MAGNETIC FIELD MEASUREMENT ON A REFINED KICKER

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Abstract

To provide wide horizontal aperture of kicker ceramic chamber at the downstream of a short insertion devices and prepare for the operation of top-up mode injection, the National Synchrotron Radiation Research Center (NSRRC) has upgraded the kicker systems. The new systems have been tested and installed. An efficient procedure of in-situ wave form tuning was proposed and tested successfully.

INTRODUCTION

The Taiwan Light Source (TLS) of the National Synchrotron Radiation Research Center (NSRRC) is an accelerator providing 1.5 GeV electron beam to generate high brightness synchrotron radiation. The storage ring has only six straight sections with four of them to accommodate insertion devices and two for electron-beam injection system and rf cavities separately. To enhance and provide more X-ray sources for users, the NSRRC has been trying to make additional space to install a series of superconducting devices [1]. The first one is a superconducting wavelength shifter (SWLS) inserted into the tight space between kicker-3 (K3) and kicker-4 (K4) of the injection section. Such arrangement is unusual for synchrotron radiation facilities. The broad angle radiation of x-ray from the SWLS was expected to shine on the inner surface of the K4 ceramic chamber. In order to remove the heat accumulation on the chamber, a pair of water-cooled copper plate had been mounted inside of the ceramic chamber [2]. This measure reduces the physical horizontal aperture of the chamber from 80 to 50 mm, and affects the performance of the storage ring.

On the other hand, several experimental tests on top-up injection were carried out at various stages on TLS upgrade path. The efficiency of the e-beam injection and reliability of the injection system was getting demanding, in terms of the radiation concern and the performance of storage ring operation. The upgrade of kicker system was then focused on the horizontal aperture of ceramic chamber, and stability and reliability of the pulser. Therefore a set of new kicker system was fabricated and tested. A design chart of new kicker magnet is shown in Fig. 1. To ease the loading of pulser by lowering the voltage, the inductance of the magnet was reduced by decreasing the gap and length of the kicker magnet. However the aperture widening compromised the inductance reduction. Meanwhile, the jittering of current excitation has been reduced to 2 ns, which was improved by an order. The pulse width was extended from 1.2 μs to 2.0 μs. Table 1 summarizes the modification.

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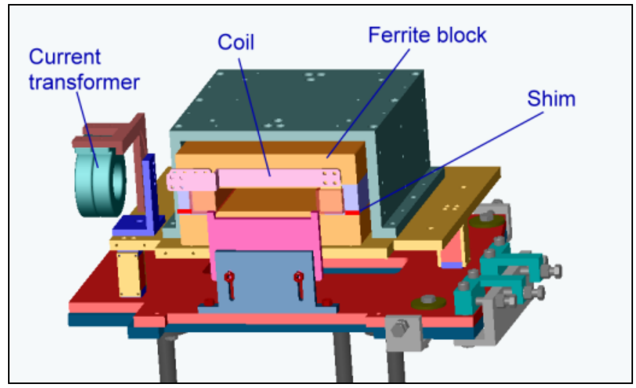

Figure 1: The new kicker.

Table 1: The comparison of kicker parameters

	Old kicker	New kicker
Dimension of magnet		
Length [mm]	414	372
Gap [mm]	56	34
Inside chamber [mm]	38	20
Width [mm]	114	160
Coil excluded	102	146
Inside chamber [mm]	80/50	120
Pulser		
Pulse width [μs]	1.2	2.0
Peak current @ 20kV [A]	5300	3500

The refined kicker systems were tested with satisfaction and installed into the injection section. After a hard work of commissioning, the storage ring has been in normal operation.

The waveform of magnetic field is mainly determined by the individual properties of pulsed current circuit, kicker magnet and metallized ceramic chamber of each kicker system. To make the waveforms of four kickers identical, an iterative but tedious tuning of each component, especially the pulser, is unavoidable. The new pulser was once air-cooled by fan, but the stringent requirement on the stabilization of environmental temperature in the storage ring turned down the design. The pulser was finally backed to oil tank with water cooling. This made the tuning of pulser inefficient. The integrated condition in storage ring is different from isolated condition of each kicker system. Therefore an efficient procedure of wave form tuning at injection section was proposed and tested.

PERFORMANCE OF NEW KICKER

The pulse current, magnetic field and trigger signal are queried simultaneously by a Tektronix oscilloscope TDS3054B. A typical result of point measurement using intrinsic average function is shown in Fig. 2.

