PERFORMANCE OF KICKER PULSERS FOR TPS PROJECT

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Abstract

A set of kicker power suppliers has been designed and fabricated for storage ring beam injection of the Taiwan Photon Source (TPS) project. In order to fulfill the requirements, the performance of the designed units has been bench tested and the results are examined. The pulse-shape matching among four kickers, the pulse-to-pulse stability and the time jitter are specified according to the beam injection requirements. The engineering evaluation and the measurement results are briefly discussed.

INTRODUCTION

The layout of TPS injection scheme and its associated geometric arrangement are illustrated in Figure 1[1,2] where the required pulse strength information concerning amplitude and stability can be readily deduced. The performance requirements of the storage ring kicker power supply has been in reference to previous work in other light sources [3] and are briefly summarized in Table 1.

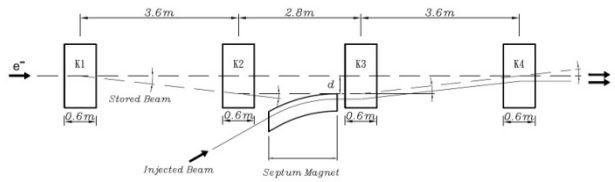

Figure 1: Injection scheme and the related parameters.

Table 1: Performance Parameters of Kicker Power Supply

Parameter	SR Injection Kicker
Number	4
Repetition rate (Hz)	3
Energy (GeV)	3
Bend angle (mrad); [Max.]	4.5; [9.6]
Mag. aperture (H x V mm)	92 * 37
Length (m)	0.6
Nominal field (T); [Max.]	0.075; [0.16]
Bend radius (m)	133.3333
Inductance (μH)	2.35
Beam aperture (H x V mm)	68 * 20
Nominal current (A); [Max.]	2208; [4710]
Pulse shape	Half sine
Pulse duration (μs)	5.18
Pulse to pulse stability (%)	± 0.1
Time jitter, p-p (ns)	± 2
Tail matching in 4 kickers	< 5%

This arrangement is an adopted version of the existing TLS (Taiwan Light Source) injection scheme [4]. At TLS, the revolution time in the storage ring is 400 ns. During the entire half-sine pulse, the stored beam experiences three times of kicker disturbance, one at the maximum strength and the other two sitting at half maximum along the slopes. Equal strength of the four kickers at nominal design is required. Moreover, the shape-matching among four half-sine current pulses is also important and cannot be neglected. Since the shape-matching of kicker pulses was not particularly specified in the early stage of TLS construction, yet the engineering outcome of the kicker pulses was well delivered and satisfied the need. A typical example of the shape-matching view of four TLS injection kicker current pulses is illustrated in Figure 2 for later on comparison purpose.

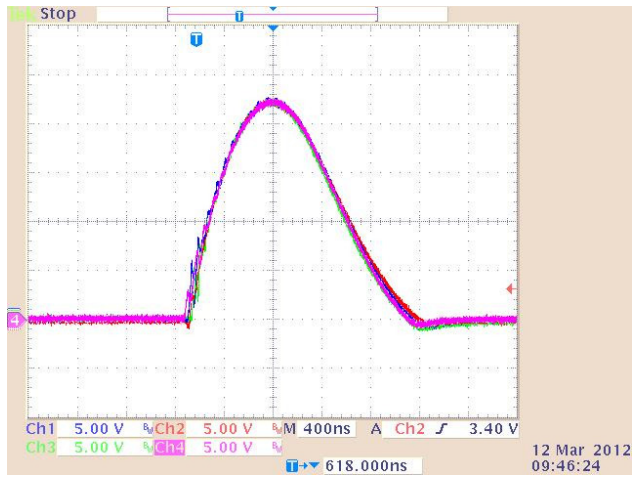

Figure 2: Example of TLS four kicker pulse current.

