R&D STATUS OF THE FAST EXTRACTION KICKER MAGNETS FOR THE KEK/JAERI 50 GEV SYNCHROTRON

Y. Shirakabe*, Y. Arakaki, T. Kawakubo, Y. Mori, S. Murasugi, E. Nakamura, I. Sakai, and M. Tomizawa, KEK, Tsukuba, JAPAN

Abstract

The fast extraction kicker magnets of the 50 GeV synchrotron have been on the R&D stage. The 50 GeV ring fast extraction system is designed to play the double role, namely, the extraction system to deliver the 50 GeV beam to the downstream neutrino oscillation experiment beam line, and the beam abort system in case of sudden hardware failures. In order to fulfil both demands, the extraction system is designed to accommodate bipolar beam extraction. The bipolar function is achieved with a newly developed Symmetric Blumlein Pulse Forming Network (SBPFN) system. The distributed line kicker magnet scheme was recently adopted for the extraction kickers. The IGBT switching module R&D has been underway. Some of the recent experimental results are presented.

INTRODUCTION

The 50 GeV synchrotron in the KEK/JAERI high intensity proton accelerator project, J-PARC, has three straight sections, as is shown in Figure 1, and the injection/extraction functions are distributed to these sections. The distinctive feature of the fast extraction line is that it is designed to work as the beam abort at the same time as the extraction line.

The main two demands for the beam abort are 1) protection of superconducting magnets in the neutrino beam line in case of quench, and 2) protection of 50 GeV ring components in case of ring hardware failures [1]. In order to achieve these two roles within the limited length of the insertion section C (Fig. 1), the fast extraction system is designed to realize the bipolar function.

In Figure 2, the hardware components for the fast extraction system, the kicker magnets and the septum magnets, are shown. For the septum magnets, the bipolar function can be achieved by simply arranging two series of magnets with opposite polarities along with two branching beam lines. For the kickers, however, a new function is required, which is the very fast reverse of the kicker field polarity whenever an abort request emerges.

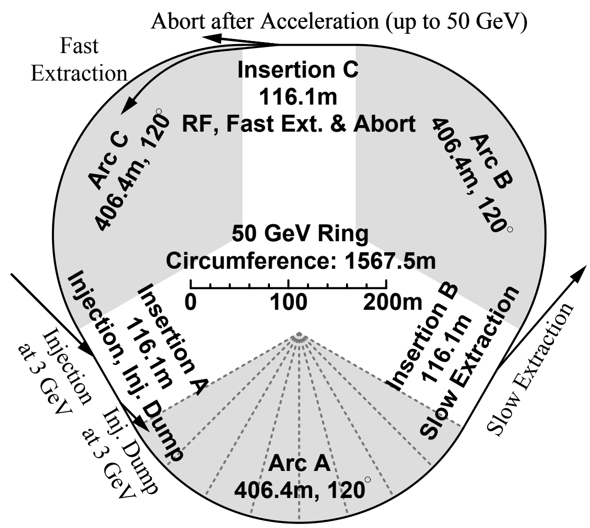

Figure 1: Injection/extraction scheme of the 50 GeV ring.

BIPOLAR EXTRACTION KICKERS

Figure 3 shows the bipolar kicker magnet scheme. The kicker pulse with a flat top duration of 4.3 μs is generated by a Blumlein Pulse Forming Network (PFN) system [2]. An essential difference from the conventional usage of Blumlein systems is that two switches are installed symmetrically at both ends of the Blumlein PFN. If one switch (left one in Fig. 3) is supposed to turn on the kicker field corresponding to the normal direction kick, the other (right one) corresponds to the reverse direction kick. This symmetric Blumlein PFN (SBPFN) scheme is capable of producing equal field strength for the normal and reverse direction. The experimental studies to prove the SBPFN principle have been carried out and reported so far [1]. If the PFN is charged to the voltage V_{PFN}, the choice between the two switches can be done whenever it is required. This allows fast reversing of the kick direction, in case of sudden hardware malfunctioning.

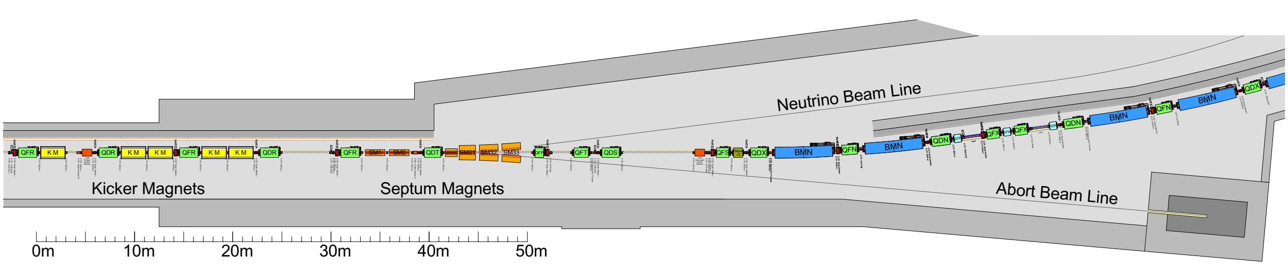

Figure 2: Fast extraction and abort beam lines of the 50 GeV ring.

