DEVELOPMENT OF THE KICKER MAGNET FOR BSR

T. Ohkawa and M. Wakasugi, RIKEN, Wako, Saitama, Japan
Y. Akutagawa, K. Kitamoto and K. Furuya, Nichicon Co. LTD, Kusatsu, Shiga, Japan
K. Abe, Hitachi Haramachi Electronics Co. LTD, Hitachi, Ibaraki, Japan
T. Katayama, CNS, Univ. Tokyo, Tokyo, Japan

Abstract

In the booster synchrotron ring (BSR) kicker magnets are used for the ion-beam injection and ion-beam and electron-beam fast extraction. The injection and extraction kicker field must rise and fall from approximately 10 % to 90 % of full strength during the time interval between bunches.1) The high performance of kicker magnet is crucial for the efficiency of beam injection and extraction. In this paper, the development of kicker magnets for BSR are presented.

1 DESIGN

1.1 Magnet

We have adopted the Pulse Forming Network (PFN)-type kicker magnet which is often used to generate a high magnetic field with a rapid rise and fall time. The characteristic impedance Z is related to the inductance Lo and capacitance Co of the unit cell by

$$Z = \sqrt{L_O / 2C_O} \quad (1)$$

and the transmission time τ_m of the total magnet is calculated by

$$\tau_m = N\sqrt{2L_O C_O} \quad (2)$$

where N is the cell number. The relationship between Z and τ_m is obtained by Eqs. (1) and (2) as

$$\tau_m = NL_O / Z \quad (3)$$

Therefore, decreasing the impedance causes an increase of the transmission time. In order to generate a magnetic field of the design value in a core gap of 30 mm, PFN voltages is required up to 100kV. When the PFN is added with 100 kV, the kicker magnet can produce a magnetic field of 0.084 T with a flat top of 1 μs and a rise time of 65 ns. The design parameters are listed in Table 1. The height and width of the kicker magnet aperture are 30 mm and 130 mm, respectively. The kicker magnet has a transmission-line structure of nine cells and the characteristic impedance is 25 Ω. Figure 1 shows a photograph of the kicker magnet.

Table 1: The parameters of the kicker magnet

ITEM	DESIGN VALUE
Gap height	30mm
Gap width	130mm
Total core length	225mm
Cell number	9
Inductance of unit cell	0.136μH
Capacitance of unit cell	108.9pF
Characteristic impedance	25Ω
Gap field	0.084T
Coil current	2000A
PFN voltage	100kV
Field rise time	65ns

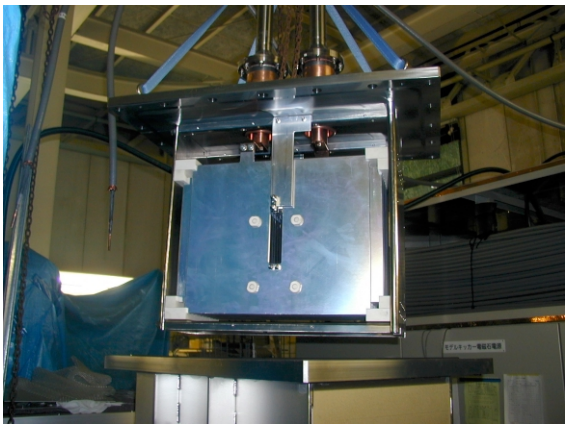

Figure 1: A photograph of the kicker magnet

1.2 Power Supply

The power supply of kicker magnet consists of the high-efficiency system power supply, the PFN, the thyratron and the termination. Table 2 shows the parameters of the power supply. The kicker magnet and the power supply are connected with the transmission cable. To avoid the reflected current into the flat top, the cable length must be more than 100 m. In order to minimize the loss in the cable, the length of the cable should be as short as possible. Thus, the length of the cable was decided to be 100 m.