SHAPE-MATCHING REQUIREMENT

Previous TLS commissioning experience showed that the tolerance of orbit distortion in the storage ring was about a few mm [4], so the imperfection on kicker pulse shape-matching was not seriously critical. As shown in Figure 2, the pulse shape-difference among tails are observed, aside from the noise interference appeares at the pulse signal leading edges. However, the TPS injection design acquires more stringent expectations on all elements involved in this process due to smaller beam size, slender beam pipe, stringent beam-stay-clear and higher beam stability need as well. Therefore, the kicker pulse shape-matching condition requires further examination. Experimental check-up on these pulse shape-matching requirements has been carried out using TLS injection condition as an elaborating platform such that the future TPS kicker pulse shape-matching requirement can be deduced. While exploring the possible tolerance in TLS routine operation, it was found that a 10% amplitude difference at one of the current pulse, either induced by amplitude adjustment or by time-shifting tuning, will knock out the stored beam. This 10%

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amplitude difference corresponds to 1 mrad kick strength difference in the injection process. In fact, the stored beam may have probably endured worse cases than the estimation during the multi-turn injection cycle.

A crosschecking practice concerning the net kick difference among these four kicker pulses is to apply the half-sine pulse current individually while setting "OFF" of the other three kickers, for all kickers. The threshold of knocking out the stored beam is also around 10% of the nominal value.

It would be feasible that a 5% difference shape-matching limit, everywhere along half-sine pulse, was chosen to start with as one of the major specification for TPS kicker power supply fabrication.

DESIGN AND FABRICATION

Design of Power Supply Circuits

The circuit diagram of the half-sine kicker pulse is shown in Figure 3. Charging of the capacitor (C1) is set by the power supply (V1). As the discharging circuit is switched on (S1), the current goes through the kicker coil (L1) accompanying with stray inductance (L2). As the voltage appears reversing across the capacitor, the diode (D1) conducts the charge flow. Thus a half-sine kicker pulse is observed at the kicker.

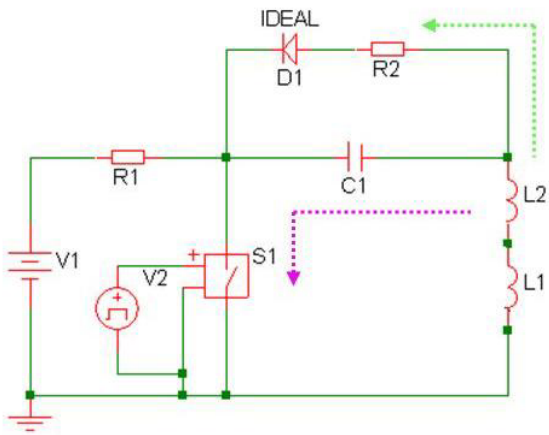

Figure 3: Circuit diagram of the half-sine kicker pulse power supply.

Details of Pulse Shape-Matching

In order to achieve good shape-matching half-sine pulses of the kicker power supplies, a couple of their fabrication items need to be considered. As follow:

1) The charging capacitors need to be individually selected and assembled for equal capacity of four units.
2) For quality assurance consideration, a testing purpose inductive load with specified inductance is applied throughout the measurement of all four kicker power supplies.
3) The resistor in the energy recovery loop (R2 of circuit diagram in Figure 3) gives characteristic falling slopes of the half-sine pulse. The selection of these resistors assembling is crucial to the fitness of pulse shape-matching.
4) Pulse jitter tolerance is stringent. It will cause the stored beam experiencing a non-matched disturbance especially on either sides of the slope along the pulse. A twin pulse trigger unit MA-2709A of E2V [6] is used to limit the pulse jitter within 2 ns.
5) For pulse-to-pulse stability concern, charging power supply with 0.1% stability is employed in this case [7].

Photos of Components Fabrications

Photos of the assembled discharge resistor sets, inductive load, and the constructed kicker power supply are shown in Figure 4, Figure 5 and Figure 6, respectively. Four units of the power supply have been bench tested individually with the inductive load and the pulse shapes are displayed together for comparison purpose.

Figure 4: The assembled discharge resistor sets.

