KEKB INJECTION KICKER MAGNET SYSTEM

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Abstract

The design, construction and operation of the KEKB injection kicker magnets are described. The magnet operates up to 35kV and 2kA with magnetic field rise and fall time of around 1μsec each. The pulsers operate at repetition rate of between 1 and 50 Hz as dictated by the operational mode of KEKB.

The orbit of kicked bunches are observed with the single pass beam position monitor and checked if the kicked bunches orbits are closed and if the model optics between two groups of kickers is set correctly.

1 INTRODUCTION

The KEKB, an asymmetric electron-positron collider is now under operation. This collider consists of a 3.5 GeV positron storage ring (LER) and an 8.0 GeV electron storage ring (HER). An injector linac complex provides the electron and positron beams. Two and four septum magnets were installed in the positron and electron beam transport line respectively. The septum magnets and the kicker magnet inject the beam into the ring. The KEKB injection kickers have to meet many requirements under KEKB operation. Six kicker magnets are implemented in each ring. Three kicker magnets are incorporated into one group and are equipped at the upper and lower stream of the injection point respectively. The betatron phase advanced between two groups of magnets is designed to be 180 degree. Figure 1 shows the current shape of kicker magnet. The designed pulse width is 2 μsec and it makes possible 50Hz beam injection. The KEKB beam repetition rate varies dynamically to protect Belle detector and certain components from damage by the beam. The main ring revolution time is around 10μsec and the transverse radiation damping time of the ring is around 45 msec.

The beam current is distributed as the following scheme. Once a RF bucket was filled by the beam, no beam will be filled during the next damping time period around the injection-bucket.

2 INJECTION KICKER SYSTEM

2.1 1 Kicker magnet

KEKB injection kicker magnet is the conventional window-frame ferrite core kicker magnet. The ceramic vacuum chambers are inserted between the ferrite and beam, with a thin Ti-Mn conducting layer deposited on the inner wall of ceramic. Dimension of the kicker magnet is written on Table 1.

Table 1: Parameters of the kicker magnet

Number of kicker magnets	6
Ferrite core length (mm)	225
Ferrite core gap (mm)	90
length of ceramic	420
Ti coating thickness (μm)	6
Peak magnetic field (Gauss)	500
Peak current (A)	2000
Peak voltage (kV)	35
Time jitter (nsec)	2-3
Repetition rate (Hz)	50
Rise time (μsec)	1
Fall time (μsec)	1
Current shape	Half sine
Peak current stability (%)	< 0.1
Pulse shape distortion (%) - Kicker dependence	< 1.5
Pulse shape distortion (%) - Pulse height dependence	< 1.5

2.2 Ceramic Chamber

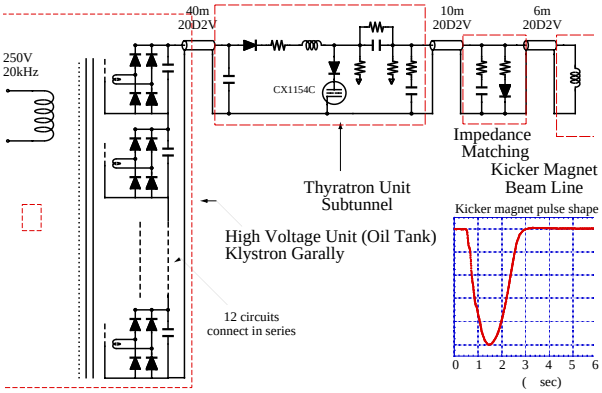
Ceramic chambers are used to allow external time varying field to penetrate the vacuum chamber. A thin metallic coating is required to carry the beam image current and protect external components from the beam field. The design beam current of KEKB is 2.6A in the LER and 1.1A in HER. The power dissipation due to the beam image current was estimated and water-cooling was chosen. Water cooling ceramic chambers are developed and used in the both rings.[1] The length of ceramic is 420 mm and 6 chambers are used for injection kicker in individual ring.

2.3 Power supply

The maximum voltage and current levels are 35kV and 2000A with the magnetic field level 500 gauss. This parameter was chosen for the stable operation of the thyratrons in the air. The number of kicker magnets is determined by this condition. Table 1 shows the parameters of the kicker magnet power supply. The deuterium filled ceramic thyratrons CX1154C (Marconi Applied Technologies) is chosen as the energy discharge switch.

