

CONSTRUCTION OF TRAVELLING WAVE KICKER MAGNET AND PULSE POWER SUPPLY FOR THE KEK-PHOTON FACTORY STORAGE RING

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Abstract

To obtain a wide acceptance for the injected beam in the KEK-Photon factory (PF) storage ring, we designed and constructed a travelling wave kicker magnet and pulse power supply. The characteristic impedance of the magnet is designed to be 6.25 Ω . The magnet consists of a 30-cell structure. Since the magnet is set outside of the vacuum chamber, we apply a silicon rubber molding for insulation of the high voltage components. The magnet operates with a newly constructed power supply. To obtain a sufficient kick, we doubled the peak current by the use of a shorted end. The new kicker magnets were installed in the PF ring in January 2000, and have been successfully operated during injection.

1 INTRODUCTION

In the Photon Factory (PF) at KEK, we inject the electron beam directly from the Linac into the storage ring. In the early stage of operation of the PF storage ring, we injected an electron beam pulse that has a pulse length longer than 1 μsec . For this reason, we used a kicker magnet that has a pulse length of 4 μsec [1]. Recently, we have successfully operated the PF ring with a high brilliance configuration of the ring optics. In this operation mode, we reduced the emittance of the beam from 130 nmrad to 36 nmrad. Since this high brilliance configuration of the ring optics has a narrow dynamic aperture, it is very important to have a wide acceptance for the injected beam to realize good injection efficiency. Since the revolution time of the PF ring is 0.64 μsec , due to the long falling time of the kicker magnet, the injected beam is kicked 3 times after injection. These kicks reduce the acceptance for the injected beam in the first few turns. This problem also limits the choice of operation point of the ring. In addition, under the high brilliance configuration, the strength of the old kicker magnet is not enough to produce a sufficient injection bump height. To improve these problems, we developed a fast kicker magnet by using a travelling wave kicker magnet [2]. A power supply for driving the new kicker magnet was also constructed. In this paper, the design of the magnet, practical problems for the construction, power supply and results are described.

2 DESIGN OF 6.25 Ω TRAVELLING WAVE KICKER MAGNET

The falling time of the kicker magnet must be shorter than the revolution time to realize a wide acceptance for the injected beam. For this purpose, we designed a fast kicker magnet by using the concept of the travelling wave kicker magnet [2]. The travelling wave kicker magnet is often set inside a vacuum chamber because of the insulation for the high voltage components. But if we insert a kicker magnet in the vacuum chamber in the electron storage ring, it will increase the impedance and will increase collective effects. For these reasons, we set the kicker magnet outside the vacuum chamber. Basic design parameters of the kicker magnet for the PF storage ring are listed in Table 1.

Table 1: Basic design parameters for the injection kicker magnet

Pulse length	1.3 μsec
Maximum kick angle at 2.5GeV	4 mrad
Total magnet length	400 mm
Gap height	60mm

To realize a large kick angle with the limited magnet length as given in Table 1, it is preferable to make the characteristic impedance of the magnet smaller. For this reason, we adopted the characteristic impedance of 6.25 Ω . The rise time T_r of the of the travelling wave type kicker magnet is given by,

$$T_r = \frac{L_t}{Z_0} + t_r$$

where L_t denotes inductance of the magnet, Z_0 denotes characteristic impedance and t_r denotes rise time of power supply. Assuming the inductance of the magnet to be 957nH and the characteristic impedance be 6.25 Ω , the rise time will be 200 nsec. If the pulse length of the power supply will be same as the rise time of magnet, the magnetic pulse length of the magnet will be approximately given by twice of the rise time. Then the magnetic pulse length of the magnet is estimated to be 400nsec. This estimated pulse length is shorter than the revolution time.

3 DESIGN OF THE MAGNET CELL

3.1 Electric design

In a travelling wave kicker magnet, the inductance L of one cell is given by,

$$L = \mu_0 \cdot l \frac{w}{h}$$

where μ_0 denotes magnetic permeability of the vacuum, w denotes gap width, h denotes gap height and l denotes length of the cell, respectively. The gap height and width are determined by the dimensions of the vacuum chamber; in our case, the gap height and width are 60mm and 170mm. Then the inductance per cell is 31.9 nH.