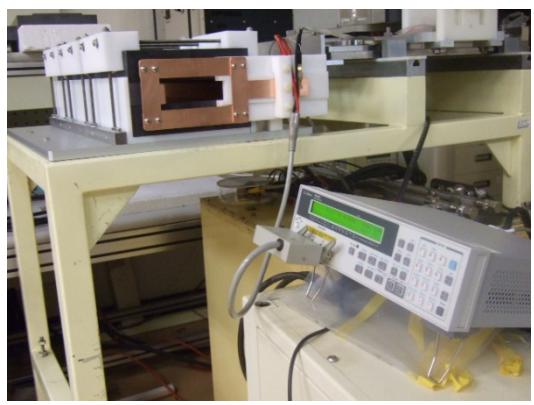

Figure 5: The standard inductive load.

Figure 6: The kicker power supply.

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MEASUREMENT RESULTS

Parameter Checklist

A checklist of the measurement results is given in Table 2 illustrating that all specifications on major parameters are met.

Table 2: Checklist of the Measured Kicker Parameters.

Parameter	Specification	Measurement
Inductance (μH)	2.35	2.58 (dummy load)
Nominal current (A); [Max.]	2208; [4710]	√ (5000A)
Pulse shape	Half-sine	√
Pulse duration (μs)	5.18	5.5
Pulse to pulse stability (%)	± 0.1	√
Time jitter, p-p (ns)	± 2	± 1.5
Tail matching in 4 kickers	< 5%	< 3%

Shape-Matching Analysis of the Kicker Pulse

The kicker pulse shape-matching measurement results are shown in Figure 7a and Figure 7b. Detailed analysis of the row data in Figure 7a gives satisfactory result concerning the half-sine pulse shape-matching among four kicker power supplies. The overall difference between any two sets of power supply is about 1%. This 1% kicker strength difference corresponds to an about 0.1 mrad disturbance to the electron beam and is well acceptable to the injection need.

SUMMARY

Four units of the TPS storage ring injection kicker power supply have been constructed and tested at their designed values. Measurement results show that the performance has met the requirements set at the specifications. The shape-matching difference limit set for these four kicker pulses is partly based on the operation experience of TLS. It shows that the shape-matching of these TPS kicker power supply is about 1% everywhere along the half-sine pulse. Preliminary reliability test of the power supplies has been carried out for 8 hours continuous operation at 3 Hz. A long term drift of less than 0.2% was observed.

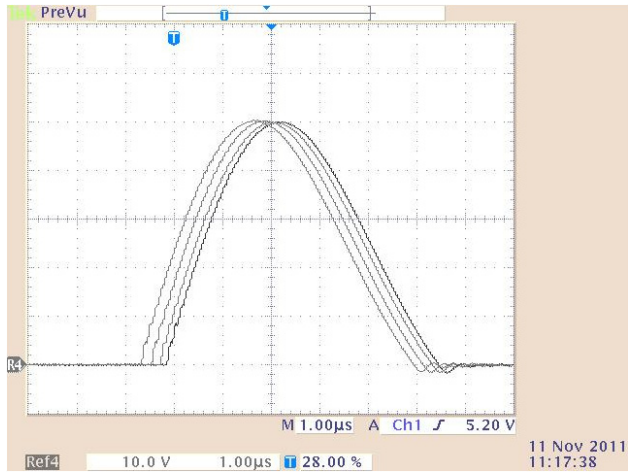

Figure 7a: The measured four kicker pulses.

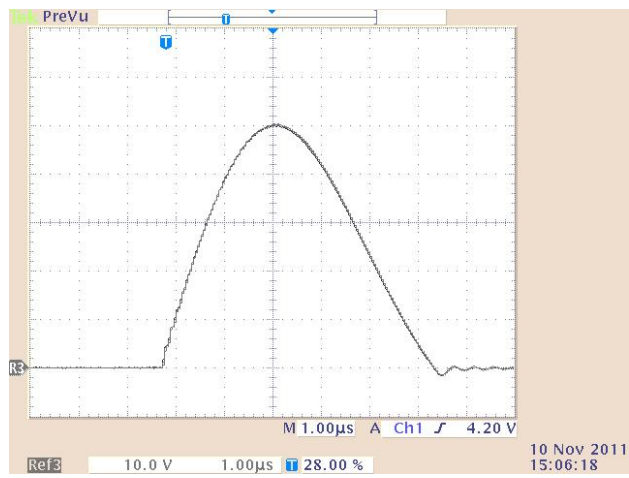

Figure 7b: The aligned four kicker pulses.

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