Table 2: The parameters of the power supply

ITEM	DESIGN VALUE
Charging voltage	100 kV
Current	2000 A
Pulse width	1125 ns
Pulse interval	0.3 s
repetition	1 Hz
Jitter	±5 ns
Thyratron type	CX1171(EEV)
Termination resistance	24±2 Ω

To avoid the mismatch of impedance and the reflection, we have adopted the feedthrough with a coaxial structure which characteristic impedance is 25 Ω. A structure of the feedthrough is shown in Fig. 2.

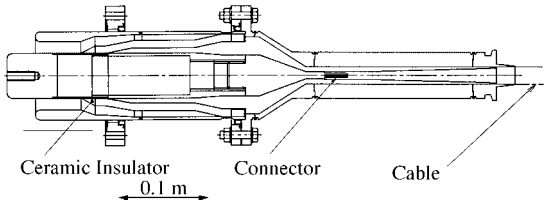

Figure 2: A structure of the feedthrough

2 MEASUREMENT

2.1 Pulse Response

The characteristic impedance and the transmission time are measured using a low-voltage short pulse. A schematic of the measurement system is depicted in Fig.3.

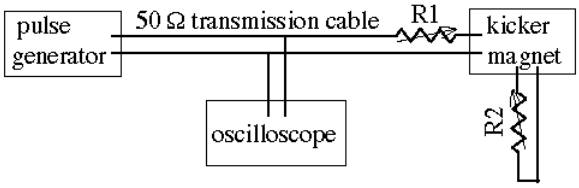

Figure 3: A schematic of the measurement system

The kicker magnet and pulse generator are connected by the 50 Ω transmission cable. In order to match the impedance, a matched resistor R1 is installed between the inlet of the magnet and the 50 Ω transmission cable and the outlet of the magnet is terminated in the matched resistor R2. The reflected signal follows the input pulse and can be presented in the same oscilloscope record. The amplitude of the reflected pulse serves as an indicator of the matching. In the ideal case the pulse travels to the matched resistor and there should be no reflected pulse. The reflected pulse is delayed by approximately 160ns with respect to the initial signal because we observe both of them on the same oscilloscope. The result of the measurement shows that the characteristic impedance of kicker magnet is 23 Ω.

The voltage pulses at the electrode of the each cell are shown in Fig. 4. The measurement shows that the transmission time of the kicker magnet is 59 ns and the field rise time is 69 ns. The calculated results of the inductance Lo and capacitance Co of the unit cell are obtained by Eqs. (1) and (2) as Lo = 0.14 μH, Co = 136 pF. The calculated value of the inductance is almost the same as the designed value, but the calculated value of the capacitance is larger than the design value. The reason why the capacitance of the unit cell is larger than the design value is that there is floating capacitance between the electrodes and the housing.

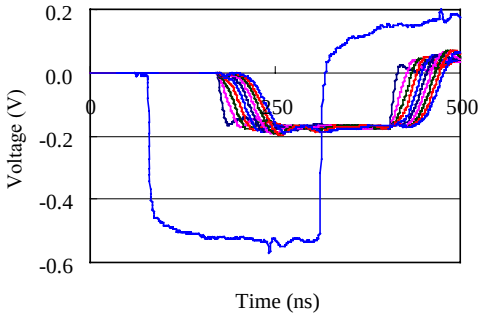

Figure 4: The voltage pulse at the electrode of the each cell

The impedance of the feedthrough from the connector to the inlet of the kicker magnet measured by the TDR method are shown in Fig. 5. The result of the measurement shows that the impedance of feedthrough is almost constant (about 25Ω) along the axis. The impedance of the feedthrough matches with that of the kicker magnet, so no reflection should occur at the feedthrough.

