the vertical kicker, the pulsed quadrupole magnets will be installed to make the cross-section large at the extraction window. The field strength is determined so that the current density should be same as KEKB at the extraction window. The HER and LER beam abort system will be constructed in the Fuji straight section.

Table 2: Parameters of kicker magnets and quadrupole magnets.

	HER			LER		
	H Kicker	V Kicker	Pulsed Quad	H Kicker	V Kicker	Pulsed Quad
θ (mrad)	2.73	1.61	-	1.98	1.4	-
B (T) or B'(T/m)	0.036	0.11	2.8 (T/m)	0.037	0.056	1.5 (T/m)
I (kA)	10 (2 /coil)	3	12 (1 /coil)	4 .2 (2.1/coil)	1.6	4.4 (0.7/coil)
Length of Ferrite (mm)	350 x 5	350 x 1	150 x 12	350 x 2	350 x 1	150 x 6
# of coils	5	1	12	2	1	6
Length of ceramic (m)	500 x 5	500 x 1	500 x 6	500 x 2	500 x 1	500 x 3

Kicker Magnet

The kicker magnets are conventional window frame type magnets made from ferrite core and they are purely inductive. Both the horizontal and vertical kicker magnets are operated by a single power supply with a single switching thyratoron so that we can prevent either kicker from miss firing.[1] The water-cooling ceramic chambers [2] are inserted in to the magnet. A thin Ti conducting layer is deposited on the inner wall of the chamber. To get the fast rise time in horizontal kicker magnet, the inductance of the magnet must be small. The number of magnets is increased and connected in parallel to lower the magnet inductance. There will be 5 horizontal kicker magnets in HER and 2 magnets in LER. The core length of each magnet is 350mm.

Pulsed Quadrupole Magnet

The pulsed quadrupole magnet made by the ferrite core, enlarge the beam size at the extraction window to prevent the heating damage of the window. These magnets are also operated with a common power supply of beam abort kickers. The 12 pulsed quadrupole magnets will be installed in HER and 6 of them will be in LER. The core length of each magnet is 150mm. Two magnets are set in 500mm ceramic chamber. The rise time of pulsed must be as short as that of horizontal kicker magnets.

Ceramic Chamber

As same as KEKB, the water-cooling ceramic chambers are chosen. Instead of Mo-Mn braze metallization of the ceramic chamber, 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. Kovar was chosen as metal brazes ring. It provides low stress hermetic seal to ceramic and flexible transition between ceramic and massive flange.

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 control system and thyratron housing are implemented at the klystron gallery where is accessible during the accelerator operation. Since the magnet located approximately 40 m from the charger, the capacitor, saturable inductance and power crowbar diodes are equipped just below the magnet. The saturable inductance switch compresses the pulse and gives the fast rise current to the load. Then the power crowbar circuit succeed to the main circuit, supplying the current to the coil for more than 10μsec. This system makes it possible to satisfy three difficult requirements, 1: Fast rise time, 2:Keep large current constantly during one revolution time, 3:Operate horizontal and vertical kicker magnets and pulsed quadrupole magnets by a single power supply with single switching thyratron.

COMPONENT DEVELOPMENTS

Abort Kicker Modulator development

The power supply* having very fast rise time and keeping stable large current more than 10 μsec with single thyratron is developed and tested. To satisfy fast raise time requirement, the saturable inductance switch is used, and to keep large current longer than 10 μsec, the power crowbar circuit is chosen.

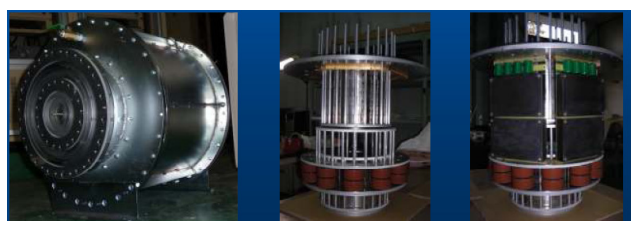


Figure 2: The picture of the saturable inductance and power crowbar circuit.

Figure 3 shows the simple circuit diagram of abort kicker power supply test circuit. Figure 4 shows test results. Assuming the 6 horizontal kickers, the test circuit could get 200nsec rise time (2% to 90%), and keep 0.92 kA current at the each dummy load coil more than 10μsec. The dummy load is connected 2 series and 3 parallels.

* The power supply is developed by Pulsed Power Japan Lab. Ltd.

