LOW BEAM-COUPLING IMPEDANCE KICKER MAGNET SYSTEM GENERATING A HIGH MAGNETIC FIELD WITH A FAST RISE TIME

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Abstract

A "twin distributed kicker magnet" has a structure such that two kicker magnets face each other and the septum coils are removed to above and below the core gap so as not to obstruct the circulating beam. The end of the magnet is grounded. Since the gap width of each magnet is half, and the propagation speed through the magnet is twice compared to the conventional one, we can generate a magnetic field that is two times as high as the conventional one with the same propagation time. Every kicker is connected to each power supply system comprising a thyratron housing, a PFN and a HV-DC-PS. The reflected current from the magnet is dumped by connecting a matched resistor with a diode to the end of the PFN. In order to remove the demerit that a short-ended kicker magnet has a much higher beam-coupling impedance, the end of the magnet is improved so as to connect a spark-gap and a matched resistor in parallel. The current induced by a circulating beam is dumped through the matched resistor, while the magnet current from the PFN is shorted by the spark-gap.

1 INCREASING THE MAGNETIC FIELD

1.1 Conventional system

In order to increase the magnetic field in a gap, we should increase the current through the magnet. Fig.1 shows the conventional kicker system. This system can feed half of the PFN added voltage to the magnet.

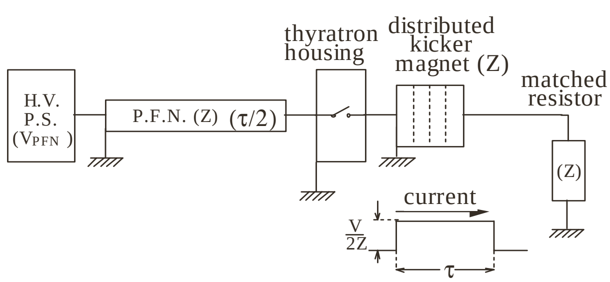


Figure 1: Conventional kicker system

1.2 Short Ended Magnet

Fig.2 shows that the output of the magnet is short ended. The current coming from PFN is reflected with changing the sigh at the magnet end. Therefore, the

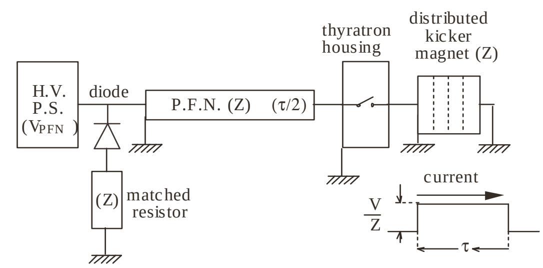


Figure 2: Short-ended kicker magnet

current through the magnet becomes twice as much as in the matched case. The reflection current is dumped by the matched resistor with a diode. However, since the current transmission time in the magnet also becomes twice, the rise time of the magnetic field is larger than that in the conventional system.

2 DECREASING RISE TIME OF THE MAGNETIC FIELD

2.1 Twin Distributed Kicker Magnet

The transmission time is proportional to the gap width. A twin distributed kicker magnet has a structure such that two C-shaped distributed kicker magnets with half the width of the normal type are connected face to face each other, as shown in Fig.3. Both C-shaped kickers are connected to every power supply system. Therefore, we can obtain double the magnetic field with the same rise time as in the conventional type. [1]

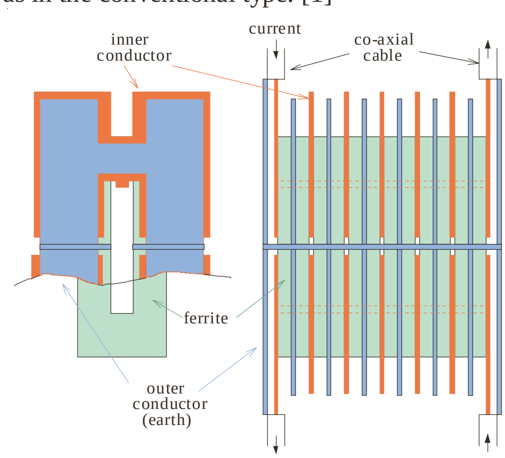


Figure 3: Twin distributed kicker magnet

2.2 Power Supply Using the Blumlein System

As explained in above, a twin distributed kicker magnet requires two sets of power supplies. For saving cost, the system shown in Fig.4 is adopted at the KEK-PS main-ring extraction system. [2]

The Blumlein system generates a pulsed potential with the full PFN charged voltage, and the transformer, which is grounded to earth at the centre of the second wire, generates positive and negative pulsed potentials of the half PFN charged voltage. The pulsed currents are fed to the magnet via co-axial cables. In order to ensure that the negative potential does not add to the anode of a thyratron, a diode is attached to the thyratron in parallel. If there is no dumped resistor with a diode connected to PFN2, current reflections at the magnet ends and at the thyratron are not dumped, but exist for a long time, as shown in Fig. 5a. The reflection time decrease very much with the dumped resistor, as shown in Fig.5b.