The characteristic impedance Z_0 is given by,

$$Z_0 = \sqrt{\frac{L}{C}}$$

where C denotes the capacitance of one cell. The characteristic impedance 6.25Ω requires the capacitance of the cell to be 815 pF. To realize such a large capacitance, we apply an alumina-ceramics plate to the capacitor. The thickness of the ceramics plate is 4mm and the dielectric constant is 9.0. A schematic drawing of the cell is shown in Fig. 1

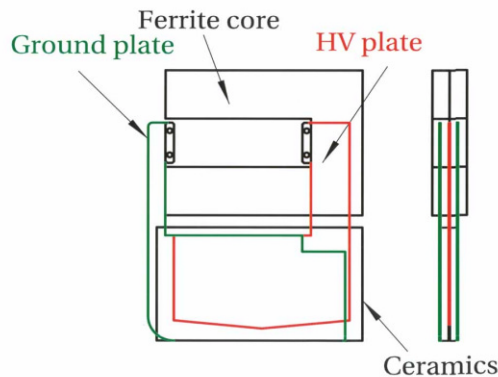


Figure 1: A schematic drawing of one cell.

In our design of the capacitor, the alumina-ceramic plate is sandwiched by the high-voltage (HV) capacitor plate and the ground plate.

3.2 Insulation of the magnet

To insulate the HV plate under atmospheric conditions, we molded the capacitor structure with a room-temperature vulcanizing silicon rubber. This molding is done cell by cell. The whole magnet is constructed by stacking 30 cells with no further insulation as shown in Fig.2. The performance of the insulation is strongly dependent on the remaining voids (bubbles) in the silicon rubber molding [3]. With almost no voids in the silicon rubber, the insulation of the magnet withstood applied voltage up to 30kV. To prevent voids in the bottom of the capacitor, we designed the shape of the HV plate to be like a cross section of the bottom of a ship as shown in Fig. 1. Since it is very difficult to remove voids

completely, we decided to use the magnet at a voltage lower than 15kV. In this range of voltage, the insulation of the capacitor was very safe. A general view of the kicker magnet is shown in Fig.3.

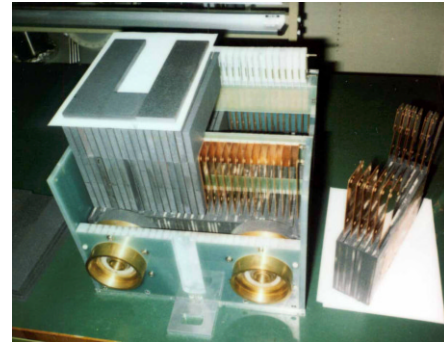


Figure 2: Assembly of the cells in the magnet case. In this photograph, the right half of the ferrite cores are removed to show the assembly of the capacitors.

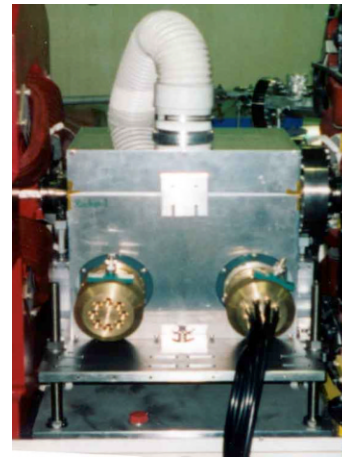


Figure 3 : General view of the kicker magnet.

4 POWER SUPPLY

To obtain a kick angle of 4mrad, we need an excitation voltage of 30kV. It is twice the safe voltage of the magnet. To make up for this problem, we introduced a shorted end on the kicker magnet [4]. If the magnet end is shorted instead of connecting to a matched resistance, the current trough in the magnet becomes double. However, the transmission time becomes double because of the current pulse returns from the magnet end to the entrance. Consequently, the pulse length will be 1μsec, but the pulse falling time is still shorter than the revolution time.