The power supplies are composed of three parts. The main part of the power supply, control part and a dc-charging power supply, is implemented in the klystron

gallery where is accessible during an accelerator operation. The thyratrons housing are placed at the sub-tunnel where is approximately 40 m from the main part of the power supply and 7m from kicker magnet. And matching impedance is placed under the kicker magnets to adjust the output current pulse shape.



KEKB Injection Kicker system power supply

Figure 1:The schematic diagram of the kicker system

Since the bunch spacing is 2 nsec in the design operation, the kicker magnet kicks not only the bunch of the injection bucket, but also kicks bunches adjacent the injection bucket. In order to close all kicked bunches orbit; the output current pulse shape of each power supply should be equal.

The kicker magnet power supplies, which can adjust the output current pulse shape, are developed and fabricated. Fig 1 shows the simple circuit diagram of the kicker magnet. Pulse shape can be controllable by changing the value of matching impedance.

Field measurement had been done with search coil.. Fig2 shows the field distribution along the beam. Effective length of the magnetic field is around 280mm.

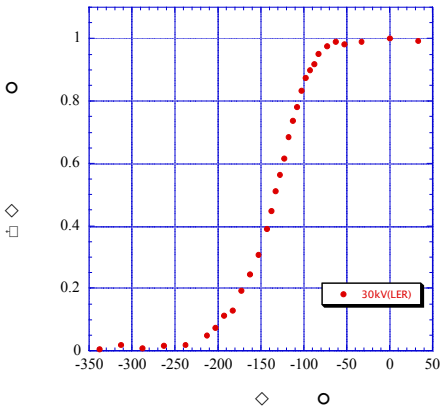


Figure 2 The magnetic field distribution of kicker magnet along the beam. (0 is the center of magnet)

In order to reduce the noise from kicker magnet, several efforts was applied. 1) The communication between the control room and power supply of the kicker magnet has been done through the optical fiber. Trigger signals, output current monitor and control signals are routed via this optical fiber. 2) Thyratrons are located at the sub-tunnel so that 2kA current exist only in the 10m around the kicker magnet. On the 40 m cables between the thyratron units and the main power supply, maximum 200mA current is flowed.

2.4 Radiation tolerance

The radiation at the matching box and the thyratrons unit are measured with an alanine dosimeter. In the high-energy ring injection area, dose rate is between 40 to 220 Gy/hour and around 40 Gy/hour in LER. They are adequate for our operation.[2]

3 KEKB OPERATION

The kicked bunches orbit are observed with the single pass beam position monitor. It was checked if the kicked bunches orbits are closed or if the phase advance between two kicker magnets are correct. And trigger timing between two groups of kicker magnets also has been adjusted using this monitor.