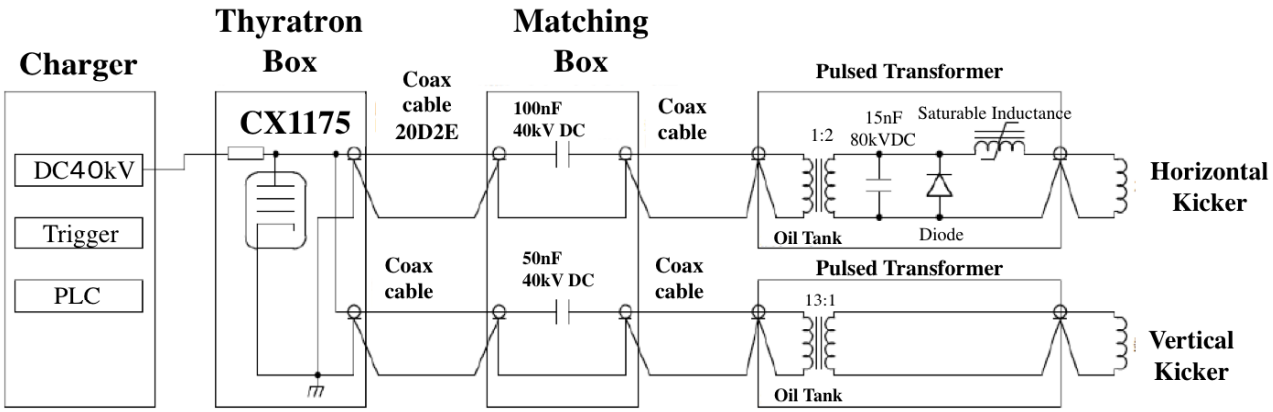


Figure 3: The circuit diagram of the test power supply of abort kicker magnet

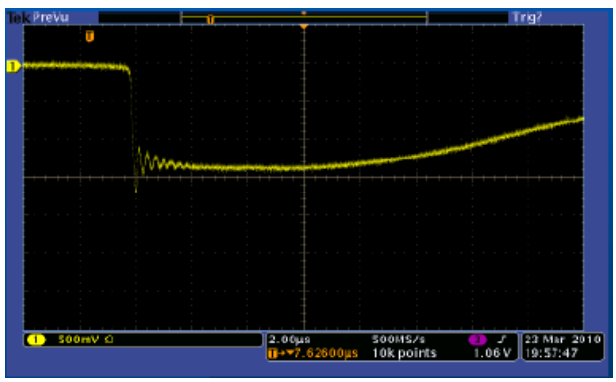
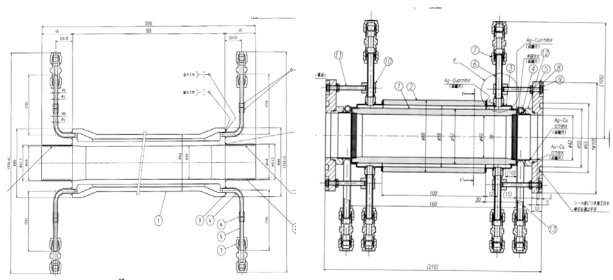


Figure 4: The output current of the power supply. X-axis is 2μsec/division. Yellow line is the horizontal kicker current.

Water Cooling Ceramic Chamber

Since the kicker magnets and pulsed quadrupole magnets are required to have very fast rise time and large current, the magnet gap of kicker 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 test chamber is developed with cylindrical ceramic. The inner diameter of the chamber is 40mm and outer diameter is less than 68mm. The thickness of the ceramic chamber is 30 % reduced from that of KEKB. Figure 5 shows structure of two types of ceramic test 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. In order to make the outer diameter small, cooling water seal were brazed outer wall of inner tube. Kovar for vacuum seal is shorten as possible and switched to cupper pipe. The cooling water pile is soldered directly to the Kovar braze ring.



(A) (B)

Figure 5: The structure of the ceramic chambers

CONCLUSION

The new beam abort system for the SuperKEKB is designed. The key components of the system are under development. The compact water-cooling ceramic chambers are fabricated. The power supply of kicker and pulsed quadrupole magnets is developed.

REFERENCES

[1] N.iida et al, "Abort System for the KEKB", EPAC' 2000, Vienna, June 2000, THP1A09, p.2423 (2000); http://www.JACoW.org.

[2] T.Mimashi et al, "Water Cooling Ceramic Chamber for KEKB Kicker Magnet", EPAC'2000, Vienna, June 2000, THP1A09, p.2444 (2000); http://www.JACoW.org.

[†] This ceramic chamber was made by Hitachi Haramachi Electronics Co. Ltd. and Kikusui Chemical Industries Co.Ltd.

[‡] This ceramic chamber was made by Kyocera Co. Ltd.