

# THE PULSED MAGNET SYSTEM FOR THE SIMULTANEOUS INJECTION OF KEK-PF AND KEKB RING

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## Abstract

The KEK Linac delivers the beam to KEK Photon factory storage ring (PF), KEKB ring and the advanced ring for photon factory (PF-AR). In order to deliver the beam to the KEK-photon factory and KEKB ring simultaneously, the pulsed bending magnet was installed at the end of KEKB Linac. The pulsed bending magnet extract 2.5 GeV electron beam to the PF beam transfers line. The deflection angle of the magnet is 0.114 radians and the field strength is about 1.22T. The peak current stability is better than 0.1% at 24kA operation. The maximum repetition rate is 25Hz. The 1.3m long ceramic chamber is inserted into the 1m long magnet. This system makes possible the top up operation of PF ring.

## INTRODUCTION

The KEK Linac provides the four different energy beams to the four storage rings. The 3.5 GeV positron and 8 GeV electron beams are injected into KEKB [1] for the high energy experiment, and the 2.5 GeV and 3 GeV electron beams are delivered to the Photon factory ring (PF) and the Photon factory advanced ring (PF-AR). KEKB has been operated in the continuous injection mode (CIM) since 2004. In the CIM operation, electron and positron beams are injected in KEKB HER and LER sequentially. It takes 30 seconds to switch the beam mode between electron and positron injection, because of magnets standardization and a mechanical movement of a positron target into the beam line. After installing the crab cavities in KEKB, the luminosity tuning has been sensitive to the beam condition of each ring. (HER and LER) Because of this reason, there is an increased demand to ensure the simultaneous injection of beams into KEKB rings. In addition to this demand, the top-up operation of the PF ring also required to obtain high-quality experimental data. In order to satisfy these requirements, the phased upgrade of the injector Linac started in FY2005. [2][3][4][5][6][8][9] The installed pulsed bending magnet is one of the hardware components of this upgrade project.

## PULSED MAGNET SYSTEM

The DC bending magnet was replaced to the pulsed bending magnet for the fast beam mode switch between PF ring and KEKB ring injection. The bunches are selectively extracted to the PF beam transport line.

Table 1 shows the specification of the pulsed bending system. For the PF operation, 2.5 GeV electron beam is injected to the ring. For this mode, the magnetic field strength is about 1.22T and the maximum repetition rate is 25Hz. The diffraction angle of the magnet is 0.114 radians. The magnet system was designed for the beam operation up to 3GeV.

Parameter name	Value
Deflection angle (mrad)	114
Maximum magnetic field (T)	1.36
Gap (W x H) (mm)	157 x 30
Coil (Turn)	1
Core Length (m)	1

Table 1: The specification of the pulsed bending magnet.

## Magnet

The pulsed bending magnet is installed at the end of linac, just before 3<sup>rd</sup> switching yard. [7] The magnet is a wind frame type magnet. Laminated core was used for the magnet. Thickness of the plate is 0.35mm. Figure 1 shows the photograph of the magnet. The core length is 1m, and the gap height is 30mm. The single turn coil is used.



Figure 1: Photograph of the pulsed bending magnet.

### Ceramic chamber

The ceramic chamber was inserted into the magnet. A thin metallic coating is required to carry the beam image current and protect accelerator components from the beam fields. Figure 2 shows the ceramic chamber and Table 2 describes the specification of the chamber. The total length of ceramic chamber is 1316.95mm, which contains 1200mm ceramic tubes with a thin Ti-Mo conducting layer. The ceramic chamber has racetrack type inner wall. An Alumina ceramic was chosen as vacuum chamber because of its greater mechanical strength and best braze metallization. Kovar was chosen as metal braze. It provides low stress hermetic seal to ceramic and flexible transition between ceramic and massive flange. Kovar matches expansion coefficient of ceramics reasonably. Mo-Mn is used for the braze metallization of the ceramic chamber.