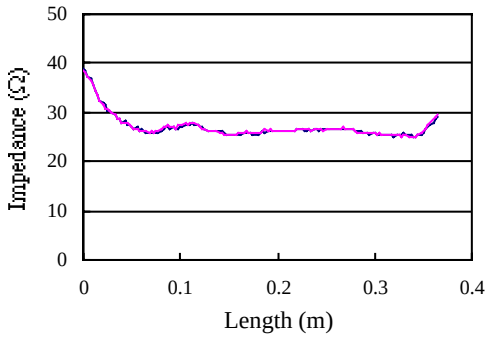

Figure 5: Impedance of the feedthrough

2.2 Magnetic Field

A current transformer (PEARSON-110) and a single-turn long search coil are used for the measurement of the current and the magnetic field, respectively. The width of the search coil is 5 mm, the length is 470 mm. The diameter of the wire is 0.5 mm. The terminal is connected with 1000:1 high-voltage probe and the digital storage oscilloscope. The waveform of the magnetic field is obtained by integrating the induced voltage at the ends of the search coil.

Figure 6 shows that the magnetic field waveform and the differential waveform in the core gap at V_{PFN} = 60 kV. In this case, the peak magnetic field of the kicker magnet is calculated to be 0.058 T. The rise time of waveform is about 90 ns, flat top time is 940 ns and fall time is 200 ns. Figure 7 shows the current waveform at the outlet of the thyratron.

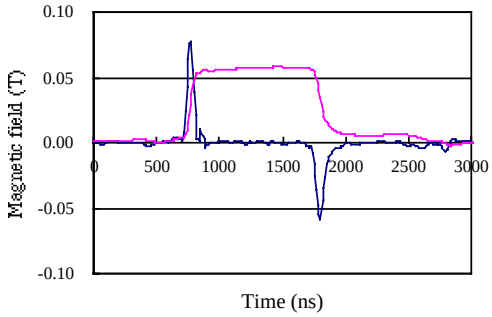

Figure 6: The magnetic field waveform and the differential waveform (at V_{PFN} = 60 kV)

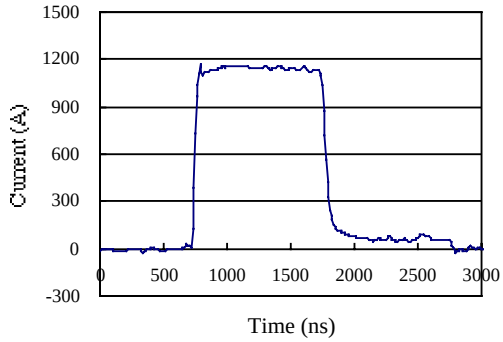

Figure 7: The current waveform at the outlet of the thyratron (at V_{PFN} = 60 kV)

The dependence of the peak magnetic field on the PFN voltage is shown in Fig. 8. The peak magnetic field of the kicker magnet is in proportion to the PFN voltage. It is estimated that we can generate a magnetic field larger than the requested value (0.084 T at V_{PFN} = 100 kV).

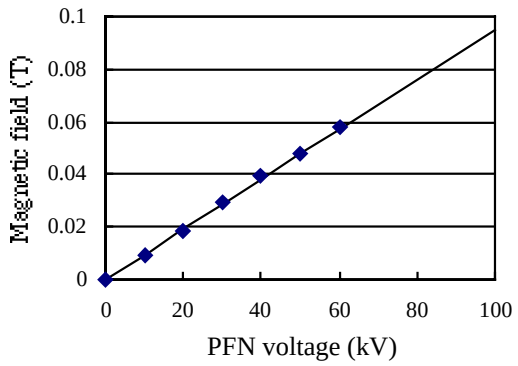

Figure 8: The dependence of the peak magnetic field on the PFN voltage

3 SUMMARY

We designed, produced and tested the PFN-type kicker magnet. We determined that the characteristic impedance of kicker magnet is 23 Ω, transmission time of the kicker magnet is 59 ns and field rise time is 90 ns. The measurements show that the design of the kicker magnet for BSR is quite realistic. We intend to perform further tests and study ultimate kick strength and the amplitude stability.

REFERENCES

[1] T. Ohkawa et al.: Proc.17th PAC'97, Vancouver, May 1997.