KEK-PS FAST-EXTRACTION KICKER SYSTEM AND ITS OPERATION RESULTS

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Abstract

A fast extraction system from 12GeV PS ring was completed at the beginning of 1999 for a neutrino-oscillation experiment. Seven kicker magnets should be set in the same space of two electrostatic septa (ESS) for slow extraction. In order to change the fast/slow extraction system within a few minutes, the kicker magnets and the ESS are installed on the same base plate, which can be moved horizontally according to the fast/slow-extraction mode without breaking the vacuum. The kicker system is composed of a Blumlein, a pulse transformer and a short-ended "twin distributed kicker magnet", which can generate double the magnetic field of the conventional type (matched distributed type) with the same rise time. The kicker magnet generates 0.11T with a rise time of 145ns and a flat-top of 1μsec in the gap (55mm high, 110mm wide, 300mm long). Since the (5%-95%) rise time of the kicker magnetic field (145ns) is larger than the empty space between bunches (65ns), it had been thought that one bunch should be taken from all bunches (9 bunches) at the injection porch. However, a measurement showed that 9 bunches were extracted with almost the same extraction efficiency as in the case of 8 bunches.

1 SELLING POINTS OF THIS SYSTEM

1.1 Saving Longitudinal Space

Before making the fast-extraction system, the main ring of the KEK-PS had only a slow-extraction system. The modes between fast and slow extraction should be changed so as to be as short as possible. However, we had no longitudinal space in the main ring to insert kicker magnets. Therefore, a huge vacuum chamber (3.1m long, 1.2m wide and 1.2m high) was set at the space of two sets of ESS, and the ESS and seven kicker magnets were set in parallel for the longitudinal axis on a huge metal plate which can be moved horizontally without breaking the vacuum, as shown in Fig. 1. According to the fast and slow extraction mode, the metal plate is set the position of (A) and (B) to the centre in Fig.1, respectively. The current inlet of the kicker magnets is connected only at the position of the fast extraction mode. The potential inlet of ESS is always connected to the DC power source by a sliding structure.

1.2 Increasing Magnetic Field

There have been kicker magnets for 500MeV-Booster extraction and main-ring injection in the KEK-PS. Their

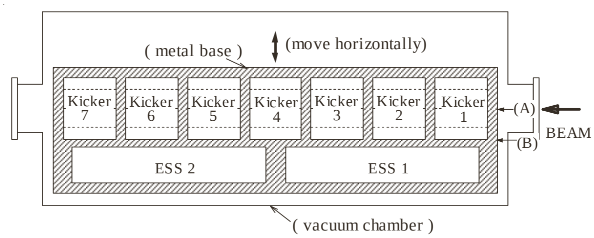

Figure 1: Ground plan of a vacuum chamber having kicker magnets and ESSs.

power supply system is conventional, i.e., composed of a resonance charging circuit, a PFN of 2 parallel 50Ω cables, a thyratron housing, transmission cables, a kicker magnet (25Ω transmission type) and a matched resistor. In order to extract a 12-GeV accelerated beam from the main ring, however, the magnetic field needs to be four-times larger than that generated by the above mentioned conventional system. In order to increase the current through the magnet, the characteristic impedance is changed from 25Ω to 12.5Ω, and the output terminal of the magnet is shorted, instead of matching. The current coming through the magnet reflects at the shorted output terminal upon changing the sign. Therefore, the current through the magnet increases to double that of the matched type [1].

1.3 Decreasing Rise Time of Magnetic Field

However, the transmission time passing through the magnet is also double. Since the transmission time is proportional to the width of the core gap, a kicker magnet having a wind frame-type of the core structure is divided into two C-shape types having the same half-core width as the original. Both magnets are connected face to face and are supplied with current separately by connecting a Blumlein and transformer power supply system, which is explained in detail in reference [1].

2 MEASURED MAGNETIC FIELD

2.1 Rise Time and Flat-top

The magnetic field measure by a long search coil is shown in Fig. 2. A 5%-95% rise time of 145ns can be obtained by attaching C (six 50 Ω-10m cables in parallel, which is equivalent to 6.9nF) to the end of the first winding of the transformer; the flat-top for extracting 9 bunches is 1 μs with the tolerance of +/-5%.

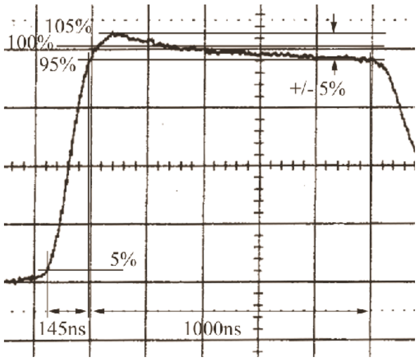

Figure 2: Magnetic field measured by a long search coil (x: 200ns/div)

2.2 Field Distribution in Longitudinal Plane

The field distribution along the longitudinal line (Z-axis) is shown in Fig. 3, which shows that the effective length of this magnet is 304mm.