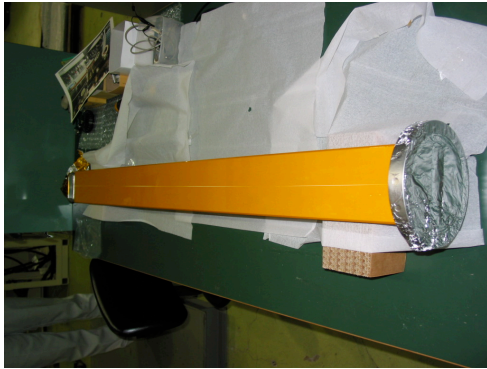


Figure 2: Photograph of ceramic chamber.

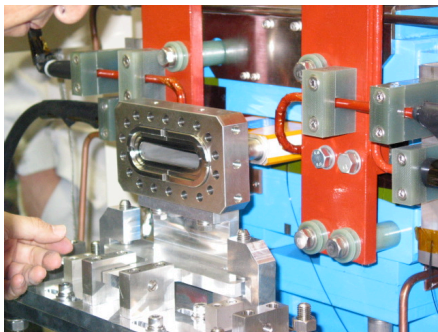


Figure 3: Special removable flange of the ceramic chamber.

Parameter name	Value
Ceramic chamber length With Flange (mm)	1316.95
Ceramic Tube size (inside) (mm)	86x16x120 0
Ceramic Tube size (outside) (mm)	99x27x120 0
Ti coating Surface resistance ( $\Omega/\square$ )	100

Table 2: Ceramic chamber parameters

Ti-Mo coating uniformity has been checked. The test piece plate was mounted on the inner wall of the test chamber. After Ti-Mo coating, the surface resistance was measured. Since the chamber is flat, coating was done 4 times by changing the Ti-Mo wire position. The surface resistance is around  $100\Omega/\square$ . As shown in Figure 3, the special removable flange is used for one side of the chamber so that the chamber can be inserted from one side to the other.

### Power supply system

Table 3 describes the specification of the magnet power supply. Maximum peak current is 27kA at the 25Hz repetition rate and 32kA at the 12.5Hz operation. The output current pulse shape is half-sinusoidal. The pulse width is 200 microseconds. The output current pulse height stability is better than 0.1%. Since the PF injection beam repetition rate may be changed often, the pulse height must be independent of the repetition rate for the fixed charging voltage. To get this order of stability, some circuit boards are stored in the constant temperature reservoir and feedback circuit parameters were well tuned.

Parameter name	Value
Maximum Peak Current (KA)	27 (32)
Output current waveform	Half sinusoid
Pulse width (microsecond)	200
Repetition rate (Hz)	25 (12.5)

Table 3: The specification of the power supply.



Figure 4: Picture of the power supply at the Linac Klystron gallery

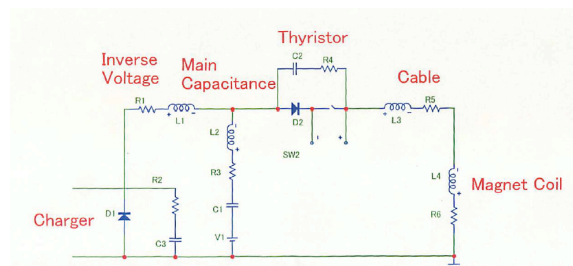


Figure 5: The schematic diagram of the power supply

The power supply is located in the klystron gallery at the end of lineac, where is accessible during an accelerator operation. It is connected with 7m long 40 coaxial cables to the magnet.

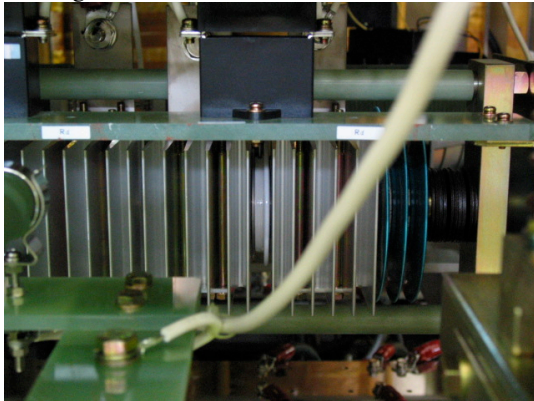


Figure 6: Switching thyristor of the power supply

Figure 4 shows the picture of the power supply. In order to reduce the noise from the pulsed bending magnet system, several efforts were applied. The exclusive earth ground is prepared for the system. The trigger signal is sent through the optical fibre cable.