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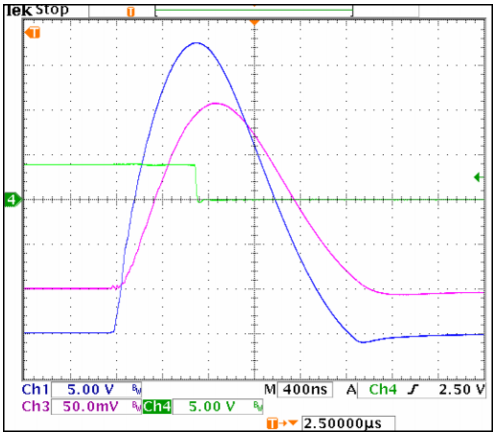

Figure 2: A typical measurement result of kicker.

Current Measurement

The pulse current was measured by a typical Pearson 101 current transformer (CT). The ratio of voltage reading over current is 0.01. The electromagnetic immunity was improved after moving the CT from inside of pulser tank to cable connector on the magnet side. To avoid the false trigger due to the firing noise from thyratron, the falling edge of the triggering pulse was extended to behind the rising edge of the excitation current pulse.

Magnetic Field Measurement

A precise 20-turn coil of 5 mm diameter was used to pick-up the induced electromotive force, which was converted to magnetic field signal by an integrator. The time constant of the integrator was precisely calibrated by fitting the charge-discharge curve of a square wave from a function generator.

To avoid the ringing of the signal, an impedance match was equipped on both ends of coaxial cable. The shielding and grounding was carefully applied to increase the immunity against electromagnetic noise.

The first integral field can be calculated by point measurement along a line or measured directly by a long loop coil.

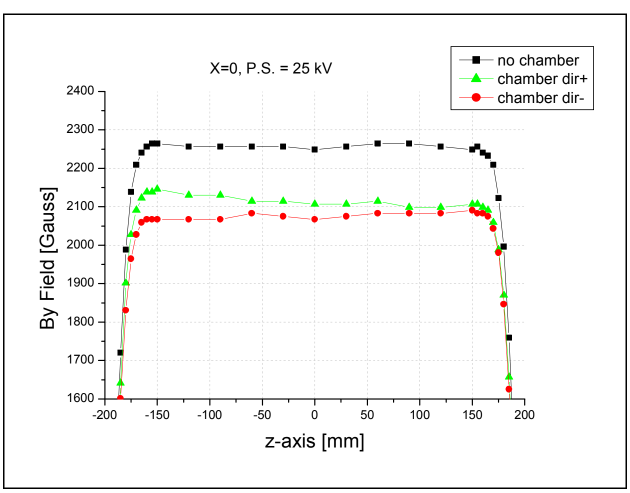

Figure 3: Zooming the plateau of the field measurement on the centerline along electron beam direction.

Metallized Ceramic Chamber

As expected, an inhomogeneous magnetic field and the reduction of the field due to the metallized ceramic chamber were observed. Fig. 3 shows that when turning the metallized ceramic chamber by 180 degrees, the slant also reverse.

WAVEFORM TUNING

Even the four kicker systems were qualified at lab; one still can tell the mismatch of the current waveforms of four kickers measured at the injection site or in control room. This mismatch is believed due to the integrated condition in tunnel is different from in lab. The first order difference can be characterized by the full width at half maximum (FWHM) of the normalized curves, as shown in Fig. 4. An efficient method to tune the kicker waveform at injection section was then proposed.

Current Waveform

To fine-tune the FWHM of the current waveform, we tried to shim the magnets of each kicker so as to modify the inductance. We inserted a series of Kapton® films with different thickness to realize this idea as shown in Fig. 1. Fig. 5 shows the result. To get a precise pulse width, the data were averaged by 64 times, and smoothed by FFT filter. One can tell that when shim thickness increases, the current amplitude also increases, and the current FWHM as well as waveform width decreases accordingly. This result makes sense since the shim will increase the gap of magnet decrease the inductance, and reduce the current pulse width in turn. The relation of the pulse decrease and the shimming thickness turns out to be quite linear when the gap perturbation is small, as shown in an empirical formula:

$$W = 1.1447 - 0.0264 \times S \,, \tag{1}$$

where W is the current FWHM in μs, and S is the shim thickness in mm. The fitting error of offset and change rate are ±0.0007 and ±0.0004 μs respectively. Therefore one can tune the pulse width by a thumb rule: 0.038 mm per ns.

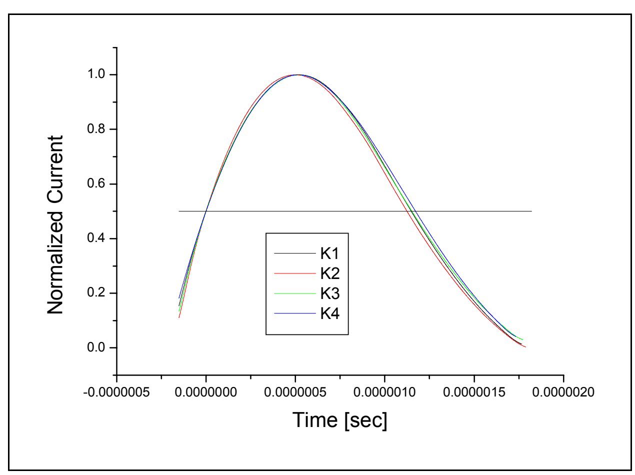

Figure 4: Mismatch of four kicker waveform.