*yoshihisa.shirakabe@kek.jp

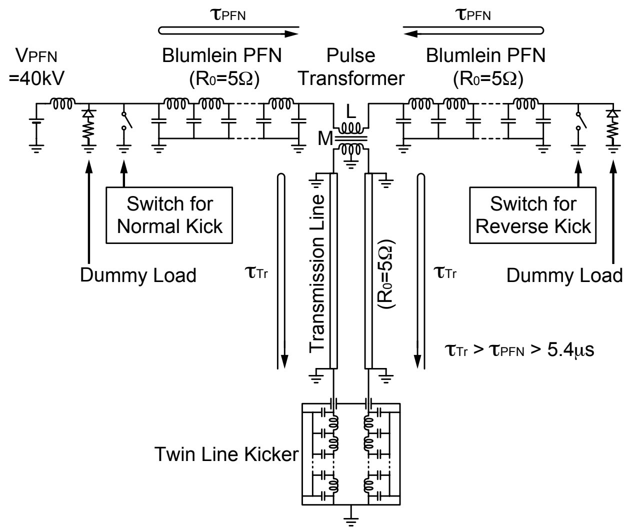

Figure 3: Bipolar fast extraction kicker system with the symmetric Blumlein PFN scheme.

DISTRIBUTED LINE KICKERS

The kicker magnet scheme for the 50 GeV fast extraction system was supposed to be of a lumped type [1]. In our recent discussions, however, the design basis moved to the safer side, and now the choice is a distributed line type for our extraction kickers.

The merits of lumped type kickers are the simplicity in structure and the smaller cost compared to distributed line type kickers. The field rise-time for the lumped type is relatively longer than the line type, but this demerit is not serious when the rise-time requirement is modest. In the 50 GeV ring fast extraction kickers, the rise-time is 1.1 μs. The choice of the lumped type, therefore, was a natural solution in this context.

The most critical point we noticed is that the lumped type kickers makes a bigger high-voltage pulse reflection compared to the line type kickers, and the reflection oscillates both in positive and negative polarities. Consequently, the high voltage stress on the transmission line cables becomes more serious. In order to assure the possible highest safety on all the high-voltage kicker

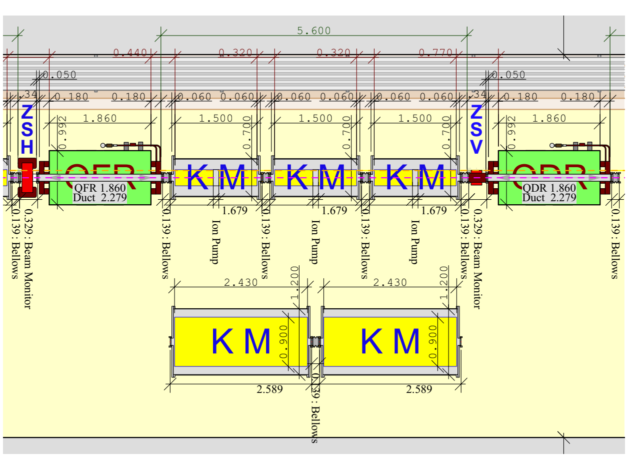

Figure 4: Comparison of three lumped kickers (upper) and two distributed line kickers (lower).

Table 1: Distributed Line Type Kicker Parameters

Parameter	Value	Unit
Ferrite Core Gap Height	110	[mm]
Aperture Height (Effective)	100	[mm]
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Section Length	24	[mm]
Ferrite Length	20.5	[mm]
Ferrite Packing Factor	85.4	[%]
Number of Sections	101	
Aperture Length	2424	[mm]
PFN Voltage (Maximum)	44	[kV]
Cable Voltage (Maximum)	60	[kV]
Cable Impedance	20	[Ω]
Parallel Number of Cables	4	
PFN Impedance	5	[Ω]
Kicker Current (Maximum)	8.8	[kA]
Kicker Field (Maximum)	0.101	[T]
Kicker Field (Average)	0.087	[T]
B·l Product (Average)	0.210	[T·m]
Kick Angle (for 50 GeV Beam)	1.238	[mrad]
Number of Kicker Units	5	

components, we decided to choose the line type. The magnet cost for the line kicker is higher, but thanks to the shorter rise-time of the line type, the mechanical length of one kicker unit can make longer and the total number of the kickers can be reduced, as is shown in Figure 4. Since the kicker power supply generally costs higher than the kicker magnet, the total construction cost of the line type kickers can keep at the same scale as that of the lumped type kickers. The designed parameters for the line type kickers are summarized in Table 1.