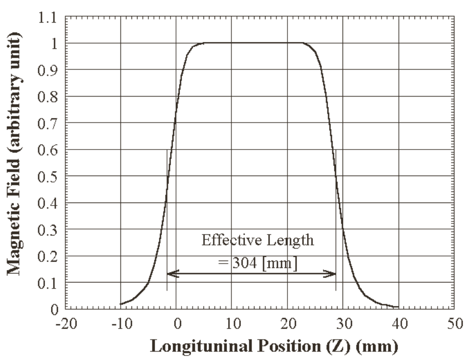

Figure 3: Magnetic field distribution along the longitudinal line (Z-axis)

2.3 Field Distribution along Horizontal Plane

The field distribution along the horizontal plane (X-axis) is shown in Fig. 4. The drop at the centre (connection of twin kicker magnet) is 2%, which is a tolerable value for kicking the beam.

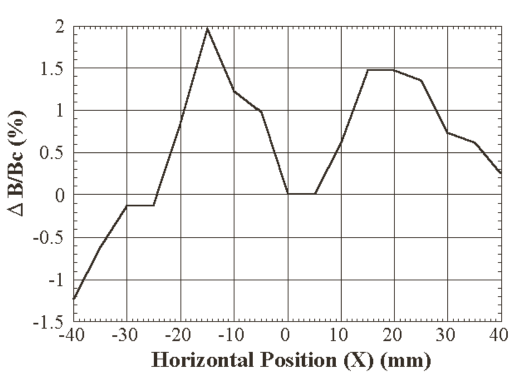

Figure 4: Magnetic field distribution along the horizontal plane (X-axis)

2.4 Field Dependence on PFN Voltage

The dependence of the flat-top magnetic field on the PFN added voltage is shown in Fig.5. The reduction of about 10% from the calculation comes from reflections at various connections of the system.

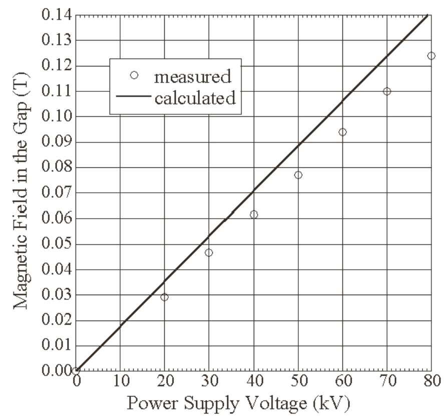

Figure 5: Magnetic field dependence on V_{PFN}

3 MAGNETIC EFFECTS ON THE BEAM

3.1 Space between Bunches

The circulating bunches just before firing the kicker magnet are shown in Fig.6. The space between bunches at 5% height of the bunch peak is 65ns. Since the 5-95% rise time of the kicker magnetic field (145ns; see Fig.2) is much longer than the space (65ns), the magnetic field would affect the beam during its rising period.

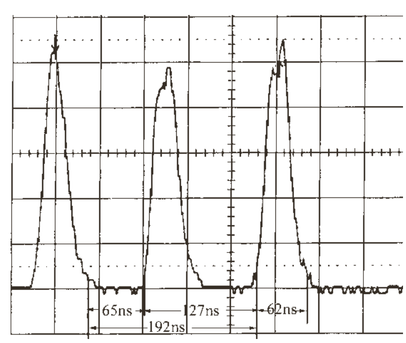

Figure 6: Circulating bunches just before extraction from the main ring

3.2 Magnetic Field Effect on the Beam

In order to measure the magnetic field effect on the beam during the rising period, we measured the dependence of various parameters (bunch height, extraction efficiency, beam loss signal by a slow and fast loss monitor, betatron amplitude of fast Δr monitor) on the trigger timing of the kicker magnet. When one bunch is removed at the injection porch, the space is sufficient for the kicker magnet to rise to the top field without affecting the circulating beam, as shown in Fig.7 (B). When the kicker magnet is fired faster than the best timing, like (A), the last bunch (No.8) is affected. On the contrary, when the magnet is fired slower, like (C), the first bunch (No.1) is affected.