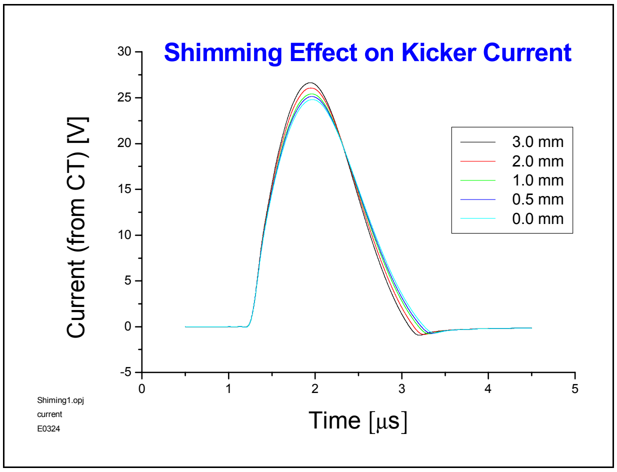

Figure 5: The shimming effect on the change of current waveform.

Magnetic Waveform

On the other hand, the increase of the shimming thickness would make the magnetic field decrease. Fig. 6 depicts the result. The behaviour of the peak field *P* dependent on shim thickness is also linear. The formula is

$$P = 0.4577 - 0.0114 \times S . \qquad (2)$$

This means that one needs to compensate the field by increase the pulser voltage by 2.4% when adding 1 mm shim.

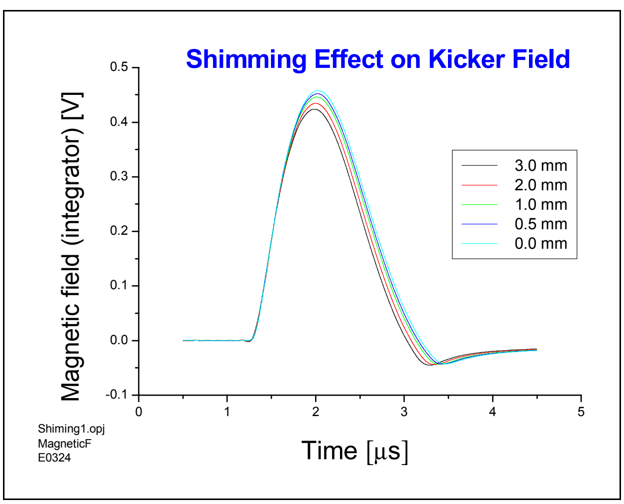

Figure 6: The shimming effect on the change of magnetic field waveform.

In-situ Tuning

Based on the experience in lab, we measured the current FWHM of each kicker. Since the shimming can only reduce the pulse width and the K2 had the smallest FWHM, the K2 pulse width was chosen as a reference value. The additional width of other kickers was defined as the error to be tuned. After shimming according to the formula (1), we had successfully tuned the FWHM to ±3 ns. The measurement error caused by long transmission of signal from injection section to control room resulted in some minor inconsistence. Then the operators in the control room were asked to compensate the magnetic field reduction by increasing the current setting according to formula (2).

Table 2: The tuning result

	Before tuning		After tuning	
	FWHM (ns)	Error (ns)	FWHM (ns)	Error (ns)
K1	1148.5	23.9	1117.6	0
K2	1124.6	0	1117.6	0
K3	1151.6	27.0	1110.4	-7.2
K4	1172.2	47.6	1112.8	-4.8

CONCLUSION

The magnetic performance of the refined kickers in TLS was proved satisfactory. The constant test showed that the kickers were reliable enough for top-up injection. We demonstrated that the in-situ tuning of the current pulse width by shimming is feasible.

Be aware that only one kicker was tested in the test shown in Fig. 5 and Fig. 6. It is Fig. 4 that compares the waveform of four kickers. Even the FWHM can be tuned to exact the same; some mutual wave form distortion of second order is to be tuned further [4].

REFERENCES

[1] C. S. Hwang et al., "Construction and Performance of Superconducting Magnets for synchrotron Radiation", this conference.

[2] Chyi-Shyan Fann et al., "Pulse Magnetic Field Measurement for the Side-plated Ceramic Chamber", Proceedings of EPAC 2002, p.2637

[3] G. H. Luo et al., "The status of Top-Up Injection at NSRRRC", Asian Particle Accelerator Conference, 2004

[4] To be submitted.