IGBT SWITCHING MODULE R&D

In recent years, high power solid-state devices, IGBTs, for example, are coming to the realistic choice for the switching device for kicker magnets. Traditionally, thyratrons have been used for this application. Solid-state devices, however, can be advantageous because of their stable and unchanged switching property. In order to prove the possibility of IGBT devices for the 50 GeV fast extraction kickers, the R&D of the IGBT switching module was started last year [1]. The constructed module is shown in Figure 5.

The module was designed to fulfil the 40kV/8kA switching requirement of the fast extraction kickers. In order to demonstrate its full switching capability, a PFN system with a 40kV/8kA/5Ω capacity is required, but that is not easily obtainable. Our tentative solution is to use 6 x 500m 10D-2V co-axial cables with an impedance of 50 Ω. When the 6 cables are connected in parallel, as is shown in the upper figure of Fig. 6, a full pulse-width switching with a reduced current can be tested. When all the cables are folded in two and connected in parallel, as in the bottom figure, a full current test with a half pulse-width can be achieved.

The obtained test results are shown in Figure 7. As long as demonstrated so far, the switching property of the IGBT module follows the initially designed

Figure 5: IGBT switching module constructed as an R&D for the bipolar fast extraction kicker system.

specifications. Since the R&D module showed the satisfactory results, the same design of the IGBT switching modules is employed in the final design of the kicker system in Figure 3.

So far, the switching tests were done with 1) 'a full pulse-width' x 'a half current', and 2) 'a full current' x 'a half pulse-width'. The more advanced studies with a full 40kV/8kA/5μs switching are currently being planned.

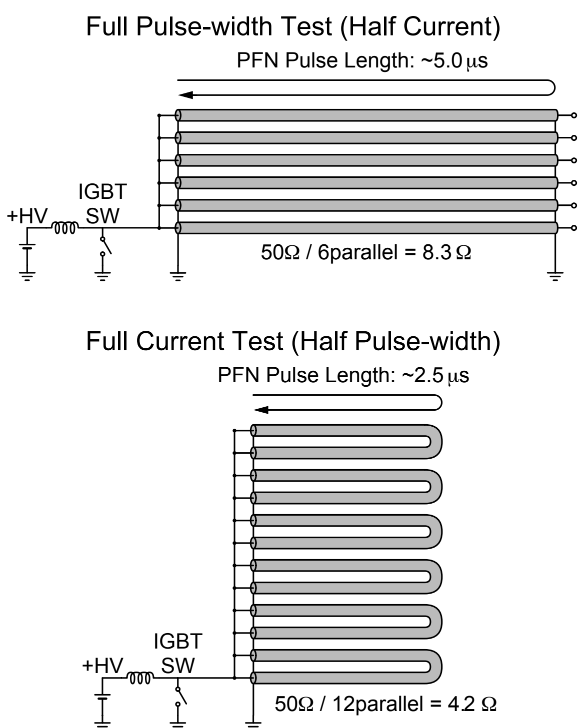

Figure 6: PFN scheme for the IGBT switching test.

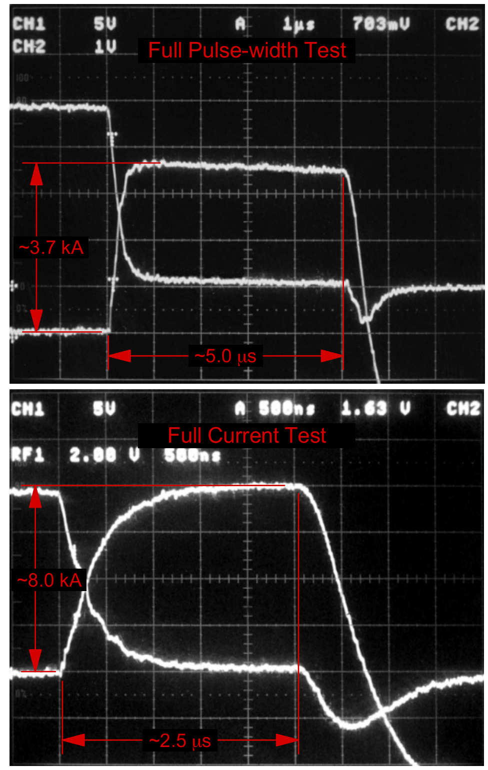

Figure 7: IGBT switching test results.

CURRENT CONSTRUCTION STATUS

The construction of the fast extraction system has already started in May 2004. Both the kicker magnets and the septum magnets are being constructed, including their magnet units, power supplies, vacuum chambers/ducts, supporting stands, and alignment systems. The contractor is Mitsubishi Elec. Co. and the construction budget is ~1.1BYen (~10M$). The delivery of the whole system is planned to be by the end of March 2005.

SUMMARY

The fast extraction system for the 50 GeV synchrotron of the J-PARC project requires the bipolar extraction function. The proposed Symmetric Blumlein PFN scheme is the promising candidate to achieve the bipolar polarity kicker. The R&D work of the IGBT switching module is now on the way. Some of the switching test results were obtained so far. The results suggest that the satisfactory switching property can be obtained with the IGBT module. The construction of the fast extraction system has started.

REFERENCES

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