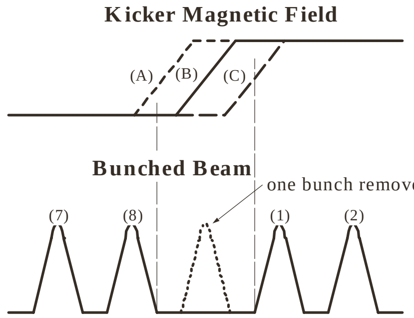

Figure 7: Relationship between the kicker magnetic field and the circulating bunches

3.3 Measurement Results

Fig.8 shows the dependence of the extraction efficiency (closed circle, at the beam transport line; open circle, at the target) on the kicker firing timing in the case of one bunch removed (i.e., 8 bunches). Since the aperture of the current transformer for measuring the extraction efficiency is large, the flatness of the efficiency is 120ns (=410-290) [loose measurement]. However, the flatness measured by the bunch height, fast loss monitor and betatron amplitude by a fast Δr monitor is narrower (70ns) [sensitive measurement].

In Fig.9, we define that "T", "a", "b" and "τ_r" are the RF period (=127ns), effective bunch width, effective rise time of the kicker magnet and the space of the kicker rise time, respectively.

There is the following relationship between τ_r, T and (a+b): (a+b) = 2T – τ_r .

Substituting the measured values for the above equation gives

(a+b) = 2*127 – 70 = 184[ns] [sensitive measurement],
= 2*127 – 120 = 134[ns] [loose measurement].

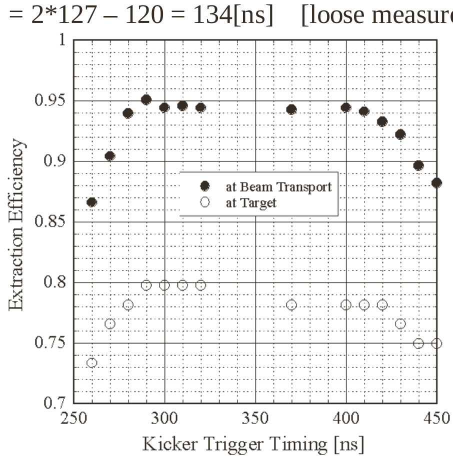

Figure 8: Dependence of the extraction efficiency on the kicker trigger timing (8 bunches)

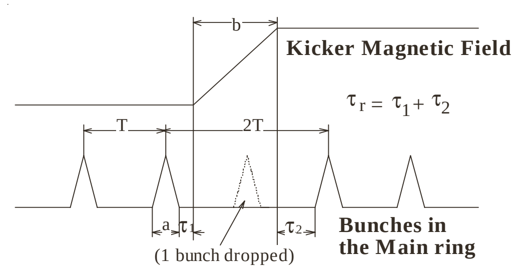

Figure 9: Definition of parameters

On the other hand, Figs.6 and.2 show that "a" is 62ns and "b" is 145ns, respectively.

Therefore, (a+b) = 207 ns .

This value is 23ns larger than the sensitive measuring value (184ns). The difference in these values might be because the bunch shape is not rectangular, but almost triangular.

We now change the bunch number from 8 to 9. In this case, τ_r = T – (a+b):

= 127 – 184 = -57[ns] [sensitive measurement],
= 127 – 134 = -7 [ns] [loose measurement].

Since even in 9 (full) bunches, the rise time of the kicker is only 7ns larger than the space between bunches [loose measurement], we hope that the difference in the extraction efficiency between 8 and 9 bunches is small. Fig.10 shows the efficiency dependence on the kicker trigger timing in the case of full bunches (9 bunches). There is no flat part at the peak, which shows that there is no space for the rise time. However, the maximum extraction efficiency is 94%, and 1% less than that in 8-bunch injection. Therefore, we are operating in the full-bunch mode.

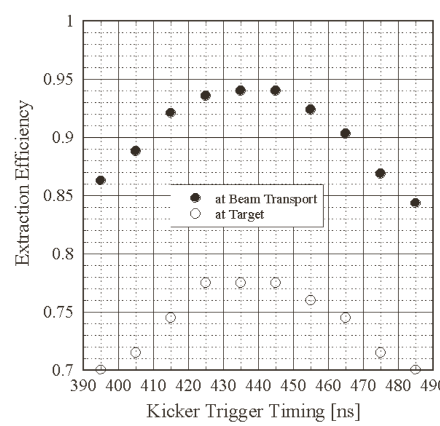

Figure 10: Dependence of the extraction efficiency on the kicker trigger timing (9 bunches)

4 REFERENCES

[1] T. Kawakubo, E. Nakamura and S. Murasugi, "Low beam coupling impedance kicker magnet system generating high magnetic field with fast rise time", EPAC'2000, Vienna, June 2000