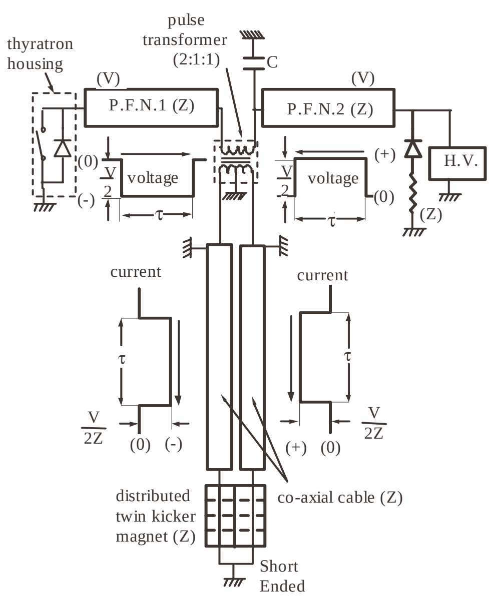
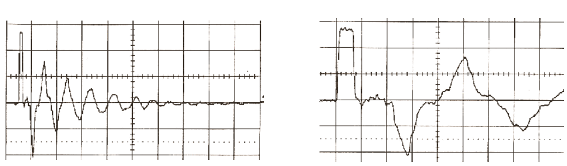


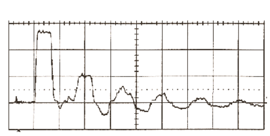
Figure 4: Blumlein system with a twin distributed kicker magnet



(x: 10μs/d) (x: 2μs/d)

Figure 5a: Magnetic field without a matching resistor

Figure 5b: Magnetic field with a matching resistor



(x: 2μs/d)

There is a start-up condenser, which is connected to the first winding of the transformer at the end of PFN2. As shown in Figs.6a and 6b, the rise time of a magnetic field without capacitance is larger than that with capacitance. We use six co-axial cables (50Ω-10m) in parallel, which is equivalent to 6.9nF as the capacitance for obtaining shortest rise time [1].

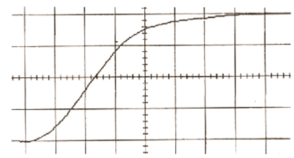


Figure 6a: Without C
(x: 50ns/d)

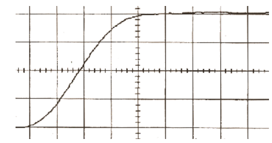


Figure 6b: With C
(x: 50ns/d)

2.3 Inserting Spark-Gap

The large rise time of the magnetic field mostly comes from the current rise time from the thyratron housing. In order to decrease the current rise time, we inserted spark-gaps (20kV discharge) between the transformer and the transmission co-axial cables shown in Fig.4. Fig.7 shows that the spark-gap greatly improves the rise time. However, it cannot be used for normal operation because of much jitter, as shown in Fig.8.

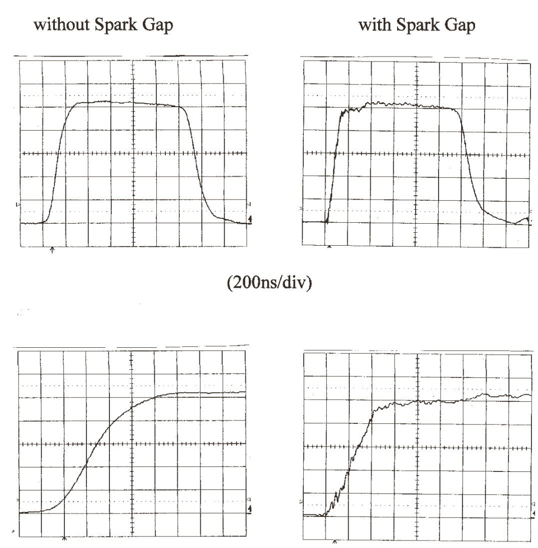


Figure 7: Effect of a spark-gap

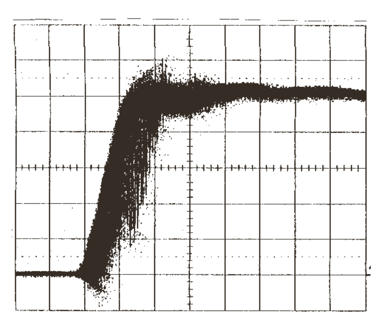


Figure 8: Much jitter caused by a spark-gap

2.4 Floating Thyratron Housing

There is a floating inductance (L_t) in the thyratron housing. When the housing is grounded as in Fig.4, the rise time of the current from the housing is

$$\tau_r = L_t / Z,$$

where Z is the characteristic impedance of the system.