Figure 5 shows the schematic diagram of the power supply. Mitsubishi FT1000A-50A thyristor was selected for the energy discharge switch. Total 24 thyristors, 6 series and 4 parallels, were used. Figure 6 shows the picture of stacked thyristors.

### *Control system*

The power supply is controlled from the remote sight through the Programmable Logic Controller (PLC) supervised by the EPICS system. The local control of the power supply can be done through the touch panel and PLC. The output current and output voltage monitor signals are prepared in the front panel. Compared with KEKB electron injection beam, PF injecting beam must be much smaller current. To protect the hardware from the big beam current, the beam-charge interlock system was developed. [10] Trigger timing system was upgraded for the simultaneous injection. The event generator and receiver system based on VME system was adopted.[8][9]

## **OPERATION STATUS**

The three ring simultaneous injection has been succeeded since April 2009. The injector Linac derives the maximum 50 Hz beam. The beam is injected into KEKB HER/KEKB LER/PF ring in the 12.5 Hz/12.5Hz/1Hz or 12.5Hz/25Hz/0.5Hz in April 2009. The storage beams in the three rings are kept constant and top-up operations of three rings have been succeeded. [11][12] The pulsed bending magnet extracts the 2.5 GeV electron beam to the PF beam transport line in 1 Hz or 0.5 Hz in the top-

up mode, and extract it 25Hz to storage the beam from 0. The pulsed bending magnet system works without any problems.

## **SUMMARY**

The three rings (KEKB LER, HER and PF rings) pulse-to-pulse simultaneous injection started successfully from April 2009. PF top-up operation improves the data quality. KEKB luminosity tuning has been performed at the constant beam current. The pulsed magnet selectively extracts the beam to the PF beam transport line.

## **REFERENCES**

- [1] S.Kurokawa et al, "KEKB B-Factory Design Report", KEK Report 95-7, August 1995.
- [2] N.Iida et al, "New Beam Transport Line From Linac To Photon Factory in KEK", Proceedings of the EPAC2006, Edinburgh, UK, June 2006, pp1505-1507.
- [3] M.Satoh and IUC, "Present Status of the KEK Injector Upgrade for Fast Beam-Mode Switch", Proceedings of the LINAC2008, Vancouver, Canada, September 2008.
- [4] M.Satoh et al, "The KEK Linac Upgrade for the Fast Beam Mode Switch", P Proceedings of the EPAC2006, Edinburgh, UK, June 2006, pp855-857.
- [5] T.Kamitani et al, "Pulse-to-Pulse Mode Switching of KEKB Injector Linac", Proceedings of the LINAC2008, Vancouver, Canada, September 2008.
- [6] Y.Ohnishi et al, "Design and Performance of Optics for Multi-energy Injector Linac", Proceedings of the LINAC2008, Vancouver, Canada, September 2008.
- [7] M.Tawada et al, "Development of Pulsed Bending Magnet for Simultaneous Top-Up Injection to KEKB and PF", Proceedings of the PAC2009, Vancouver, Canada, May 2009.
- [8] K.Furukawa et al, "Development of Timing and Control Systems for Fast Beam Switch at KEK 8 GeV Linac", Proceedings of the LINAC2008, Vancouver, Canada, September 2008.
- [9] K.Furukawa et al, "Timing System Upgrade for Top-Up Injection at KEK Linac", Proceedings of the EPAC2006, Edinburgh, UK, June 2006, pp3071-3073.
- [10] T. Suwada, E. Kadokura, M. Satoh, and K. Furukawa, "New beam-charge interlock system for radiation safety at the KEKB injector linac", Review of Scientific Instruments, Vol.79, 023302 (2008).
- [11] N.Iida et al, "Simultaneous Injections of Various Energy Particles into Two Rings in KEK Injector LINAC", Proceedings of the PAC2009, Vancouver, Canada, May 2009.
- [12] T.M.Mitsuhashi et al, "Top-Up Operation of the Photon Factory", Proceedings of the PAC2009, Vancouver, Canada, May 2009.