A new pulse power supply is designed and constructed to drive the kicker magnet that has a shorted end. The design parameters of the power supply are listed in Table 2. The outline of the power supply circuit is shown in Fig. 4. We used four parallel-connected 25Ω coaxial cables for the pulse forming line (PFL) to achieve a characteristic impedance 6.25Ω. To produce a fast rise time of the pulse, we designed a coaxial structure for the

housing of the switching thyatron. To absorb the reflected pulse, a diode assembly is connected in series to the end of the PFL. A matching resistance is set after the diode assembly.

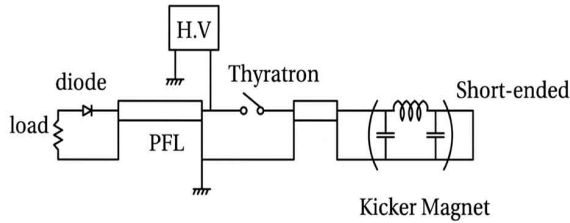


Figure 4: The outline of the power supply circuit.

Table 2: Design parameters of the power supply.

Impedance	6.25.
Output terminal	shorted
Charging voltage of PFL	30KV
PFL cable impedance	25Ω
Number of cables in PFL	4
Length of cable in PFL	75m
Thyatron	EEV CX1175

5 PERFORMANCE

The magnetic field of the total system is measured with a single-turn search coil. A result of the measurement is shown in Fig. 5. The observed pulse length of the magnetic field is 1.25μsec. Due to the magnetic coupling between the cores in the assembly of cells, the inductive component is not exactly cancelled by the capacitive component, and the input current pulse becomes wider. The pulse falling time is about 600 nsec and it is still shorter than the revolution time. A small undershoot is observed just after the pulse. The excitation of the magnet is shown in Fig. 6.

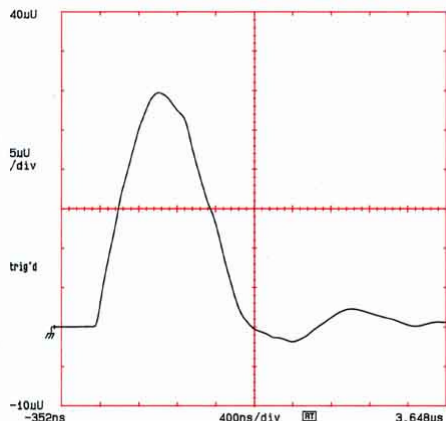


Figure 5: A result of the magnetic field measured with a single-turn search coil.

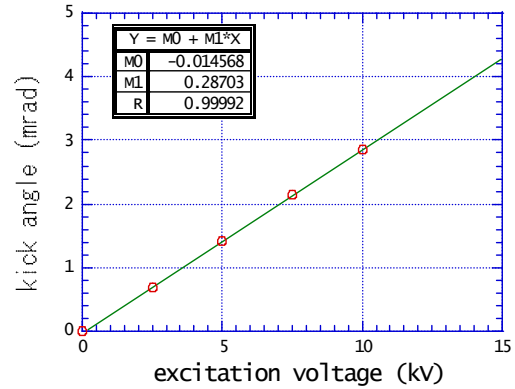


Figure 6: The excitation of the magnet.

In Fig.6, the result of linear least squares fitting is also shown. From this fit, the excitation voltage of 15kV gives a kick angle of 4.2mrad.

6 CONCLUSIONS

We designed and constructed a travelling wave kicker magnet and pulse power supply for injection to the Photon Factory. The characteristic impedance of the magnet is designed to be 6.25Ω. The magnet is set outside of the vacuum chamber and we apply a silicon-rubber molding for the insulation. Due to a remaining voids in the silicon rubber molding, the insulation performance was limited and we used the magnet at the voltage lower than 15kV. The magnet operates with a newly constructed power supply with a shorted end configuration. The new kicker magnets were installed in the PF ring in January 2000, and have been successfully used for injection.

7 ACKNOWLEDGEMENT

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