On the other hand, the current rise time of the floating housing as in Fig.1 is

$$\tau_r = L_t / (2Z).$$

Therefore, the floating thyratron housing is better than the grounded housing from the viewpoint of the current rise time. The system shown in Fig.9 has another merit: dumping the reflection current perfectly.

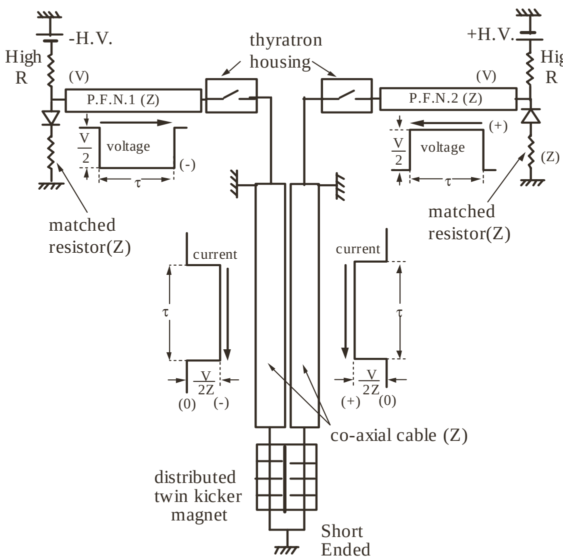


Figure 9: Separated power supply of the PFN potential with opposite the sign

Making the thyratron housing for a negative charged PFN costs more than the positive case, because the circuit connected with the thyratron cathode should hold against the full PFN potential instead of the half potential. Therefore, we also tested the system shown in Fig.10. The magnetic fields in the systems of Fig.9 and 10 were both measured by a long search coil. Since both magnetic fields completely agree with each other, it might be better to adopt the system of Fig.10 in any future project from the viewpoints of cost and current reflection.

3 DECREASING BEAM-COUPLING IMPEDANCE

Since the end of the kicker magnet is grounded, an induced current by the circulating beam is reflected at the end of the magnet and the thyratron, and cannot be dumped, which makes the beam-coupling impedance of this magnet system high. Therefore, a spark-gap

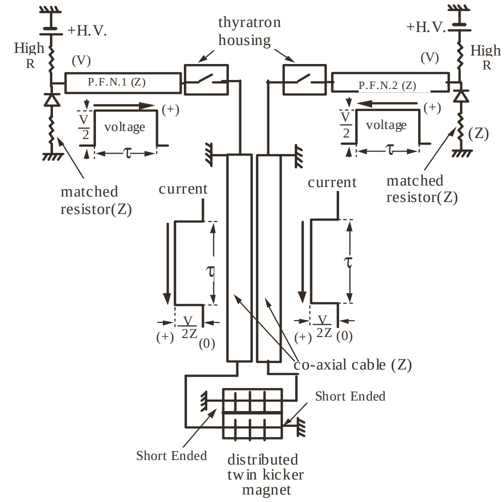


Figure 10: Separated power supply of the PFN potential with same the sign

(discharged at 500V) is connected to the end of the magnet parallel to the matched resistor, as shown in Fig.11. Usually, since the circulating beam sees the matched resistor, the beam-coupling impedance is as low as that in the conventional system (Fig.1). When the thyratron is fired and a pulsed voltage reaches the end of the magnet, the spark-gap is fired and the end of the magnet is completely grounded. When the charging voltage is more than 20kV, we obtained almost the same magnetic field as in the case of the grounded end. Unfortunately, the lifetime of the spark-gap is not sufficient for the operation time; therefore, we are using a saturated inductance (ferrite ring) in place of a spark-gap.

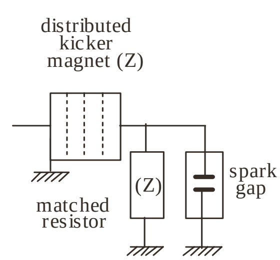


Figure 11: Spark-gap for decreasing the beam-coupling impedance

4 REFERENCES

[1] T. Kawakubo and S. Murasugi, “New devices for generating a high magnetic field with a fast rise and long flat top”, XVI RCNP, Osaka, Japan, March, 1997

[2] T. Kawakubo, E. Nakamura and S. Murasugi, “KEK-PS fast extraction system and its operation results”, EPAC’2000, Vienna, June 2000