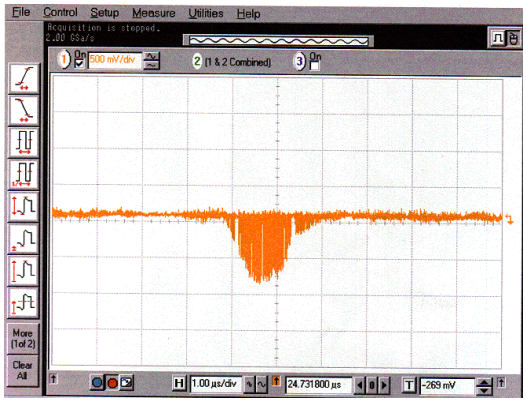


Figure 3 – A

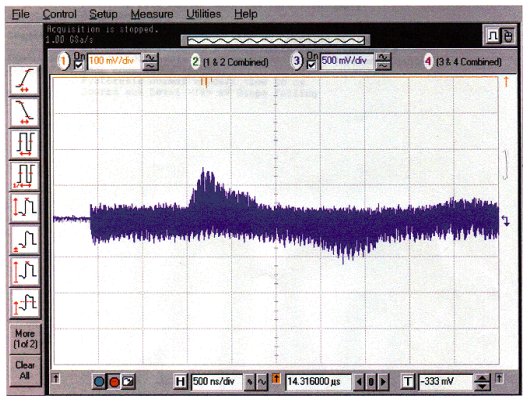


Figure 3 - B

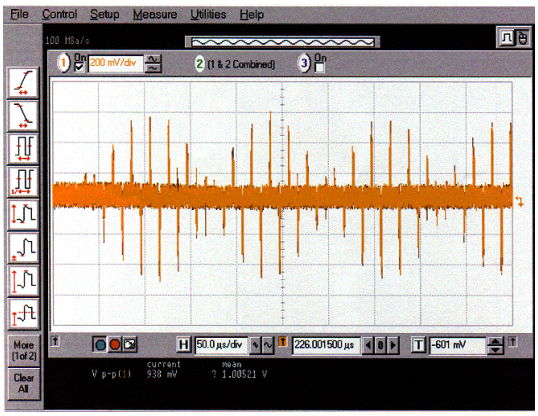


Figure 3 – C

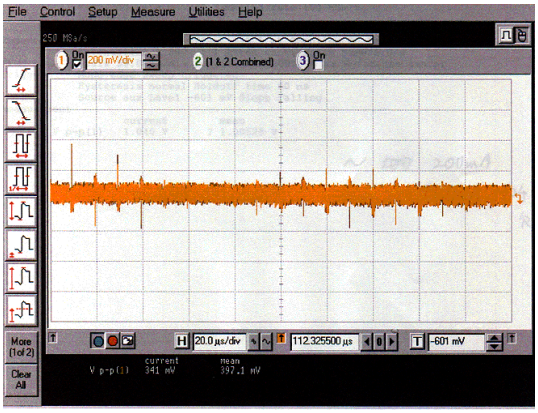


Figure 3 - D

Figure 3: Horizontal beam position of the bunches surrounding the injected-bucket at one pass beam position monitor.

In order to measure the orbit of bunches around the injection bucket, RF buckets are filled by beam uniformly whole the ring except a gap for beam abort. Horizontal beam positions are measured at the outside of two groups of kicker magnet. Fig 3 shows the pictures of an oscilloscope. It shows horizontal beam position of individual bunch at the beam position monitor. The difference of kick angle between upper and lower stream kickers gives sine like distribution. (Figure 3-A) Amplitude of beam position is proportional to the difference of kicker angle. And cosine like distribution is produced by the time lag of bunch kick. The effective kick angle at the time domain changes when the kicked timing are slightly changed, and it gives cosine like distribution that is proportional to the time derivative of the kicker magnetic field distribution. (Figure 3-B) Trigger timing are adjusted to minimize this cosine component in the accuracy of less than 4 nsec which correspond the 1.5 % of the pulse shape distortion. The model optics between two kicker magnets is also checked. Beta function is almost same at two groups of kicker magnet. If the betatron phase advance between two kickers is set to 180 degree correctly, and the kicker angle of two groups of kickers are adjusted to the horizontal beam position of the bunch becomes 0 at the BPM in the first turn of the beam, the horizontal beam position should be always 0 at the following turns. The situation is shown in Fig 3-D. But if the betatron phase advance is not set to 180 degree, the horizontal beam position oscillate. Fig 3-C shows beam position oscillation when the optics was not set correctly. Since the deflection angle at the normal operation is 1-2 mrad, the only 10-30µrad of extra kick is caused by these distortions.

4 CONCLUSION

The injection kicker was successfully installed and operated in the KEKB ring. Trigger timing is adjusted by using the beam in the ring. The diffraction angle at usual operation is 0.7-1.1mrad in HER and 1-1.5mrad in LER respectively. The thyratrons are operated 12-20kV in HER and 10-16kV in LER, which is the half of the maximum allowed voltage. The magnetic field pulse shape of individual magnet is well controlled. The extra deflection angle coming from pulse shape distortion and trigger timing drift is 10-30µrad. In beginning of 2000, the beam are delivered into more than 1000 circulating bunches, 8 nsec apart in time in the 50 Hz repetition rate.

ACKNOWLEDGEMENTS

The authors sincerely appreciate Mr. Odagiri for his development of the control software for kicker magnets base on EPICS system.

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